Lao People's Democratic Republic

1st National REDD+ Results Report for REDD+ Results-Based-Payment under the UNFCCC

June 2020

Department of Forestry

Ministry of Agriculture and Forestry, Lao PDR

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Acronyms

AD	Activity Data
AE	Allometric Equation
AFOLU	Agriculture, Forestry and Other Land Use
AGB	Above Ground Biomass
B	Bamboo
BGB	Below Ground Biomass
BUR	Biennial Update Report
CF	Coniferous Forest
DBH	Diameter at Breast Height
DCC	Department of Climate Change
DD	Dry Dipterocarp Forest
DOF	Department of Forestry
DW	Dead Wood
EG	Evergreen Forest
E/R factors	Emission and Removal Factor
FIPD	Forestry Inventory and Planning Division
FREL/FRL	Forest Reference Emission level/Forest Reference Level
GHG	Greenhouse Gas
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
Lao PDR	Lao People's Democratic Republic
MAF	Ministry of Agriculture and Forestry
MCB	Mixed Coniferous Broadleaved Forest
MD	Mixed Deciduous Forest
MONRE	Ministry of Natural Resources and Environment
NC	National Communication
NFI	National forest Inventory
NFMS	National Forest Monitoring System
NRTF	National REDD+ Taskforce
OA	Other Agriculture
P	Forest Plantation
QC	Quality Control
REDD+	Reducing Emissions from Deforestation and forest Degradation plus the conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks
RV	Regenerating Vegetation
TWG	Technical Working Group
UC	Upland Crop
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Verified Carbon Standard

Acknowledgement

The Department of Forestry (DOF) and the Government of Lao PDR would like to acknowledge the technical support and collaboration on REDD+ received from the various development partners. The development and submission of Lao PDR's 1st National REDD+ Results Report has been supported by Japan International Cooperation Agency. A staff from Food and Agriculture Organization contributed to the review of the report.

INTRODUCTION

Lao PDR submitted its initial Forest Reference Emission Level/Forest Reference Level (FREL/FRL) on 8 January 2018, and the modified version was submitted in October 2018. The technical assessment completed in January 2019 and all the information are published in the UNFCCC REDD+ web platform[1].

This report presents the REDD+ results achieved by Lao PDR for the period of 2015-2018.

The REDD+ results is measured in full consistency with the FREL/FRL in methodology and scope, by using updated data. As a result, the REDD+ results for the period of 2015-2018 is 12,805,253 tCO2e for reduced emissions and 1,873,301 tCO2e for increased removals respectively over 4 years.

For the benefit of the readers, comparison of the scope and methodologies between the FREL/FRL and the REDD+ results are summarized in Table 2 below. Where the methodology used for the estimation of REDD+ results was consistent with that of the FREL/FRL, "Same" is injected to indicate methodological consistency.

Table 1: Comparison of the FREL/FRL and REDD+ results

Scope	FREL/FRL	REDD+ results
Forest definition	"Current Forest" with - Stand DBH: minimum of 10cm - Crown density: minimum of 20% - Minimum area of 0.5ha. and "Potential Forest" defined as 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.	Same.
Land and forest classification system	National land and forest classification system with two levels of classification: - Level 1 consisting of seven classes including "Current Forest" and "Potential Forest"; and - Level 2 which further classifies "Current forest" class under Level 1 into six natural and plantation forest classes.	Same.
Stratification	For the purpose of the REDD+, the national land and forest classification explained above are condensed into five land/forest strata.	Same.

[1] https://redd.unfccc.int/submissions.html?country=lao

Activities included	Deforestation Forest degradation including selective logging Forest enhancement (restoration) Forest enhancement (reforestation)	Same
Carbon Pools	Included: AGB, BGB Not included: Deadwood, Litter, Soil – lack of data, insignificant	Same.
Gases	Only CO2 included. (Non-CO2 gases from field burning approx. 2.9% of all forest-related CO2).	Same.
Scale	National	Same.
Reference period and proposed validity	2005-2014 (10 years) The validity of FREL/FRL is for the period 2015–2025 (11 years)	The proposed results period is 2015-2018 (4 years) and within the validity period of the FREL/FRL.
Emission Factor	Data source: 2nd NFI; country-specific allometric equation; IPCC default values; data of Vietnam. Then, stratified into five strata. Calculation: Amount of changes in carbon stock of among the five strata.	Data source: 3rd NFI; Otherwise same.
Activity Data	Data source: National-scale forest type maps for year 2005, 2010 and 2015. Then, stratified in to five strata. Calculation: Amount of changes in areas among the five strata. Estimated through reference sampling (‘Design-Based Area Estimation’)	Data source: National-scale forest type maps for year 2019. Otherwise same.
Model applied	Historical average	Same.
Adjustment	No.	Same.

1. FOREST DEFINITION

Consistent with the FREL/FRL.

According to the Land Law (2003) and Forestry Law (2019), 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 stocked and temporarily un-stocked forests.

Lao PDR has applied definitions for Current and Potential forests respectively, as national definitions of the forests, for which a summary is shown in the following Table 2. This definition is consistently used in the national FREL/FRL as well as in the estimation of the REDD+ results summarized in this report. The approach of using both "Current Forest" and "Potential Forest" classes is corresponding to the IPCC forestland category.

Table 2: Summary of the definition of "Current Forest" and "Potential Forest" of Lao PDR

Current Forest	Potential Forest
Stand DBH: minimum of 10cm **Crown density: minimum of 20%** **Minimum area of 0.5ha.**	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, and not permanently being used for other purposes (i.e. residential, agriculture etc.). It also does not include Upland Crop (UC), despite its common nature as a cropping stage of shifting cultivation cycle, based on de facto land-use at the time of observation

This definition was used for the past two National Communications on Climate Change, and has been agreed to be used for the future national Greenhouse Gas (GHG) inventory starting with the Third National Communication and the 1st Biennial Update Report which the GoL plans to submit both to the UNFCCC in 2020.

2. LAND AND FOREST CLASSIFICATION AND STRATIFICATION SYSTEMS

2.1. Land and forest classification system

Consistent with the FREL/FRL.

The land and forest classification system of the country applies two levels of classification, namely, Level 1 consisting of seven classes including "Current Forest" and "Potential Forest" among others, and Level 2 which further classifies "Current forest" class under Level 1 into six natural and plantation forest classes. The land classification system is illustrated in Table 3 below, and a full description of the definition of each Level 2 class is available at the Department of Forestry (DOF)'s website[2].

Table 3: National level land and forest classification system of Lao PDR with IPCC definition on land use categories

IPCC Definition	National level classification system		
	Level 1	**Level 2**	
Forest Land	**Current Forest**	**Evergreen Forest**	**EG**
		Mixed Deciduous Forest	**MD**
		Dry Dipterocarp Forest	**DD**
		Coniferous Forest	**CF**
		Mixed Coniferous and Broadleaved Forest	**MCB**
		Forest Plantation	**P**
	Potential Forest	**Bamboo**	**B**
		Regenerating Vegetation	**RV**
Grassland	**Other Vegetated Areas**	**Savannah**	**SA**
		Scrub	**SR**
		Grassland	**G**
Cropland	**Cropland**	**Upland Crop**	**UC**
		Rice Paddy	**RP**
		Other Agriculture	**OA**
		Agriculture Plantation	**AP**
Settlement	**Settlement**	**Urban Areas**	**U**
Other land	**Other Land**	**Barren Land and Rock**	**BR**
		Other Land	**O**
Wetland	**Above-ground Water Source**	**River (Water)**	**W**
		Wetland (Swamp)	**SW**

2.2. Stratification

Consistent with the FREL/FRL.

For the purpose of the estimation of emissions and removals both in the FREL/FRL and this REDD+ results, the national land and forest classification explained in Section 2.1 are condensed into five land/forest strata as shown in Table 4.Table 4: Land/forest classes and stratification Such simplified

[2] http://dof.maf.gov.la/en/home/

stratification will help reduce uncertainty of emissions and removals while balancing the accuracy of sampling and the cost/efforts required:

Table 4: Land/forest classes and stratification

Land/forest classes			FREL/FRL		REDD+ results		
Level 1	Level 2		Area (ha)	% of total area	Area (ha)	% of total area	Strata
Current Forest	Evergreen Forest	EF	2,605,557	11.3%	2,594,961	11.3%	1
	Mixed Deciduous Forest	MD	9,437,688	40.9%	9,267,624	40.2%	2
	Coniferous Forest	CF					
	Mixed Coniferous and Broadleaved Forest	MCB					
	Dry Dipterocarp Forest	DD	1,188,198	5.2%	1,171,873	5.1%	3
	Forest Plantation	P	6,300,445	27.3%	6,385,287	27.7%	4
Potential Forest	Bamboo	B					
	Regenerating Vegetation	RV					
Other Vegetated Areas	Savannah	SA	3,522,370	15.3%	3,634,513	15.8%	5
	Scrub	SR					
	Grassland	G					
Cropland	Upland Crop	OA					
	Agriculture Plantation	AP					
	Rice Paddy/Other Agriculture	RP/OA					
Settlement	Urban Areas	U					
Other Land	Barren Land and Rock	BR					
	Other Land	O					
Above-ground Water Source	Wetland (Swamp)	SW					
	River (Water)	W					
Total			23,054,258	100%	23,054,258	100%	

3. SCOPE FOR THE REDD+ RESULTS

3.1. Activities

Consistent with the FREL/FRL.

The REDD+ activities applied under the FREL/FRL and the REDD+ results of Lao PDR are as follows;

Table 5: REDD+ activities included in the FREL/FRL and the REDD+ results

Activities	Included?	Justification / Explanation
Emissions from deforestation	Yes	A deforestation event is a change of a forest land stratum to a non-forest land stratum. This 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 land strata from a higher biomass stratum to lower biomass stratum, and also through measurement of tree stumps as a proxy indicator of logging activities (see Section4.2.3). This can be caused by activities such as selective logging. The event of a conversion of natural forest to forest plantation is also by definition, a degradation event. The short-term changes between certain stages of rotational agriculture may also be recorded as a degradation event. Such degradation events occur most often in Evergreen forests (Stratum 1) and Mixed Deciduous forests (Stratum 2) being degraded into RV (Stratum 4).
Removals from forest enhancement (Restoration)	Yes	A restoration event is a change within forest land strata from a lower biomass stratum to a higher biomass stratum (in IPCC terms, "forest land remaining forest land"). This is often a result of regrowth of the RV (Stratum 4) to other natural forest classes.
Removals from forest enhancement (Reforestation)	Yes	A reforestation event is a change of non-forest stratum (Stratum 5) to forest land strata (Strata 1-4). This is often a result of a non-forest land (Stratum 5) being converted into the Forest Plantation class, or regenerating into the RV (both Stratum 4).
Emissions and Removals from conservation of carbon stocks	No	There is no national definition for this REDD+ activity.
Emissions and Removals from sustainable management of forests	No	There is no national definition for this REDD+ activity. However, there is a comprehensive accounting for GHG emissions and removals from forests so GHG emissions and removals that could potentially be included in this activity are included in the other REDD+ activities.

3.2. Carbon Pools

Consistent with the FREL/FRL.

The following table shows the carbon pools considered in the FREL/FRL and the REDD+ results.

Table 6: Carbon pools accounted for in the FREL/FRL and the REDD+ results

Carbon Pools	Selected?	Justification / Explanation
Above Ground Biomass (AGB)	Yes	AGB consists the majority of the forest biomass in Lao PDR, thus, considered as a significant carbon pool.
Below Ground Biomass (BGB)	Yes	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	DW is considered as an insignificant carbon pool. Lao PDR currently lacks complete data to account DW consistently in the FREL/FRL and MRV, and considers to improve this in the measurement of the future NFIs. Exclusion of DW is considered to be conservative on the basis of future improvements in forest management being successful.
Litter	No	Litter is considered as an insignificant carbon pool in Lao PDR, thus, not measured in the NFIs. 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 basis of future improvements in forest management being successful.
Soil	No	There is no reliable country specific data for soil organic carbon. Inclusion of soil organic carbon in the measurement will be considered in the future step-wise improvement. Exclusion of soil organic carbon is considered to be conservative on the basis of future improvements in forest management being successful.

3.3. Gases

Consistent with the FREL/FRL.

The following table shows the GHG gases considered in the FREL/FRL and the REDD+ results.

Table 7: Gases accounted for in the FREL/FRL and the REDD+ results

Greenhouse gases	Selected?	Justification / Explanation
CO_2	Yes	CO_2 emissions and removals are accounted.
Non-CO2 (CH4 and N2O)	No	Shifting cultivation is an important disturbance event nationally. CH4 and N2O are the gases emitted from biomass burning where forest lands are affected by slash and burn practices. Due to data constraints, non-CO2 gases are excluded.

3.4. Scale

Consistent with the FREL/FRL.

The scale of the FREL/FRL and the REDD+ results are both national.

3.5. Result period

The reference period of the FREL/FRL is 10 years, with 2005/01/01 as the start-date and 2014/12/31 as the end-date. The proposed validity of the FREL/FRL is for the period 2015-2025 (11 years).

The REDD+ results is for 4 full year, with 2015/01/01 as the start-date and 2018/12/31 as the end-date, which is within the validity period of the FREL/FRL.

4. ESTIMATION OF THE 1ST NATIONAL REDD+ RESULTS

4.1. Background context and method of estimation

4.1.1. National circumstances and adjustments

Consistent with the FREL/FRL.

Same with the FREL/FRL, no adjustments due to the national circumstances are applied to the 1st National REDD+ Results.

4.1.2. General methodologies

Consistent with the FREL/FRL with updated data used.

Lao PDR presents historical emissions and removals separately per each source and sink activity. Accordingly, the four sources and sinks (i.e., emissions from deforestation and degradation, and removals from restoration and reforestation) are estimated by calculating the changes in biomass caused by the shift from one strata 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 Activity Data (AD) and Emission/Removal Factors (E/R factors). Both emissions and removals occurring in forests remaining in the same stratum are not accounted, except in the case of emissions from selective logging estimated through measurement of tree stumps as a proxy data.

Regarding the AD and E/R factors:

- The AD is generated spatially using satellite-based analysis of land/forest cover for the two years: 2015 and 2018. National-scale Forest Type Maps are used as the basis for estimating the AD. Changed areas are detected by change detection method, and then applied reference sampling (so called 'design based area estimation' in FREL/FRL report) with respect to generating statistically reliable estimates, and also to conduct the uncertainty assessment of AD.
- E/R factors are basically generated using national-scale biomass data from the 3rd National Forest Inventory combined with country-specific allometric equations, and an independent biomass measurement data for RV class[3]. IPCC default and data from neighbouring Vietnam are used for some land/forest classes where no country-specific data are available.

Apart from the above, Lao PDR estimates emissions from forest degradation by selective logging through proxy approach (see Section 4.2.3). The approach uses the tree stump records measured through the 3rd NFI to complement the impact of selective logging which was considered as under-represented. The approach also complements quantifying forest degradation in stable forest classes where forest biomass change data is limited.

[3] The reason for not using the 1st NFI data is explained in the Annex 2: Emission and Removal Factors Report.

4.2. Data used for the estimation of the REDD+ results

4.2.1. Activity Data[4]

Consistent methodologies with the FREL/FRL applied to generate updated data for the 2015-2018 period[5].

The Activity Data (AD) are developed through two-folded process, namely:

1) Development of Forest Type Map of Lao PDR for year 2019 (Forest Type Map 2019); and
2) Application of the forest type stratification (i.e. into five land/forest strata) to the Forest Type Map 2019 and initial analysis of forest cover change between the Forest Type Maps of year 2015 and 2019 to conduct reference sampling (so called 'design-based area estimation' in the FREL/FREL report) and revise into the final AD and finally, to conduct the uncertainty assessment of AD.

It should be noted that the methods and results explained in this section are limited to the AD estimated through the Forest Type Maps. The emission from forest degradation by selective logging is estimated by proxy-based approach, therefore, explained separately in Section 4.2.3.

<u>**Development of the Forest Type Map 2019**</u>

Consistent with the Forest Type Maps used for the FREL/FRL[6], Forest Type Map 2019[7] was developed for the national level for year 2019, applying the 'Level 2' of land/forest classification system[8], and then further stratified into the five land/forest strata.

a. Satellite imagery used

The satellite imagery used for creating Forest Type Map 2005, 2010, 2015 and 2019 are summarized in Table 8 below. In addition, Planet imagery of year 2019, which has higher spatial resolution, was used as a supplementary source to assist the interpretation of the land-use after the change.

Table 8: Details of the satellite imagery used for the development of Forest Type Maps

Name	SPOT4 / 5 MS	RapidEye	RapidEye	Sentinel-2
Forest Type Map	2005	2010	2015	2019

[4] The detailed process of the development of AD is described in "Annex 1: Activity Data Report".
[5] While maintaining consistency in the overall methodologies, some improvements were applied to the Forest Type Map 2019 development process: use of Google Earth Engine for creating cloud-free mosaic imagery; and use of higher resolution satellite, globally available forest monitoring data and parameters to detect and classify the changes more accurately. See "Annex 1: Activity Data" Report for details.
[6] As explained in the FREL/FRL submission (Section 3.5), three maps are used for the FREL/FRL:
- Forest Type Map 2005 is considered as a map of 2005/01/01,
- Forest Type Map 2010 is considered as a map of 2011/01/01,
- Forest Type Map 2015 is considered as a map of 2015/01/01.

[7] The same rule with the FREL/FRL is applied to the REDD+ results, namely the Forest Type Map 2019 is considered as a map of 2019/01/01. It is noted that this map was produced with satellite imageries from the dates of Jan. 2019 to Mar. 2019
[8] In fact, UC and OA were merged at the time of classification for efficiency, however, this does not affect the estimation of REDD+ results.

Spatial resolution	10m	5m	5m	10m

The technical processes undertaken for the development of Forest Type Map 2019 are shown in Figure 1 below.

The mapping scale of 1:100,000, and a minimum mapping unit of 0.5 ha were consistently used for developing all Forest Type Maps. In order to secure time-series consistency among the maps, and also taking into account associated cost and map quality, the following process was applied to develop Forest Type Map 2019: first detecting changes in satellite imageries of years 2015 and 2019, then overlaying the detected changed areas with the Forest Type Map 2015 (the latest map used for FREL/FRL). This methodology is consistent with that for Forest Type Map 2015 (i.e. overlaying extracted changed area between years 2005 and 2015 with Forest Type Map 2010), which was developed as the benchmark map for the FREL/FRL using object-based classification. For quality control of the visual (manual) interpretation process, a three-fold control process was introduced: 1) initial interpretation by FIPD remote sensing engineers; 2) review by FIPD senior remote sensing engineers for correction; and 3) sample-based random quality check by external international remote sensing engineers.

To avoid overestimation of changes, cases where changes were marginal or questionable were omitted (i.e. not considered change).

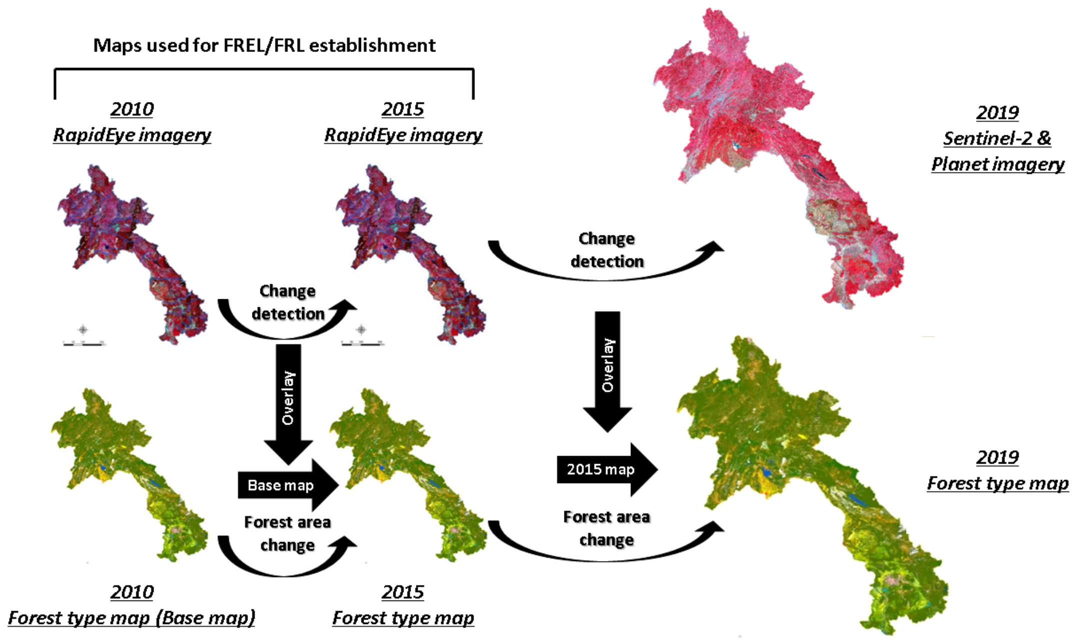

Figure 1: Outline workflow of developing the Forest Type Map 2019

From the draft Forest Type Map 2019 developed above, Initial Forest Change Maps for the period 2015-2019 was generated to conduct initial analysis of forest change and collect "illogical changes" by overlaying the Forest Type Maps of the two years (2015 and 2019).The resulting Final Forest Type Maps with Level 2 classification were stratified into five land/forest strata (as explained in Section 2.2).

Reference sampling ('Design-based area estimation') of Activity Data

Using the stratified Forest Type Map, Lao PDR apply reference sampling (so called 'design based area estimation in the FREL/FRL report) with respect to generating statistically reliable estimates of AD following good practice recommended by Olofsson et al. (2014), which regards the stratified Forest Type Map to serve as an initial stratification of the population of interest for the purposes of designing and collecting reference data which is then used to re-estimate the actual changed areas[9]. The sample size was determined by using the formula by Cochran (1977), assuming that the sampling cost of each stratum is the same. The calculation was done using FAO's SEPAL which allows automated calculation of sampling size and distribution.

The final AD based on the stratification for the period 2015-2019 are shown in Table 9 below.

Table 9: Activity data 2015 – 2019

Unit: ha

		2019					
	ha	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Legend
2015	Stratum 1	2,594,412	891	4	2,593	7,658	Deforestation
	Stratum 2	388	9,173,675	2,125	174,504	86,996	Degradation
	Stratum 3	0	1,149	1,169,435	4,663	12,951	Restoration
	Stratum 4	160	91,910	308	6,047,925	160,141	Reforestation
	Stratum 5	0	0	0	155,603	3,366,767	No Change
					Total	23,054,258	

Table 10: Activity Data 2015 – 2019: annual amount of change

Unit: ha

		2019					
	ha/year	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Legend
2015	Stratum 1	648,603	223	1	648	1,914	Deforestation
	Stratum 2	97	2,293,419	531	43,626	21,749	Degradation
	Stratum 3	0	287	292,359	1,166	3,238	Restoration
	Stratum 4	40	22,978	77	1,511,981	40,035	Reforestation
	Stratum 5	0	0	0	38,901	841,692	No Change

[9] The detailed process is described in "Annex 1: Activity Data Report" attached to the submission.

4.2.2. Emission and Removal Factors[10]

Consistent methodologies with the FREL/FRL to generate updated data for the 2015-2018 period

The Emission and Removal factors (E/R factors) are developed for each type of land/forest cover change, stratified into five land/forest strata, and by taking the difference in carbon stock of each land/forest strata.

The sources of E/R factors consists of a combination of national dataset, and other data from Vietnam and IPCC defaults which are regarded as the best available options. For the 1st National REDD+ Results, the source of data are as follows;

Five forest classes subject to the 3rd NFI (EG, MD, DD, CF and MCB)
For strata 1 (EG), 2 (MD, CF, MCB) and 3 (DD), measurement data from the 3rd NFI is used.

The 3rd NFI was conducted in the dry seasons of 2018-2019, and a total of 415 survey plots were distributed across these strata through stratified-random-sampling.

The same country-specific allometric equations used for the FREL/FRL were applied for the three major Level 2 forest classes (EG, MD and DD). The other two forest classes (CF and MCB) also used the same allometric equations with the FREL/FRL developed in Vietnam.

The BGB is estimated using the root-shoot ratio derived from the IPCC Guideline 2006 Volume 4 Chapter 4 Table 4.4. (0.2 for AGB < 125, and 0.24 for AGB > 125).

Biomass is converted to carbon stocks by using the carbon fraction (CF= 0.46 or 0.47 depending on the land/forest class) derived from the IPCC Guideline 2006, Volume 4, Chapter 4, Table 4.3.

Regenerating Vegetation (RV)

Carbon stocks of RV is estimated based on the results from the "2nd RV survey"[11]. A total of 189 survey plots (63 survey clusters with three survey plots each) were distributed across seven provinces and the measurement of DBH for trees, and measurement of the biomass weight for the understories were conducted.

Bamboo (B)

The E/R factors of the Northern Central Coast region of Vietnam is used.

Forest Plantation (P)

Carbon stocks were derived from default factors of the IPCC database.

Other land/forest classes

The carbon stocks of remaining land/forest classes are derived mostly from IPCC Guideline 2006.

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[10] The detailed process of the development of E/R factors is described in "Annex 2: Emission/Removal Factors" attached to the submission.
[11] DOF, et al. (2017). Development of a Lao-specific Equation for the Estimation of Biomass of 'Regenerating Vegetation' and Determination of the Threshold Years for its Regeneration into Forest. <http://dof.maf.gov.la/en/publications/>

Same with the methods applied in the FREL/FRL, in order to derive the changes of carbon stocks among the five land/forest strata, the average carbon stocks for each stratum was calculated by using weighted values as follows:

$$Cstrata\ (tC/ha) = (C1*A1+ C2*A2+....+Cn*An)/(A1+A2+....+An)$$

Where:

Cstrata = average carbon stocks (tC/ha) of strata calculated from carbon stocks and area of land/forest class;

Ci = carbon stocks of land/forest class (tC/ha);

Ai = area (ha) of land/forest class in 2019.

The following table shows the resulting carbon stocks of the five land/forest strata.

Table 11: Carbon stocks of the five land/forest strata

Strata	tC/ha
Stratum 1 (EG)	205.8
Stratum 2 (MD, CF, MCB)	87.8
Stratum 3 (DD)	50.8
Stratum 4 (P, B, RV)	11.5
Stratum 5 (NF)	4.7

By taking the difference in average carbon stocks of each land/forest strata the E/R factors are derived as shown in the table below.

Table 12: Emissions/Removals Factors for changes (tCO2e)

	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	-169.1
Stratum 4 (P, B, RV)	712.4	279.6	144.1	0.0	-25.0
Stratum 5 (NF)	737.4	304.7	169.1	25.0	0.0

4.2.3. Supplementary analysis of the impact of selective logging

Consistent methodologies with the FREL/FRL.

Unsustainable selective logging, both legal and illegal, continue to be a major driver of forest degradation which could make forest degradation a significant source of emission for Lao PDR. Considering the Government's strong commitment to tackle illegal logging, the FREL/FRL attempted to explore methods to quantify historical emissions caused by selective logging.

The 3rd NFI recorded the diameter and height of tree stumps observed in the measurement plots in a consistent manner with the 2nd NFI. As it was done for the FREL/FRL, the data were used to estimate the historical emissions caused by selective logging applying the same methodologies (see 4.3.2 for the calculated results).

4.3. Calculation of the REDD+ results

Consistent methodologies with the FREL/FRL.

4.3.1. Emission and removals calculated based on changes among land/forest strata

Based on the calculation method explained in Section 4.1, average annual historical emissions and removals based on the changes among land/forest strata for the results period of 2015-2018 are calculated.

Further, two adjustments were made with an aim to make the estimation as accurate as possible:

i) Adjustment of removals (regrowth rate and reversals)
For land cover changes which result in emissions (i.e. 'Deforestation' and 'Forest Degradation'), the entire expected emission is assumed to occur (i.e. evenly distributed) over the time period in question. Meanwhile, for land/forest cover changes which result in removals (i.e. 'Restoration' and 'Reforestation') adjustments were applied as follows;

a. Adjustments were made based on the typology summarized below, by considering the types of changes and rate of tree growth. This recognizes that in forest ecosystems, forest biomass increase slowly over time to reach their full biomass (IPCC 2006)[12].

Table 13: Typologies of change for removals

Sinks	From	To	Adjustment of removals
Restoration	Stratum 4 (predominantly RV)	Stratum 1, 2 and 3	In principle, 40-years[13] 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 stocks (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.

[12] 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.
[13] The assumption is based on references in the FCPF Carbon Fund Emissions Reduction Program Document of neighbouring 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.

	Stratum 2 (MD, CF and MCB) Stratum 3 (DD)	Stratum with higher biomass	In principle, 20 years[14] is assumed as the transition period for forest with lower biomass to reach forest with higher biomass.
Reforestation	Stratum 5 (non-forest)	Stratum 4 (predominantly, RV)	Removal factor is applied at the time change is observed taking into account the fact that RV reaches its average biomass stocks after 5 years. Adjustment based on 40-years default applied to the years following.
	Stratum 5 (non-forest)	Stratum 1, 2 or 3	No such change observed.

b. Reversals during the results period of 2015-2018 were identified through time-series analysis of polygons, in order to avoid double-counting. This is because due to the estimation method of generating AD for the results period, there is a chance that the emissions from reversal events which have occurred are unreported (in other words, removals are over-estimated). This was done by tracking all the change patterns which are regarded as reversals as shown in Table 14 below. The respective estimated areas were multiplied with the accumulated biomass of the respective stratum calculated based on typologies in Table 13 above, and the results were deducted as over-estimated removals. The resulting over-estimation from such removals, which was 602,179 tCO_2e, were deducted from "Restoration" of the 2015-2018 period.

Table 14: Over-estimated removals tracked

	Stratum in 2005	Stratum in 2010	Stratum in 2015	Stratum in 2019	Estimated area (ha)	Emissions to be deducted from Reversals (tCO_2e)
Change patterns from time series	**4**	**2**	**3**	**any stratum**	**2**	**79**
	4	**2**	**4**	**any stratum**	**3,615**	**115,542**
	4	**2**	**5**	**any stratum**	**3,547**	**113,364**
	4	**3**	**5**	**any stratum**	**5**	**86**
	4	**1**	**5**	**any stratum**	**1**	**121**
	2	**1**	**4**	**any stratum**	**5**	**434**
	2	**1**	**5**	**any stratum**	**17**	**1,508**
	any stratum	**4**	**2**	**5**	**2,668**	**85,263**
	any stratum	**4**	**2**	**4**	**2,719**	**86,901**
	any stratum	**4**	**3**	**5**	**4**	**61**
	any stratum	**5**	**4**	**5**	**18,798**	**94,037**
	4	**2**	**2**	**4**	**1,558**	**49,784**
	4	**2**	**2**	**5**	**1,697**	**54,240**
	4	**3**	**3**	**4**	**19**	**321**
	4	**3**	**3**	**5**	**26**	**434**
	Total					**602,179**

Note: Figures have been rounded to the nearest whole number

[14] 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. Such changes are: 71ha for 2005-2010, nil for 2010-2015 and 1,537ha for 2015-2019.

ii) Adjustment of emissions from deforestation and degradation

The resulting estimation (based on above) presents the risk of overestimation of emissions from deforestation and degradation. This is because, the E/R factors are strata-specific and do not reflect the actual accumulated biomass which may be lower. For example, a MD forest which 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, stratum 2, and back to stratum 4, the indication would be that the stratum 2 forests before the disturbance event would have reached at maximum, only about 9-10 years. Such change patterns were tracked through the time-series-analysis of forest maps as shown in Table 15 below. The respective estimated areas were multiplied with the accumulated biomass of each land calculated based on typologies in Table 13 above. The resulting over-estimation of emissions from deforestation, which was 1,304,610 tCO_2e, and over-estimation of emissions from forest degradation, which was 943,945 tCO_2e, were estimated and deducted, respectively.

Table 15: Tracked over-estimation of emissions

	Stratum in 2010	Stratum in 2015	Stratum in 2019	Estimated area (ha)	Overestimation of emissions to be deducted (tCO_2e)
Change patterns from time series	**5**	**4**	**5**	**9,472**	**189,529**
	4	**2**	**4**	**3,811**	**943,906**
	4	**2**	**5**	**4,129**	**1,114,261**
	4	**3**	**5**	**5**	**820**
Total					**2,248,555 (Def.: 1,304,912) (Deg.: 943,945)**

Note: Figures have been rounded to the nearest whole number

The comparison of before and after the adjustment is shown in the following table.

Table 16: Comparison of before and after adjustment

	Before adjustment		**After adjustment**	
	2015-2018 (tCO_2e)	**Annual average 2015-2018 (tCO_2e/yr)**	**2015-2018 (tCO_2e)**	**Annual average 2015-2018 (tCO_2e/yr)**
Deforestation	46,279,186	11,569,797	44,974,274	11,243,569
Degradation	73,507,252	18,376,813	72,563,307	18,140,827
Reforestation	-5,516,572	-1,379,143	-4,337,947	-1,084,487
Restoration	-24,684,521	-6,171,130	-27,669,584	-6,917,396

The average annual historical emissions and removals over the results period after the adjustment of removals are described in the following table.

Table 17: Historical Emissions and Removals – based on changes among land/forest strata

Source/Sink	Emissions(+)/ Removals(-) 2015-2018 (tCO2)	Average annual 2015-2018 (tCO2/year)
Deforestation	44,974,274	11,243,569
Forest Degradation	72,563,307	18,140,827
Reforestation	-4,337,947	-1,084,487
Restoration	-27,669,584	-6,917,396
Total Emission	116,582,305	29,384,395
Total Removals	-32,007,531	-8,001,883

4.3.2. Emissions from selective logging (degradation)

Consistent methodologies with the FREL/FRL.

As explained in Section 4.2.3, the 3rd NFI recorded the tree stumps of the trees felled by human activities. The biomass of the felled trees were estimated from the measured size of each tree stump, aggregated for each of the five forest class (i.e. EG, MD, DD, CF, CF) in order to estimate the average loss of carbon stocks, and converted to tCO2e. Then, the results were multiplied with the area of each forest class calculated from the Forest Type Map 2019, to estimate the assumed emissions from such logging events as shown in Table 18 below.

Table 18: Estimated total emissions from selective logging

	Average loss (tCO2e/ha)	Area from Forest Type Map 2019 (ha)	tCO2e/12 year[15]
EG: Evergreen Forest	11.4	2,594,961	29,646,105
MD: Mixed Deciduous Forest	5.8	9,036,767	51,974,068
DD: Dry Dipterocarp	11.6	1,171,873	13,541,141
CF: Conifer Forest	13.1	124,009	1,626,038
MCB: Mixed Conifer and Broadleaved forest	9.0	106,848	965,339
Total			**97,752,691**
Annual average (tCO2e) (Total divided by 12 years)[16]			**8,146,058**

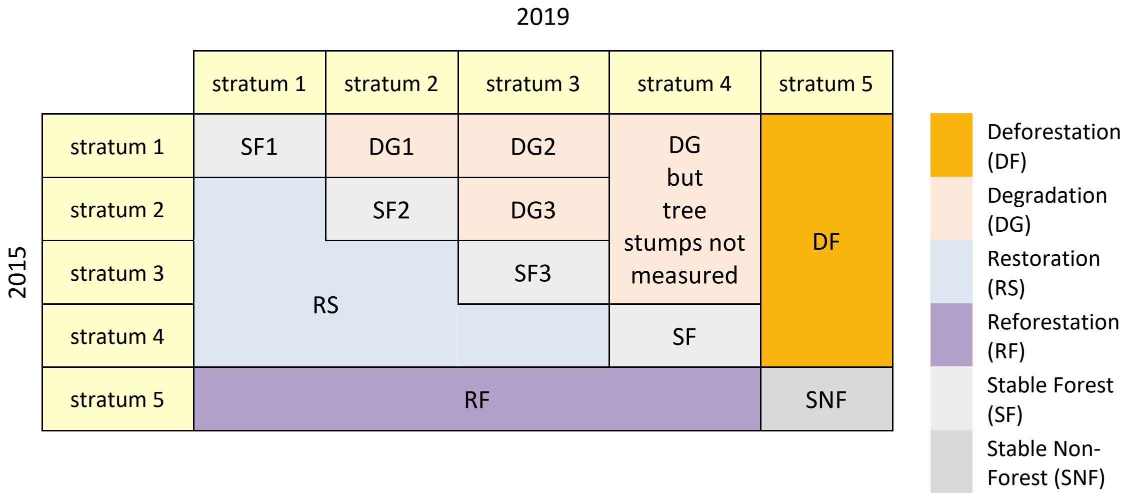
[15] It is considered reasonable to assume that the stumps observed and recorded were felled within 12 years before its field survey. The details are presented in Section 4.2.3 of the FREL/FRL Report.
[16] As the 2nd NFI in fact includes tree stumps of 2015 and 2016, this data represents only the tree stumps of 2017 and 2018.

4.3.3. Results of calculation

Consistent methodologies with the FREL/FRL.

The REDD+ results for Lao PDR is an aggregation of the historical emissions and removals calculated based on land/forest strata as explained in Section 4.3.1, and the emissions from selective logging as explained in Section 4.3.2.

However, if the latter is simply added to the former, the problem of double-counting of emissions occurs.



Same with the FREL/FRL, this issue was addressed applying the following steps of estimations (noting that figures have been rounded to the nearest whole number):

a. The emissions from forest degradation based on changes among land/forest strata (i.e. DG1 + DG2 + DG3 + DG) = 18,140,827 tCO_2e/year.
b. The emissions from forest degradation based on changes among forest strata within the stratum (i.e. DG1 + DG2 + DG3) = 238,819 tCO_2e/year.
c. The emissions from selective logging (included in SF1, SF2, SF3, DG1, DG2, DG3) = 8,146,058 tCO_2e/year.

The total emissions from forest degradation is therefore 26,048,065 tCO_2e/year
(18,140,827 (a) – 238,819 (b)) + 8,146,058 (c) = 26,048,065 tCO_2e/year

As the result, the emissions and removals for the period 2015-2018 are as summarized in Table 19 below.

Table 19: Average Annual Emissions and Removals over the 1st National REDD+ Results period

Source/Sink	Emissions(+)/ Removals(-)		
	2015-2018 (tCO_2)	Average annual 2015-2016 (tCO_2e/year)	Average annual 2017-2018 (tCO_2e/year)
Deforestation	44,974,274	11,243,569	11,243,569
Forest Degradation	106,273,739	27,088,804	26,048,065

Changes among land/forest strata	71,608,030	17,902,008	17,902,008
Selective logging[17]	34,665,708	9,186,797	8,146,058
Reforestation	-4,337,947	-1,084,487	-1,084,487
Restoration	-27,669,584	-6,917,396	-6,917,396
Total Emission	**151,248,013**	38,332,373	37,291,634
Total Removals	**-32,007,531**	-8,001,883	-8,001,883

From the above, average value for each period was estimated in order to derive the annual historical emissions and removals. The results for the period 2015 - 2018 were calculated as the difference between the average annual emissions and removals of 2015-2018 and the FREL/FRL of 2005-2014. The results are shown in Table 20 below.

Table 20: 1st National REDD+ Results - annual

Unit: tCO2e/year

	Year	Annual historical emissions and removals 2005-2015		Annual emissions and removals 2015-2018		1st National REDD+ Results 2015-2018	
		Emissions: Deforestation and Forest Degradation	Removals: Reforestation and Restoration	Emissions: Deforestation and Forest Degradation	Removals: Reforestation and Restoration	Emissions reduction	Removals increase
Reference period	2005	41,013,316	-7,533,558				
	2006	41,013,316	-7,533,558				
	2007	41,013,316	-7,533,558				
	2008	41,013,316	-7,533,558				
	2009	41,013,316	-7,533,558				
	2010	41,013,316	-7,533,558				
	2011	41,013,316	-7,533,558				
	2012	41,013,316	-7,533,558				
	2013	41,013,316	-7,533,558				
	2014	41,013,316	-7,533,558				
Results period	2015	41,013,316	-7,533,558	38,332,373	-8,001,883	2,680,944	468,325
	2016	41,013,316	-7,533,558	38,332,373	-8,001,883	2,680,944	468,325
	2017	41,013,316	-7,533,558	37,291,634	-8,001,883	3,721,683	468,325
	2018	41,013,316	-7,533,558	37,291,634	-8,001,883	3,721,683	468,325
	Total					12,805,253	1,873,301

*Figures have been rounded to the nearest whole number

[17] As the 2nd NFI in fact includes tree stumps of 2015 and 2016, emissions from selective logging accounted in the FREL/FRL (i.e. 9,186,797 tCO2e/year) is also accounted as the emissions from selective logging for the 2015-2016 period. For the 2017-2018 period, tree stump data from the 3rd NFI is used to estimate the emissions from selective logging (i.e. 8,146, 058 tCO2e/year).

In conclusion, the 1st National REDD+ Results for Lao PDR for the period of 2015-2016 and 2017-2018 is 2,680,944 tCO2e/year and 3,721,683 tCO2e/year respectively (12,805,253 tCO2e over 4 years) for emissions and 468,325 tCO2e/year (1,873,301 tCO2e over 4 years) for removals as shown in Table 21.

Table 21: Proposed 1st National REDD+ Results for Lao PDR (2015-2018)

Emissions/Removals	tCO2e/year	4 years total
Average emissions reduction 2015-2016	2,680,944	12,805,253
2017-2018	3,721,683	
Average removals increase 2015-2016	468,325	1,873,301
2017-2018	468,325	

5. ASSESSMENT OF UNCERTAINTY

5.1. Identification and assessment of sources of uncertainty

Consistent methodologies with the FREL/FRL.

Uncertainty associated with AD and E/R factors is quantified by providing accuracy, confidence interval, distribution error and propagation of error following the 2006 IPCC Guidelines for National GHG Inventory (Chapter 3). The quantification method applied is simple error propagation equations, since errors in data and methods are not considered large as defined in the IPCC Guideline.

The Sources and Sinks of emission and removals are:

- Emission from Deforestation (DF)
- Emission from Forest degradation (DG)
- Removals from Reforestation (RF)
- Removals from Restoration (RS)

Apart from the above, the uncertainty associated with selective logging is assessed.

5.2. Assessment of uncertainty of Activity Data[18]

Consistent methodologies with the assessed FREL/FRL.

The sources of uncertainty of AD is the error from procedures for interpretation of land/forest classes. This is commonly associated with the quality of satellite data, interoperability of the different sensors, image processing, cartography and thematic standards, location and co-registration, the interpretation procedure itself and post-processing.

Errors are calculated following the good practices for assessing accuracy assessment of land change as recommended in Olofsson et al (2014)[19]. To employ this approach, the land use change classes were validated using Collect Earth[20]. The results are shown in the tables below:

Table 22: Map accuracy and uncertainty of Activity Data 2015 - 2019

Class	DF	DG	RF	RS	SF	SNF
AD uncertainty	**30.9%**	**38.5%**	**44.7%**	**26.6%**	**1.6%**	**9.4%**
User accuracy	**86.7**%	**80.0**%	**76.7**%	**76.7**%	**97.4**%	**82.8**%
Producer accuracy	**83.9%**	**72.7%**	**79.3%**	**88.5%**	**97.0**%	**84.2**%
Overall accuracy	**93.2%**					

[18] See Annex 1: Activity Data Report for details.
[19] Olofsson et. al., 2014.
[20] Details at: http://www.openforis.org/tools/collect-earth.html

5.3. Assessment of uncertainty of Emission/Removal factors[21]

Consistent methodologies with the FREL/FRL.

The IPCC GL 2006 for National Greenhouse Gas Inventories (Volume 1, Chapter 3), lists out eight broad causes of uncertainties: lack of completeness; model; lack of data; lack of representativeness of data; statistical random sampling error; measurement error; misreporting or misclassification; and missing data. Some cause of uncertainty (e.g. bias) may be difficult to identify and quantify.

For Lao PDR, the main parameters which cause uncertainty of E/R Factors are considered as follows:

1. Uncertainty of AGB originating from sampling error (3rd NFI data)
2. Uncertainty of AGB originating from biomass equation
3. Uncertainty of Root-to-Shoot ratios due to the use of IPCC default values (IPCC GL 2006)
4. Uncertainty of Carbon Fraction factor due to the use of IPCC default values (IPCC GL 2006)
5. Uncertainty of AGB originating from measurement error (QC of 3rd NFI)

After the uncertainty of each parameter are assessed, following the 'propagation of error approach' and by using the generic equations given in the IPCC Guidelines 2006 (Equation 3.1 and 3.2), the steps below were undertaken:

a. Calculate the total uncertainty of carbon stocks per land/forest classes;
b. Combine into five strata by using weighted value based on area proportion;
c. Calculate the uncertainties of E/R factors (Table 23); and
d. Calculate the uncertainty of E/R factors per sources and sinks (Table 24).

Table 23: Emission/Removal Factors Uncertainty

	Stratum 1 (EG)	Stratum 2 (MD/CF/MCB)	Stratum 3 (DD)	Stratum 4 (P/B/RV)	Stratum 5 (NF)
Stratum 1 (EG)		**12.0%**	**13.3%**	**15.3%**	**15.7%**
Stratum 2 (MD/CF/MCB)	**12.0%**		**10.5%**	**12.5%**	**13.3%**
Stratum 3 (DD)	**13.3%**	**10.5%**		**13.2%**	**14.4%**
Stratum 4 (P/B/RV)	**15.3%**	**12.5%**	**13.2%**		**15.1%**
Stratum 5 (NF)	**15.7%**	**13.3%**	**14.4%**	**15.1%**	

Table 24: Uncertainty of E/R factors per sources and sinks

	Uncertainty (%)
Deforestation	10.1%
Forest Degradation	6.5%
Reforestation	10.1%
Restoration	6.5%

[21] See Annex 2: Emission/Removal Factors Report for details.

5.4. Quantification of uncertainty of 1st national REDD+ Results

5.4.1. Uncertainty of the emissions and removals based on changes among five strata

Consistent methodologies with the FREL/FRL.

Based on the uncertainty assessment of AD and E/R factors, the uncertainty of the emissions and removals through changes among the five strata is calculated per sources and sinks using propagation of error approach. Table 25 and show the results of the calculation, which are 27.1% for emissions and 24.5% for removals.

Table 25: Uncertainty of the 1st National REDD+ Results – based on changes among five strata

Source/Sink	Per Sources and sinks (2015-2018)			Per Emission/removal (2015-2018)		
	Amount (tCO_2e/year)	**Uncertainty range (tCO_2e/year)**	**Uncertainty range (%)**	**Amount (tCO_2e/year)**	**Uncertainty range (tCO_2e/year)**	**Uncertainty range (%)**
DF	**11,243,569**	**3,660,107**	**32.6%**	**29,145,576**	**7,890,995**	**27.1%**
DG	**17,902,008**	**6,990,810**	**39.1%**			
RF	**-1,084,487**	**-497,007**	**45.8%**	**-8,001,883**	**-1,958,216**	**24.5%**
RS	**-6,917,396**	**-1,894,095**	**27.4%**			

5.4.2. Uncertainty of emissions by selective logging

Consistent methodologies with the FREL/FRL.

In addition, uncertainty of emissions from forest degradation by selective logging was assessed with the same propagation of error approach. Based on the method explained in Section 4.2.3, uncertainty of Forest Type Map 2019 shown in Table 26 and uncertainty of E/R factors shown in Table 27 are used as the two parameters.

Table 26: Uncertainty of the Forest Type Map 2019 for the uncertainty assessment of emissions from selective logging

	Area(ha)	**Uncertainty (%)**
EG	2,594,961	3.7%
MDF	9,036,767	4.4%
CF	124,009	15.8%
MCB	106,848	0.0%
DD	1,171,873	10.3%

Table 27: Uncertainty of the E/R factors for the uncertainty assessment of emissions from selective logging

Forest class	Uncertainty					AGB+BGB Ave tCO2/ha	Uncertainty (%)
	①	②	③	④	⑤		
EG	10.2	30.0	11.5	2.7	10.0	11.4	35.3%
MD	4.8	30.0	11.5	2.7	10.0	5.8	34.1%

CF	11.1	30.0	20.3	2.7	10.0	13.1	39.3%
MCB	14.1	30.0	11.5	2.7	10.0	9.0	36.6%
DD	8.2	30.0	11.5	2.7	10.0	11.6	34.7%

1. Uncertainty of AGB originating from sampling error (2nd NFI data): same with the E/R factors.
2. Uncertainty of AGB originating from biomass equation: expert judgement for applications of stump-to-DBH model from Cambodia, and uncertainty of the E/R factors (3.6-18.0 for the forest classes in subject)
3. Uncertainty of Root-to-Shoot ratios, due to the use of IPCC default values (IPCC GL 2006): same with E/R factors.
4. Uncertainty of Carbon Fraction factor, due to the use of IPCC default values (IPCC GL 2006): same with E/R factors.
5. Uncertainty of AGB originating from measurement error (QC of 2nd NFI): expert judgement for uncertainty of the E/R factors (3.1-8.7%)

The resulting uncertainty is estimated as 21.8% as show in the table below[22].

Table 28: Estimated emissions for degradation from selective logging

	Emissions (tCO2e)	Uncertainty (%)
EG	29,646,105	35.5%
MDF	51,974,068	34.4%
CF	1,626,038	42.4%
MCB	965,339	36.6%
DD	13,541,141	36.2%
Total	**97,752,691**	**21.8%**

5.4.3. Estimation of overall uncertainty of the emissions and removals for the 1st national REDD+ Results period

As the result, uncertainty of the emissions excluding logging, and uncertainty for the removals for the period 2015-2018 are as summarized in Table 29 below.

Table 29: Estimated uncertainty of the emissions excluding logging and removals

Source/Sink	2015-2018		
	Amount tCO2e/year	Uncertainty range tCO2e/year	Uncertainty range %
Emission	29,145,576	7,890,995	27.1%
Removal	-8,001,883	-1,958,216	24.5%

22 However, this level of uncertainty does not include potential uncertainties contained in the applied method, namely the use of biomass decay model developed in Malaysia. As this is difficult quantify objectively, it is not included in the current assessment.

The uncertainty of the emissions from selective logging for the period 2017-2018 is as summarized in Table 30 below.

Table 30: Estimated uncertainty of the emissions from selective logging

Source/Sink	2017-2018		
	Amount tCO2e/year	Uncertainty range tCO2e/year	Uncertainty range %
Emission from selective logging	8,146,058	1,776,135	21.8%

5.4.4. Estimation of overall uncertainty of the 1st National REDD+ Results

After the overall uncertainty of the emissions and removals for the 1st National REDD+ Results period are assessed as presented in Section 5.4.3 above, the overall uncertainty of the 1st National REDD+ Results was calculated also through 'propagation of error approach'.

As the final result, the overall uncertainty of the proposed 1st National REDD+ Results is considered as 16.5% for emissions and 15.7% for removals for the 2015-2016 period, and 12.7% for emissions and 15.7% for removals for the 2017-2018 period.

Table 31: Overall uncertainty of the proposed 1st National REDD+ Results (2015-2016)

Source/Sink	2015-2016		
	Amount tCO2e/year	Uncertainty range tCO2e/year	Uncertainty %
Emission	2,680,944	442,697	16.5%
Removal	468,325	73,592	15.7%

Table 32: Overall uncertainty of the proposed 1st National REDD+ Results (2017-2018)

Source/Sink	2017-2018		
	Amount tCO2e/year	Uncertainty range tCO2e/year	Uncertainty %
Emission	3,721,683	470,809	12.7%
Removal	468,325	73,592	15.7%

6. TRANSPARENCY AND DATA NECESSARY FOR THE RECONSTRUCTION OF THE 1st NATIONAL REDD+ RESULTS

Lao PDR is in the process of developing its full National Forest Monitoring System (NFMS) including the database system and web-based portal.

For the development of a database system which enables automated estimation of forest carbon stocks and its changes over time, this will be done through developing functions to:

1. Archive, calculate and output the AD
2. Archive, calculate and output the E/R factors
3. Calculate, evaluate and output the forest carbon stocks and its changes, and convert to tCO_2e.

The advantage of such system is that it will unify all the existing official data used for the emissions and removals into one single database, reduce costs by means of automating, and facilitate 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 analyse forests according to their interest.

Table 33: Data to be presented in the NFMS web-portal

Data related to AD	Data type
Forest Type Map 2000, 2005, 2010, 2015, 2019	Raster data
Forest cover change map 2000-2005, 2005-2010, 2010-2015, 2015-2019	Raster data (partly vector data)
Satellite imagery used for the development of Forest Type Maps Landsat (2000), SPOT4, 5 MS(2005), RapidEye (2010, 2015) (both false colour and true colour), Sentinel 2 (2019)	Raster data
Data related to E/R factors	**Data type**
1st NFI data	Tabular data
2nd NFI data	Tabular data including GIS points
3rd NFI data	Tabular data including GIS points
Other data	**Data type**
Administrative area: national, province, district	Vector data
Forest category: Production Forest, Protection Forest, Conservation Forest	Vector data
Reports	**Data storage**
FREL/FRL Report to the UNFCCC including annexes	Available in UNFCCC website
1st National REDD+ Results to the UNFCCC including annexes	To be made available in UNFCCC website
1st National Communication to the UNFCCC	Available in UNFCCC website
2nd National Communication to the UNFCCC	

The NFMS web-portal will enable access through internet[23]. The information to be presented in the NFMS web-portal will be further enhanced, although step-wise, to ensure transparency.

[23] <http://nfms.maf.gov.la:4242/nfms/>. As the web-portal is currently inaccessible due to its system upgrading in progress (as of June 2020), the temporary back-up website can be accessed through <http:/nfms-lao.net/nfms/>

7. ISSUES FOR FUTURE FREL/FRL AND MRV

7.1. Issues for future improvement

Lao PDR has identified the areas for future improvement in its FREL/FRL and MRV as follows. More details are described in Annex 1 and Annex 2 respectively:

1) Areas for future improvements related to the Activity Data

- Improvement of classification between forest classes “Mixed Deciduous Forests” (MD) and “Regenerating Vegetation” (RV)

Improvement of classification between RV and MD, which often represent different phases of land use in a shifting cultivation cycle continues to be a challenge. For the future forest mapping exercises, Lao PDR will continue to consider applying dataset being developed globally and/or regionally to detect repeated slash and burn events in order to enable further analysis of land/forest cover change over time.

- Updating the classification of classes “Upland Crop” (UC) and “Other Agriculture” (OA)

Distinguishing UC and OA was also a challenge as they give off very similar texture on satellite imagery. In the future, Lao PDR may explore using options, such as the technologies to analyze ‘big data’, multi-temporal satellite dataset, and GIS data from different sources (e.g. land concession data), which meet its needs.

- Further capacity building of the remote sensing, GIS and IT engineers of FIPD

In order to periodically generate AD, continuous capacity building efforts is inevitable. FIPD has been increasing their remote sensing capacity with the technical and financial support, however, under rapid innovation in remote sensing, GIS and IT technologies and products, demand for competent engineers is increasing. Development partners can continue to play an important role on systemizing know-how, training on planning, development and analysis of data, and support the FIPD/DOF staff to be updated on innovative technology.

2) Areas for future improvements related to the Emission/Removal Factors

- Carbon stocks of RV

The carbon stock of 2nd Regenerating Vegetation (RV) survey was calculated from the average carbon stock of each fallow year. The uncertainty reduced in the 2nd RV survey (i.e. accuracy improved) compared to the 1st RV survey, however, there is still a limitation in the representativeness of data and resulting uncertainty was still relatively high. For future NFI surveys, the number of years after abandonment is suggested to be included as a survey item with support from remote sensing.

- Continuous improvement of E/R factors

Default values from the IPCC Guidelines were used to estimate carbon stocks for some of the land/forest classes where country-specific data do not exist. Also, allometric equations for minor forest classes applied ones from neighboring country (i.e. Vietnam). Having improved set of country-specific carbon stock data and allometric equation shall contribute to reducing the uncertainty of E/R factors.

3) Others

- Inclusion of non-CO2 gases emission from shifting cultivation and forest fire

Shifting cultivation is an important source of emission in Lao PDR. Due to the lack of reliable data (AD and E/R factors including specific combustion factor for shifting cultivation), non-CO2 gas emission from shifting cultivation and consequent uncontrolled spreading of fire are not accounted in the current FREL/FRL. Although exclusion of such non-CO2 gases (mostly CH4 and N2O) are considered as conservative, Lao PDR will consider this as one area for technical improvement in the future.

➢ Inclusion of dead wood (DW) as a carbon pool

In addition to the DW for five natural forest classes measured in the 2nd NFI, the 3rd NFI added measurement of DW for the RV class. This already gives a foundation for Lao PDR to improve its estimation in the future. However, for consistency with the FREL/FRL, the 1st national REDD+ results does not include DW as a carbon pool. In the future estimations,

➢ Measurement of emissions from forest degradation by selective logging

To keep the measurement consistent with the FREL/FRL, tree stumps recorded in the 3rd NFI are used for measuring emissions by selective logging. Although it is still difficult to measure this type of emissions in the current remote sensing capacity of Lao PDR, there are some initiatives in the country to measure through advanced remote sensing techniques which may in the future, pave ways for a shift to alternative methods.

➢ Avoidance of double-counting of emissions and removals with other GHG mitigation initiatives

Currently, three GHG mitigation initiatives exist which their accounting areas and periods overlaps with the 1st national REDD+ results:

- VCS Project ID 1684 "Mitigation of GHG: Rubber based agro-forestry system for sustainable development and poverty reduction in Pakkading, Bolikhamsay Province": a project to develop rubber plantation in Bolikhamsay province. The project has an area of 969.20ha, which expects to sequestrate approximately 1,107,495 tCO2e during its 30 year project period from 2008-2037 (36,916 tCO2e/year);
- VCS Project ID 1398 "Reducing Emissions from Deforestation and Carbon Enhancement in Xe Pian National Protected Area": a project to provide sustainable long-term finance for an effective management of the Xe Pian National Protected Area (NPA) in Champasack province, in order to avoid deforestation and enhance carbon stocks. The Project Area presents an extent equal to 141,963 ha of the Xe Pian NPA, however, excluding the core parts of the NPA equivalent to 51,892 ha, which expects to sequestrate approximately 5,735,413 tCO2e during its 30 year project period of 2014-2043 (191,180 tCO_2e/year), approximately 0.65 million tCO_2e during its 1st baseline period (10 years) from 2014-2024 (64,981 tCO2e/year); and
- A Joint Crediting Mechanism (JCM)[24] project titled "Reducing GHG emissions from deforestation and forest degradation through controlling shifting cultivation in Phonxay District, Luang Prabang Province of Lao PDR". The project negotiation is yet to be concluded (as of March 2020), however communication between the two Governments have identified such a possibility occurring into the future, including possibly overlapping with the 1st national REDD+ results.

These activities will be tracked and recorded in a carbon registry (to be developed).

[24] The JCM is a climate change mitigation mechanism initiated by the Japanese government with partner countries including Lao PDR. <https://www.jcm.go.jp/la-jp/about>

7.2. Consistency with national GHG inventory

National GHG-Inventory

According to the UNFCCC decision 12/CP.17, paragraph 8, the FREL/FRL shall be established taking into account decision 4/CP.15, paragraph 7, while maintaining consistency with anthropogenic forest-related greenhouse gas (GHG) emissions by sources and removals by sinks as contained in each country's GHG inventories.

Lao PDR has so far submitted two National Communications (NCs) to the UNFCCC including GHG inventories. There is a plan to submit the 3rd NC and 1st Biennial Update Report (BUR) to the UNFCCC in 2020:

- The 1st NC submitted in year 2000 for the GHG Inventory of 1990;
- The 2nd NC submitted in year 2013 for the GHG Inventory of 2000;
- The 3rd NC to be submitted in year 2020 for the GHG Inventory of 2010; and
- The 1st BUR to be submitted in year 2020 for the GHG Inventory of 2014.

The overview of the comparison between the FREL/FRL and the latest GHG inventory for the Agriculture, Forestry and Other Land Use (AFOLU) of the 1st BUR (only the items comparable to the FREL/FRL) is provided in the table below. Noting that the FREL/FRL and the REDD+ results are estimated with full consistency as explained throughout this report, the comparative relation between the above therefore also applies in comparing the REDD+ results and the GHG inventory.

Table 34: Comparison of the FREL/FRL and GHG inventory of the 1st BUR

Scope	FREL/FRL	GHG inventory of the 1st BUR
Forest definition	Same definition of "Current Forest" and "Potential Forest" used.	
Land and forest classification system	'Level 2' land and forest classification (20 classes) is applied for the development of Forest Type Maps. The Forest Type Maps are the initial dataset for generating the Activity Data for both the FREL/FRL and GHG inventory.	
Activities included	Deforestation Forest degradation including selective logging Forest enhancement (restoration) Forest enhancement (reforestation)	Emissions and removals associated with land use and land use change; Emissions from biomass burning and Harvested Wood Products are also included.
Carbon Pools	Only AGB and BGB. Other carbon pools excluded due to insignificance and lack of data.	For each of the land use and land use change categories, the following components are estimated: - Initial change in biomass carbon stocks (AGB and BGB) due to conversion - Annual increase in carbon stocks in biomass due to growth - Annual decrease in carbon stocks due to wood/fuelwood removals and disturbances - Changes in dead organic matter

		- Changes in soil carbon (mineral soil, organic soil) due to land conversion
Gases	Only CO2 included.	In addition to CO2, CH4 and N2O emissions from biomass burning in forestlands (forest fire) are included.
Scale	National	
Emission Factor	Data source: 2nd NFI; country-specific allometric equation; IPCC default values; data of Vietnam. Then, stratified into five strata. Calculation: Amount of changes in carbon stock of among the five strata.	Same dataset with FREL/FRL used for forest classes and RV. Mostly using IPCC default taken from IPCC Guideline 2006 for the rest.
Activity Data	Data source: National-scale forest type maps for years 2005, 2010 and 2015. Then, stratified in to five strata. Calculation: Amount of changes in areas among the five strata. Estimated through reference sampling ('Design-Based Area Estimation')	Data source: using the same initial dataset with FREL/FRL. Calculation: no further stratification and reference sampling applied
Others		Emissions from biomass burning in forestlands (forest fire) included.

As summarized in the table above and presented in details in the GHG Inventory report of the 1st BUR, there is an attempt to harmonize the FREL/FRL and GHG Inventory for the AFOLU sector approaches and estimations to the extent possible (e.g. using the same Gain-Loss method, forest definition, land/forest classification, and land/forest cover change dataset as the data source for generating the AD, country-specific biomass dataset) but with differences in parts of the scope (e.g. activities, sources of emissions/removals included).

The most significant difference between the FREL/FRL and the GHG Inventory is the inclusion of biomass increase in forest remaining in the same category in the latter, which resulted in forestlands to be a sink opposed to the FREL/FRL. The concern that led to excluding biomass increase in forest remaining in the same category for the FREL/FRL was due to lack of reliable data and difficulties in judging whether such removals can be considered as 'anthropogenic'. In the end, Lao PDR decided to exclude biomass increase in forest remaining in the same category in order to reduce uncertainty and to be conservative in its estimates (and the REDD+ results)[25].

[25] See Section 3 of the FREL/FRL Report.

Although countries can decide the scope of REDD+ such as the emissions and removals, activities, gasses and pools according to their national circumstances, Lao PDR acknowledges such differences as areas to be improved, and is committed to take step-wise measures to enhance the consistency between the FREL/FRL and the GHG Inventory for the AFOLU sector to the extent possible.

Measures to enhance consistency

The GHG Inventory Division of Department of Climate Change (DCC) under the Ministry of Natural Resources and Environment (MONRE) is responsible for coordinating the compilation of the GHG Inventory. Therefore, coordination between DOF and DCC will continue to be important to maintain consistency between FREL/FRL (and MRV) and GHG Inventory in the future.

Several avenues exist that will facilitate this process:

- The DCC is one of the members of the REL/MRV Technical Working Group (TWG). All the issues related to REL and MRV are discussed, technically reviewed and endorsed by the TWG before the final decision is made by the Government. Harmonization between national FREL/FRL the GHG Inventory is listed as one of the tasks of the TWG; this issue has been, and will continue to be discussed through this coordination mechanism.
- The Deputy Director of DCC is a member of the National REDD Task Force (NRTF). The NRTF is responsible for endorsing the issues related to REDD+, including FREL/FRL and MRV.
- Under the coordination of DCC, a GHG Inventory Task Force for the 3rd NC and the 1st BUR led the preparation of the GHG Inventories. Staff from FIPD is assigned as a member of the GHG Inventory Task Force to bridge coordination between REDD+ and the GHG Inventory.
- Development partners (e.g. Food and Agriculture Organization, Global Green Growth Institute and World Bank supporting DOF and DCC coordination through their respective support) are pro-actively raising this issue in various venues, to facilitate the collaboration between DOF and DCC.

Lao People’s Democratic Republic

1st National REDD+ Results Report for REDD+ Results Payment under the UNFCCC

Annex 1

Activity Data Report

March 2020

Department of Forestry
Ministry of Agriculture and Forestry, Lao PDR

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Acronyms

AD	Activity Data
B	Bamboo
CF	Coniferous Forest
DBH	Diameter at Breast Height
DD	Dry Dipterocarp Forest
DOF	Department of Forestry
EG	Evergreen Forest
FIM	Forest Information Management Project
FIPD	Forestry Inventory and Planning Division
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GHG	Greenhouse Gas
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
Lao PDR	Lao People's Democratic Republic
M	Million (when used for expressing units)
MAF	Ministry of Agriculture and Forestry
MCB	Mixed Coniferous Broadleaved Forest
MD	Mixed Deciduous Forest
MRV	Measurement, Reporting and Verification
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
OA	Other Agriculture
P	Plantation
REDD+	Reducing Emissions from Deforestation and forest Degradation plus the conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks
RV	Regenerating Vegetation
UC	Upland Crop
UNFCCC	United Nations Framework Convention on Climate Change

1. OBJECTIVES

The objective of this report is to outline the process and results for generation of Activity Data (AD) for the purpose of estimating the emission reductions and increased removals in association with the four sources and sinks from REDD+ results for the 2015-2018 period at the national scale. The report describes the two main areas of work, namely:

1) Development of Forest Type Map of Lao PDR for year 2019[1]; and

2) Application of the forest type stratification (i.e. into five strata) to the Forest Type Map and initial analysis of forest cover change to conduct the design-based area estimation and revise the into the final AD and finally, to conduct the uncertainty assessment of AD.

It should be noted that the methods and results explained in this report are limited to the AD estimated through the Forest Type Maps. Other emissions from forest degradation from selective logging is estimated through a proxy-based approach, therefore, not included in this report.

[1] The map is officially referred to as the "Forest Type Map 2019". It is noted that this map was produced with satellite imageries from the dates of Jan. - Mar. 2019.

2. METHODOLOGY

Overview

The Forest Type Map 2019 was developed consistently with the methods applied for the FREL/FRL. Based on the Forest Type Map 2019 and the existing Forest Type Map 2015, the Initial Forest Change Map and Initial Forest Change Matrix was developed. Forest Type Maps are developed applying the 'Level 2' of land/forest classification system which is further stratified into the five land/forest strata (See Table 2). The resulting stratified Forest Type Maps were overlaid to create the Final Forest Cover Change Map and Final Forest Cover Change Matrix. The accuracy of the resulting data was assessed and the change area was adjusted accordingly to derive the Activity Data (AD). From this, the uncertainty of AD was estimated.

2.1 Mapping interval

The AD was developed for the period of 2015-2018 which is the proposed period for the 1st National REDD+ Results. As shifting cultivation is a common practice in the landscape of Lao PDR's, a 4-year reporting period was considered appropriate to capture this land use dynamics.

2.2 Forest definition and land/forest classification system

Forest definition

According to the Land Law (2003) and Forestry Law (2019), forest and forest resources in Lao PDR occur in lands that are designated by the Lao government as forest lands, and in areas outside forest lands, and includes stocked and temporarily un-stocked forests.

Lao PDR has applied definitions for "Current Forests" and "Potential Forests" respectively, as national definitions of the forests, for which a summary is shown in Table 1. This definition is consistently used in the national FREL/FRL as well as in the estimation of the REDD+ results summarized in this report. Both "Current Forest" and "Potential Forest" classes correspond to the IPCC forestland category.

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 and one plantation forest classes. The land classification system is illustrated in Table 2.

Table 1: Summary of the definition of "Current Forest" and "Potential Forest" of Lao PDR

Current Forest	Potential Forest
Stand DBH: minimum of 10cm Crown density: minimum of 20% Minimum area of 0.5ha.	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, and not permanently being used for other purposes (i.e. residential, agriculture etc.). It also does not include Upland Crop (UC), despite its common nature as a cropping stage of shifting cultivation cycle, based on de facto land-use at the time of observation

This definition was used for the past two National Communications to the UNFCCC, and has been agreed to be used for the future national Greenhouse Gas (GHG) inventory starting with the Third National Communication and the 1st Biennial Update Report. The Lao government plans to submit both to the UNFCCC within 2020.

Land/forest classification system

The land/forest classification system of the country applies two levels of classification, including Level 1 consisting of seven classes including "Current Forest" and "Potential Forest" among others, and Level 2 which further classifies the Level 1 current forest class into six natural and plantation classes. The relation between the national land/forest classification system and the land-use category definition of the IPCC is illustrated in Table 2 below.

Table 2: National level classification system of Lao PDR with IPCC definition on land use categories

IPCC Definition	National level classification system		
	Level 1	Level 2	
Forest Land	Current Forest	Evergreen Forest	EG
		Mixed Deciduous Forest	MD
		Dry Dipterocarp Forest	DD
		Coniferous Forest	CF
		Mixed Coniferous and Broadleaved Forest	MCB
		Forest Plantation	P
	Potential Forest	Bamboo	B
		Regenerating Vegetation	RV
Grassland	Other Vegetated Areas	Savannah	SA
		Scrub	SR
		Grassland	G
Cropland	Cropland	Upland Crop	UC
		Rice Paddy	RP
		Other Agriculture	OA
		Agriculture Plantation	AP
Settlement	Settlement	Urban Areas	U
Other land	Other Land	Barren Land and Rock	BR
		Other Land	O
Wetland	Above-ground Water Source	River (Water)	W
		Wetland (Swamp)	SW

For the development of Forest Type Map 2019, two of the Level 2 classes under "Cropland" category, namely "rice paddy" (RP) and "other agriculture" (OA), were merged into a single class to simplify the interpretation work in order to detect changes from Forest Type Map 2015. This neither affect the stratification of Level 2 classes into the five land/forest strata (see Section 2.4) nor their correspondence to the IPCC land-use category.

2.3 Development of the Forest Type Map 2019

2.3.1 Satellite imagery used

The satellite imagery used for the development of Forest Type Map 2019 is summarized in Table 3. The satellite imagery used for Forest Type Maps for the years 2005, 2010 and 2015, which were used for the FREL/FRL, are also summarized in the same table as a reference.

Table 3: Satellite images used for the development of Forest Type Maps

Name	SPOT4 / 5 MS	RapidEye	RapidEye	Sentinel-2[2]
Forest Type Map	2005	2010	2015	2019
Observation term	From Oct. 2004 to Apr. 2006	From Nov. 2010 to Mar. 2011 for Forest Type Map 2010	From Nov. 2014 to Feb. 2015 for Forest Type Map 2015	From Jan. 2019 to Mar. 2019 for Forest Type Map 2019
Number of scene	114	146	94	229
Spatial resolution	10m	5m	5m	10m
Bands	Band1: Green Band2: Red Band3: NIR Band4: SWIR	Band1: Blue Band2: Green Band3: Red Band4: Red edge Band5: NIR	Band1: Blue Band2: Green Band3: Red Band4: Red edge Band5: NIR	Band2: Blue Band3: Green Band5: Red Band8: NIR Band11: SWIR

2.3.2 Technical process

Overview of the process

The general process for the development of Forest Type Map 2019 is described in Figure 1.

The mapping standards were determined considering various factors, such as the appropriateness of mapping scale, spatial resolution of satellite imagery and time resources. The mapping scale of 1:100,000, and a minimum mapping unit of 0.5 ha were consistently used for developing all Forest Type Maps.

In order to secure time-series consistency among the maps, and also taking into account associated cost and map quality, the following process was applied to develop Forest Type Map 2019: first detecting changes in satellite imageries of years 2015 and 2019, then overlaying the detected changed areas with the Forest Type Map 2015 (the latest map used for FREL/FRL). This methodology is consistent with that for Forest Type Map 2015 (i.e. overlaying extracted changed area between years 2010 and 2015 with Forest Type Map 2010), which was developed as the benchmark map for the FREL/FRL using object-based classification.

[2] In addition, Planet imagery (5m spatial resolution) and other freely available imageries were referenced to support the interpretation.

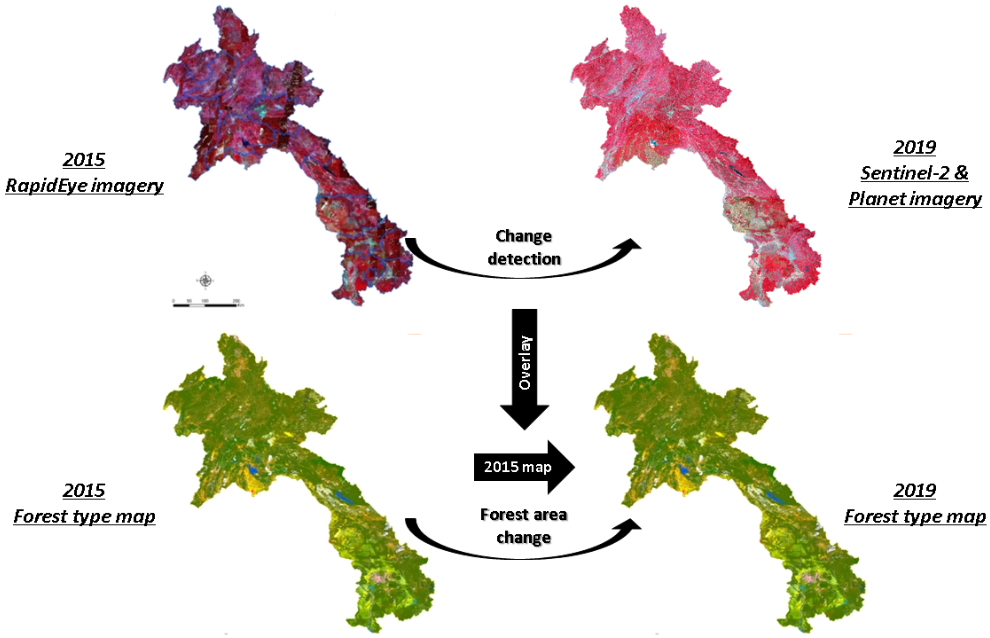

Figure 1: Overview of the Forest Type Map development process

Data processing

First, each satellite imagery was pre-processed. For year 2019, cloud-free mosaic of Sentinel-2 imagery was generated combining available Sentinel-2 images obtained between January and March 2019 using Google Earth Engine[3] and was downloaded into the server of the Forest Inventory and Planning Division (FIPD) of the Department of Forestry (DOF) under the Ministry of Agriculture and Forestry (MAF). For 2015, where RapidEye imagery were used, absolute position and relative position accuracy were improved by ortho-rectifying and using ground control points collected from the entire country as well as from very high resolution satellites. Afterwards they were mosaicked.
Normalized Difference Vegetation Index (NDVI) was created for every processed imagery. Color enhancement was carried out for each mosaic imagery to evenly adjust the color tone to the extent possible, and minimize the effect of differences to the interpretation results.

Change detection

As explained above, by using Forest Type Map 2015 as the benchmark map, Forest Type Map 2019 was developed though change detection method. The option was taken to identify and classify the changes through visual (manual) interpretation comparing RapidEye imagery of year 2015 and Sentinel-2 imagery of year 2019[4]. Planet imagery of year 2019, which has higher spatial resolution, was used as a supplementary source to assist the interpretation of the land-use after the change. Available data for the same period on regional forest loss and gain[5] and NDVI were also referenced to better detect changed areas.

For quality control of the visual (manual) interpretation process, a three-fold control process was introduced:

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[3] https://earthengine.google.com/
[4] The effect of the difference in satellite imagery (RapidEye and Sentinel-2) in visual interpretation was minimal according to the FIPD technicians.
[5] https://rlcms-servir.adpc.net/en/forest-monitor/#

Step 1: Interpretation by FIPD remote sensing engineers. Each engineer was assigned a region (a group of provinces) – noting their experience and knowledge of the region;

Step 2: Review of Step 1 by FIPD senior remote sensing engineers. Potential misinterpretation and errors were returned to the Step 1 engineer for review.

Step 3: Sample-based random quality check by external international remote sensing engineers from F-REDD Project. Potential misinterpretation and errors were returned to the Step 1 engineer for review.

Following general recommendations, the remote sensing imagery interpretation exercise was combined with a nation-wide ground truth survey to improve and verify the map quality, and also to build the interpretation capacity of the FIPD remote sensing engineers involved in the task. The results of ground truth survey were organized into a system for improvement, such as establishing interpretation standards for each satellite imagery and classification item, preparation/updating of interpretation cards, then shared among the interpretation team.

To avoid overestimation of changes, cases where changes were marginal or questionable were omitted (i.e. not considered change).

Challenges related to the classification of land under shifting cultivation

A technical challenge faced throughout the forest mapping exercise was to accurately and consistently distinguish the classes "Upland Crop" (UC), "Regenerating Vegetation" (RV) and "Mixed Deciduous Forest" (MD). It is noteworthy that these three classes are generally considered to have potential association with shifting cultivation practices.

As a supplementary measure to improve the classification accuracy and time-series consistency for UC, RV and MD classes, and to be consistent with the historical Forest Type Maps used for the FREL/FRL, corrections were made to the Initial Forest Type Map classes based on the information of the number of years since slash and burning event, by using the annual vegetation loss dataset by Hansen et al[6] [7].

However, in using the dataset from Hansen et al., the following two issues were taken into account, while maintaining conservativeness in estimates, and only the plots (polygons) which clearly satisfy the criteria above were corrected:

1) The Hansen et al. dataset includes vegetation loss occurring outside forest land (e.g. on agriculture land). Therefore, for land parcels (polygons) interpreted as UC in both of the two latest Forest Type Maps (namely, of years 2015 and 2019), a rule was applied that such parcels would be considered as permanent agricultural land and the classification of the polygon in the Forest Type Map of year 2019 would be revised to "Other Agriculture" (OA) class; and
2) The Hansen et al. dataset does not identify repeated loss events, thus, repeated loss could be underestimated. Considering eight (8) years as the standard number of years for forest regeneration, MD polygons where vegetation loss was confirmed in the past eight (8) years

[6] Hansen, M. C. et al. (2013) "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest.

[7] DOF et al. (2017) "Development of a Lao-specific Equation for the Estimation of Biomass of 'Regenerating Vegetation' and Determination of the Threshold Years for its Regeneration into Forest. The report concludes that on average, land slashed and burnt would regenerate into forest status after eight (8) years (i.e. one (1) year as UC and seven (7) years under fallow, or RV) <http://dof.maf.gov.la/en/home/>

were corrected to RV; the assumption being that regeneration into MD does not happen in less than eight (8) years.

Accuracy assessment of the Forest Type Map 2019

After the Forest Type Map 2019 was developed, an accuracy assessment was undertaken. The overall accuracy for classification of "forest" and "non-forest" was 93.1% (Table 4), and the overall accuracy of classification among the land/forest classes (eight forest land classes and aggregation of all non-forest lands) was 79.8% (Table 5).

Table 4: Accuracy assessment of forest and non-forest

2019		Reference data			
		Forest	Non-forest	Total	U.A
Map	Forest	**1690**	80	1770	95.5%
	Non-forest	66	**265**	331	80.1%
	Total	1756	345	2101	
	P.A	96.2%	76.8%		
Overall Accuracy		**93.1%**			

Table 5: Accuracy assessment of land/forest classes

2019				Reference data										
				Forest Land								Non-forest	Total	U.A
				Current Forest						Potential Forest				
				EG	MD	DD	CF	MCB	P	B	RV			
Map	Forest Land	Current Forest	EG	**214**	6	1					8	2	231	92.6%
			MD		**589**	10			2	1	195	18	815	72.3%
			DD			**87**			1		4	10	102	85.3%
			CF				**17**				2		19	89.5%
			MCB					**15**					15	100.0%
			P		1				**16**		8	2	27	59.3%
		Potential Forest	B	1						**18**			19	94.7%
			RV		30				7	1	**456**	48	542	84.1%
	Non-forest				3	9			11		43	**265**	331	80.1%
		Total		215	629	107	17	15	37	20	716	345	2101	
		P.A		99.5%	93.6%	81.3%	100.0%	100.0%	43.2%	90.0%	63.7%	76.8%		
Overall Accuracy				**79.8%**										

Development of Initial Forest Change Maps

From the draft Forest Type Map 2019 developed above, Initial Forest Change Maps for the period 2015-2019 was generated to conduct initial analysis of forest change and collect "illogical changes" by overlaying the Forest Type Maps of the two years (2015 and 2019). From the vector map which recorded the forest changes for the period of 2015-2019, the Initial Forest Change Matrix was generated by exporting the attributes in the GIS, and using the Pivot Table tool of Microsoft Excel to sum up the area size of the changed polygons per each land/forest class.

Table 6: Initial Forest Cover Change Matrix 2015 - 2019

ha	2019	EF	MD	DD	CF	MCB	P	B	RV	SA	SR	G	SW	UC	AP	RP/ OA	U	BR	O	W	
2015		11	12	13	14	15	16	21	22	31	32	41	42	51	63	64	71	72	80	81	total
EF	11	2,594,412	891	4	0	0	158	11	2,424	0	0	0	0	2,114	143	330	60	0	387	4,624	2,605,557
MD	12	388	8,942,811	2,125	0	0	11,824	388	161,350	0	0	22	0	23,686	1,871	47,135	2,140	0	1,205	10,090	9,205,036
DD	13	0	1,149	1,169,435	0	0	2,246	8	2,409	49	5	27	0	520	233	9,126	2,434	0	95	463	1,188,198
CF	14	0	0	0	124,009	0	0	0	530	0	0	0	0	109	0	117	1	0	6	0	124,772
MCB	15	0	6	0	0	106,848	0	0	411	0	0	0	0	34	0	57	0	0	1	523	107,880
P	16	0	140	40	0	0	123,611	0	6,541	0	0	0	0	28	337	6,979	126	0	16	147	137,965
B	21	17	88	0	0	0	519	80,998	5,943	0	0	0	0	334	10	862	7	0	0	121	88,900
RV	22	143	91,682	268	0	0	44,167	2,164	5,783,983	0	0	71	0	91,107	6,653	40,475	4,472	0	1,048	7,348	6,073,581
SA	31	0	0	0	0	0	254	0	0	69,869	0	0	0	36	1	31,541	268	0	19	122	102,110
SR	32	0	0	0	0	0	1	0	1	0	26,365	0	0	33	0	236	0	0	0	2	26,637
G	41	0	0	0	0	0	83	0	0	0	0	250,217	0	58	11	3,622	152	0	32	201	254,376
SW	42	0	0	0	0	0	6	0	0	0	0	0	6,072	4	0	3,329	9	0	0	142	9,561
UC	51	0	0	0	0	0	2,292	723	97,018	0	21	265	0	0	95	49,499	310	0	127	171	150,519
AP	63	0	0	0	0	0	721	0	990	0	0	0	0	12,007	68,906	637	1	0	12	31	83,306
RP/ OA	64	0	0	0	0	0	27,519	269	23,455	0	0	0	0	2,716	4,796	2,176,180	14,636	0	265	2,635	2,252,472
U	71	0	0	0	0	0	2	0	252	0	0	0	0	68	0	74	75,153	0	1	89	75,638
BR	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	185,954	0	203	186,157
O	80	0	0	0	0	0	184	0	1,833	0	0	0	0	40	17	8,152	1,228	1	19,105	730	31,289
W	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82	0	0	0	350,222	350,304
total		2,594,961	9,036,767	1,171,873	124,009	106,848	213,585	84,561	6,087,141	69,918	26,391	250,603	6,072	132,892	83,072	2,378,434	100,994	185,954	22,319	377,863	23,054,258

From the Initial Forest Change Matrix, ecologically impractical changes, or changes practically not feasible within the period of four years, were identified as "Illogical changes" (Table 7). Through this diagnostic check, all of these areas were double-checked and corrected. All of the changes which were unlikely to occur, although not definite, were double-checked and corrected.

Table 7: Patterns of illogical changes

			EF	MD	DD	CF	MCB	P	B	RV	SA	SR	G	SW	UC	RP	OA	AP	RP/OA	U	BR	O	W
			11	12	13	14	15	16	21	22	31	32	41	42	51	61	62	63	64	71	72	80	81
Evergreen Forest	EF	11	○	○	△	△	△	○	○	○	×	×	△	×	○	○	○	○	○	○	×	○	△
Mixed Deciduous Forest	MD	12	○	○	△	△	△	○	○	○	×	×	△	×	○	○	○	○	○	○	×	○	△
Dry Dipterocarp Forest	DD	13	×	△	○	△	△	○	○	○	○	○	△	×	○	○	○	○	○	○	×	○	△
Coniferous Forest	CF	14	×	×	×	○	○	○	○	○	×	×	△	×	○	○	○	○	○	○	×	○	△
Mixed Coniferous and Broadleaved Forest	MCB	15	×	△	×	○	○	○	○	○	×	×	△	×	○	○	○	○	○	○	×	○	△
Forest Plantation	P	16	×	△	△	△	△	○	○	○	×	×	△	×	○	○	○	○	○	○	×	○	△
Bamboo	B	21	△	△	△	△	△	○	○	○	×	×	△	×	○	○	○	○	○	○	×	○	△
Regenerating Vegetation	RV	22	△	○	○	○	○	○	○	○	×	×	△	×	○	○	○	○	○	○	×	○	△
Savannah	SA	31	×	×	×	×	×	○	×	×	○	△	△	×	○	○	○	○	○	○	×	○	△
Scrub	SR	32	×	×	×	×	×	○	×	×	×	○	△	×	○	○	○	○	○	○	△	○	△
Grassland	G	41	×	×	×	×	×	○	×	×	×	×	○	×	○	○	○	○	○	○	×	○	△
Swamp	SW	42	×	×	×	×	×	○	×	×	×	×	×	○	○	○	○	○	○	○	×	○	△
Upland Crop	UC	51	×	×	×	×	×	○	○	○	○	○	○	○	○	○	○	○	○	○	×	○	△
Rice Paddy	RP	61	×	×	×	×	×	○	○	○	×	×	×	×	×	○	○	○	○	○	×	○	△
Other Agriculture	OA	62	×	×	×	×	×	○	○	○	×	×	×	×	△	△	○	○	○	○	×	○	△
Agriculture Plantation	AP	63	×	×	×	×	×	○	○	○	×	×	×	×	△	△	△	○	○	○	×	○	△
Urban	U	71	×	×	×	×	×	△	△	△	△	△	△	△	△	△	△	△	△	○	×	○	△
Barren Land and Rock	BR	72	×	×	×	×	×	×	×	×	×	△	×	×	×	×	×	×	×	×	○	×	△
Other Land	O	80	×	×	×	×	×	△	△	△	△	△	△	△	△	△	△	△	△	△	△	○	△
Water	W	81	×	×	×	×	×	×	×	×	×	×	△	△	×	△	△	×	△	×	○	△	○

X: illogical changes which should not occur

△: changes unlikely to occur, although not impossible

O: possible changes

Final Forest Type Maps

Figure 2 and Figure 3 show the Final Forest Type Maps for years 2015 and 2019, and Table 8 shows the areas of land/forest classes calculated from these maps.

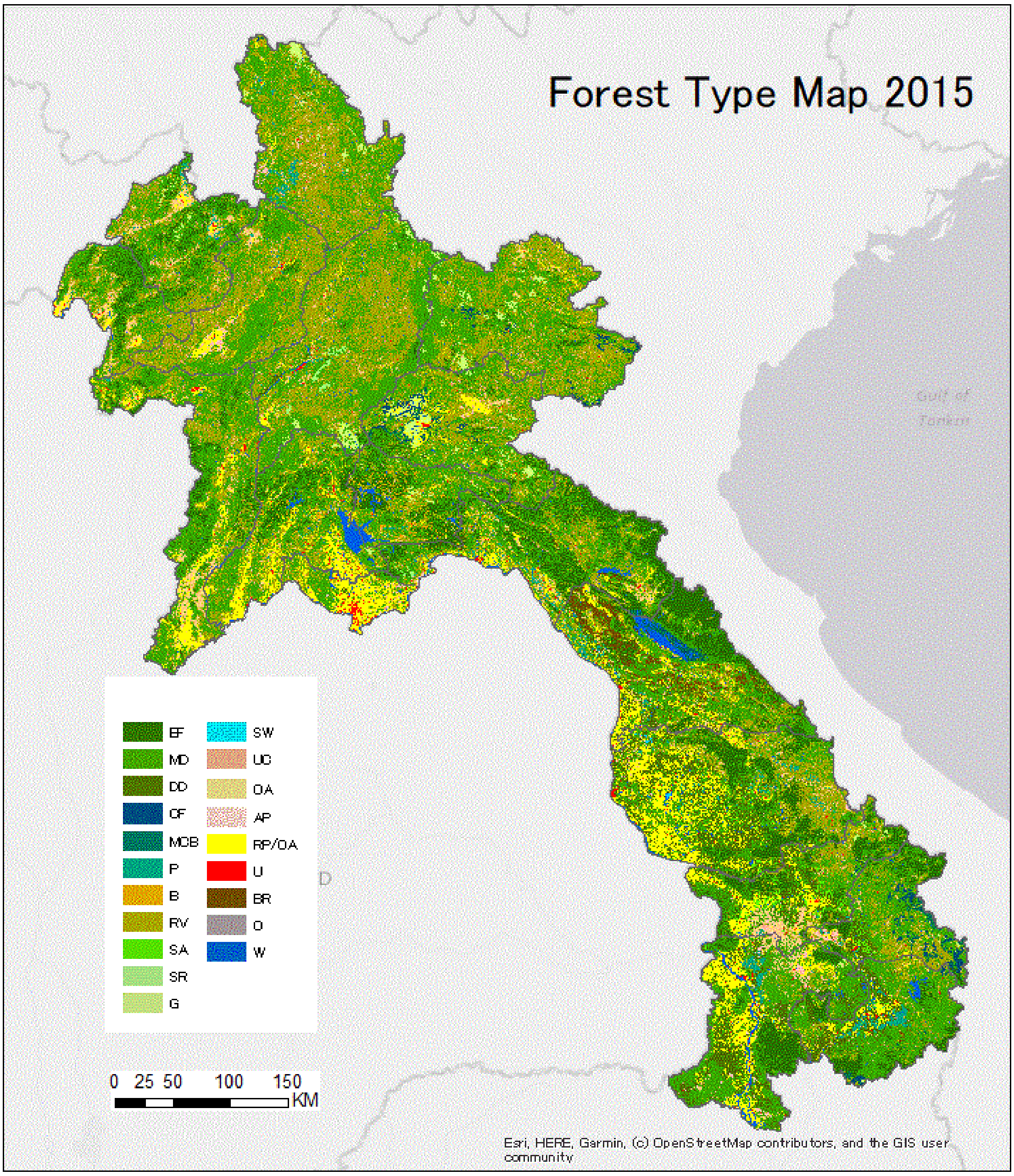


Figure 2: Forest Type Map 2015

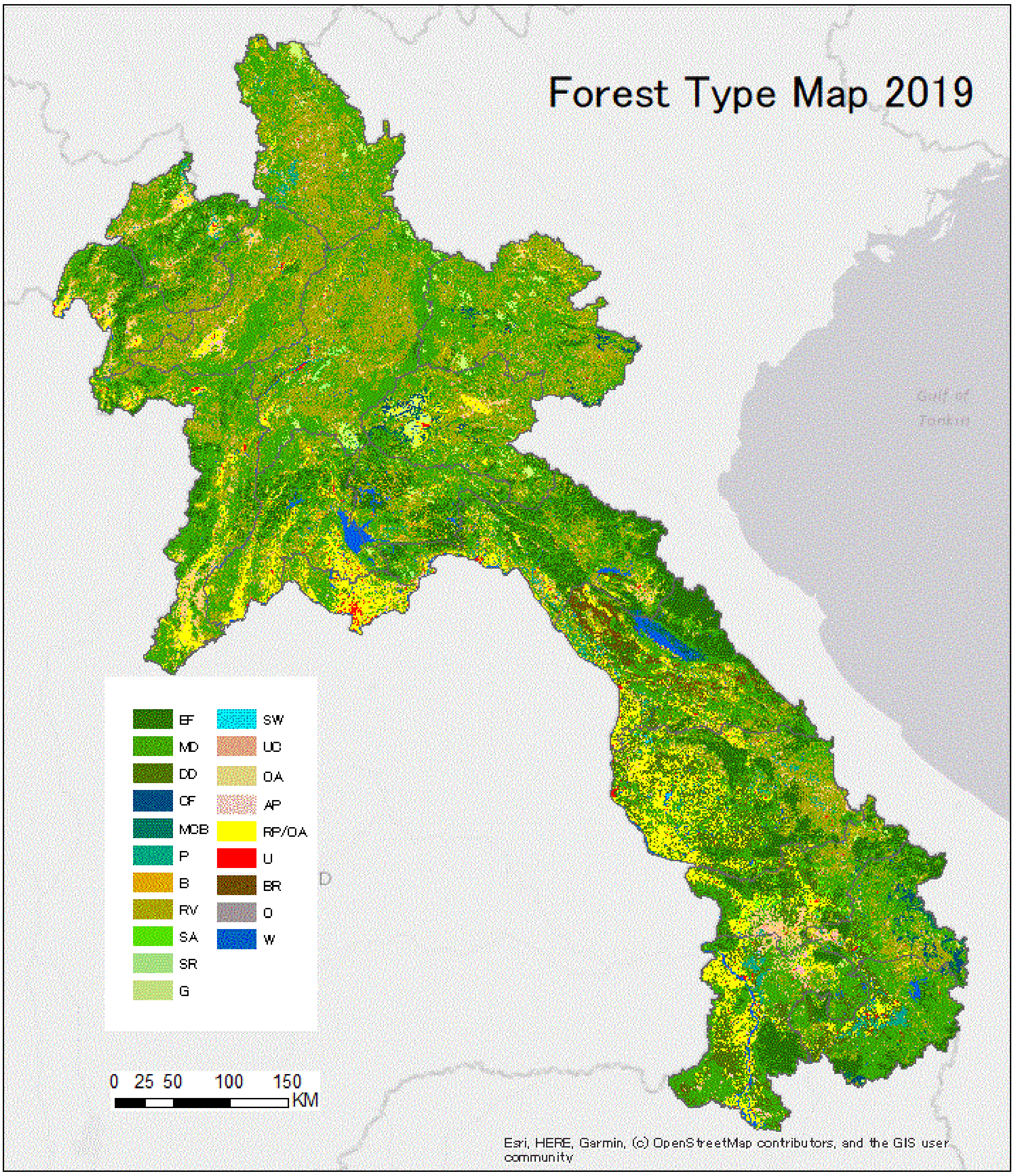


Figure 3: Forest Type Map 2019

Table 8: Areas of land/forest classes from Final Forest Type Maps 2015 and 2019

		Area (ha)	
		2015	2019
Evergreen Forest	EG	2,605,557	2,594,961
Mixed Deciduous Forest	MD	9,205,036	9,036,767
Coniferous Forest	CF	124,772	124,009
Mixed Coniferous and Broadleaved Forest	MCB	107,880	106,848
Dry Dipterocarp Forest	DD	1,188,198	1,171,873
Forest Plantation	P	137,965	213,585
Bamboo	B	88,900	84,561
Regenerating Vegetation	RV	6,073,581	6,087,141
Savannah	SA	102,110	69,918
Scrub	SR	26,637	26,391
Grassland	G	254,376	250,603
Swamp	SW	9,561	6,072
Upland Crop	UC	150,519	155,068
Agriculture Plantation	AP	83,306	83,072
Rice Paddy/Other Agriculture	RP/OA	2,252,472	2,356,258
Urban	U	75,638	100,994
Barren Land and Rock	BR	186,157	185,954
Other Land	O	31,289	22,319
Water	W	350,304	377,863
Total		**23,054,258**	**23,054,258**

2.4 Stratification of land/forest classes

Echoing the process from the FREL/FRL, to reduce uncertainty of emissions and removals while taking into account the accuracy from sampling and the cost and efforts required, the land/forest classification was further stratified into five strata as below and as summarized in Table 9:

Table 9: Land/forest classes and stratification

Land/forest classes			Area (ha)	% of total area	Strata
Level 1	Level 2				
Current Forest	Evergreen Forest	EG	2,594,961	11.3%	1
	Mixed Deciduous Forest	MD	9,267,624	40.2%	2
	Coniferous Forest	CF			
	Mixed Coniferous and Broadleaved Forest	MCB			
	Dry Dipterocarp Forest	DD	1,171,873	5.1%	3
	Forest Plantation	P	6,385,287	27.7%	4
Potential Forest	Bamboo	B			
	Regenerating Vegetation	RV			
Other Vegetated Areas	Savannah	SA	3,634,513	15.8%	5
	Scrub	SR			
	Grassland	G			

Cropland	Upland Crop	OA			
	Agriculture Plantation	AP			
	Rice Paddy/Other Agriculture	RP/OA			
Settlement	Urban Areas	U			
Other Land	Barren Land and Rock	BR			
	Other Land	O			
Above-ground Water Source	Wetland (Swamp)	SW			
	River (Water)	W			
Total			23,054,258	100%	

Stratified Forest Type Maps

Figure 4 and Figure 5 show the stratified Forest Type Maps for year 2015 and 2019 respectively, and Table 10 summarizes the area and percentage of each stratum for the respective years.

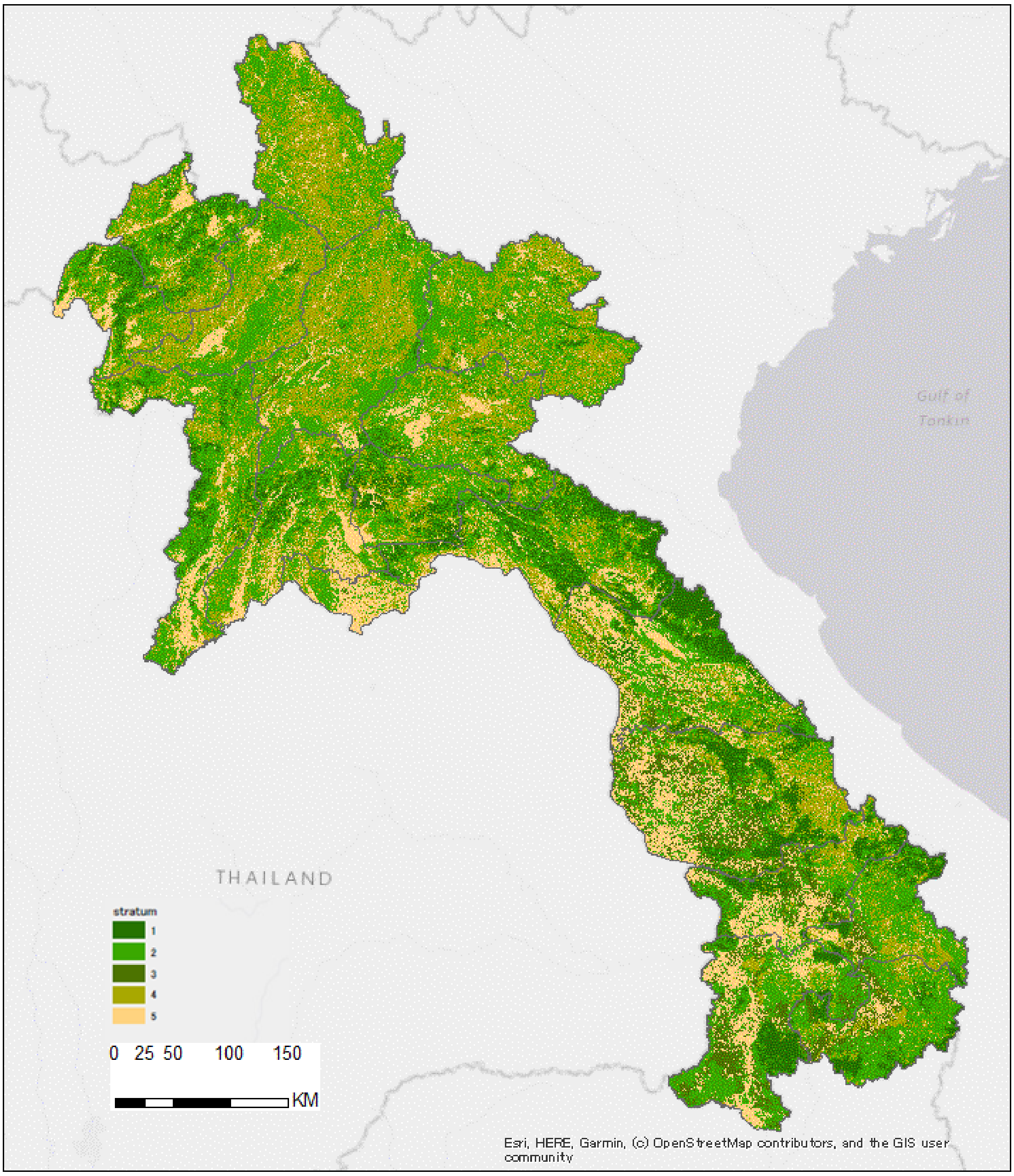


Figure 4: Stratified Forest Type Map 2015

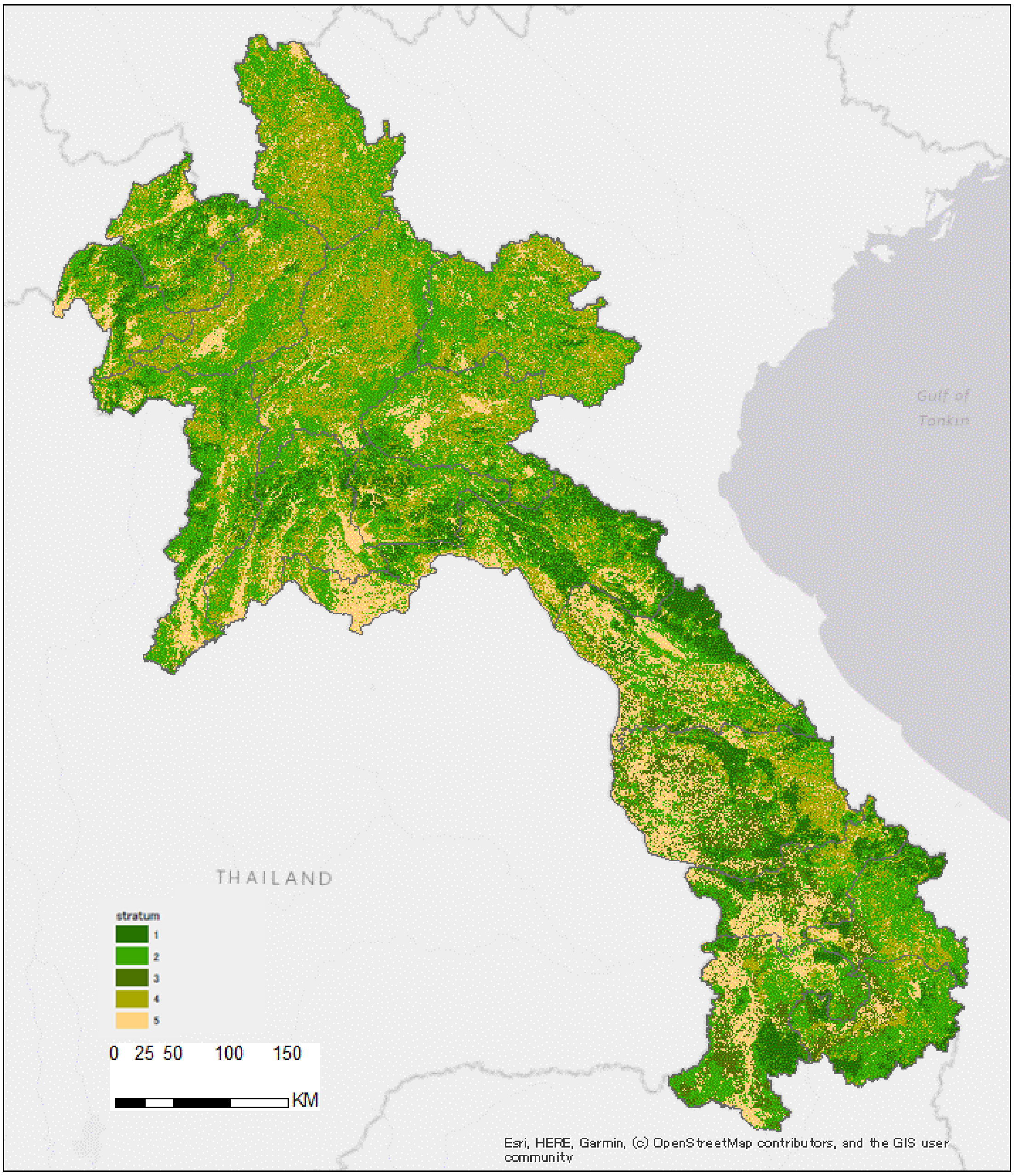


Figure 5: Stratified Forest Type Map 2019

Table 10: Area and percentage per stratum for 2015 and 2019

Unit: ha, percentage

	2015	%	2019	%
Stratum 1	2,605,557	11.3%	2,594,961	11.3%
Stratum 2	9,437,688	40.9%	9,267,624	40.2%
Stratum 3	1,188,198	5.2%	1,171,873	5.1%
Stratum 4	6,300,445	27.3%	6,385,287	27.7%
Stratum 5	3,522,370	15.3%	3,634,513	15.8%
Total	23,054,258	100%	23,054,258	100%

2.5 Sources and sinks selected

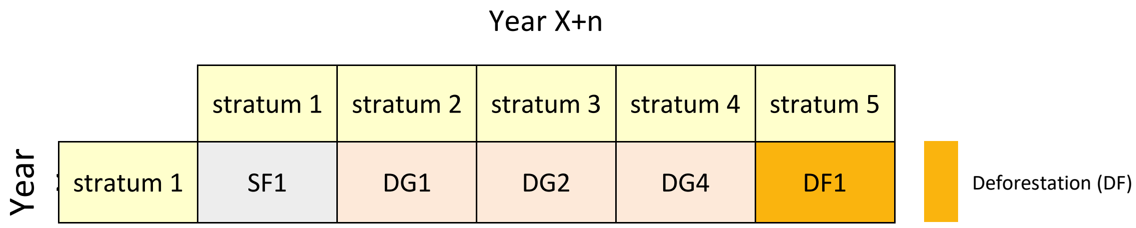
The emissions and removals are estimated by first applying Emission Factors to the area estimates from the AD. Then, the results were aggregated into the selected four sources and sinks associated with the REDD+ Activities over the period (i.e. 2015-2018), which are:

- **Emissions from Deforestation (DF),** caused by loss of forest carbon stock due to conversion of a forest land stratum to non-forest land stratum;
- **Emissions from Forest Degradation (DG)**, caused by downward shift of a forest stratum from a higher carbon stock strata to another forest stratum with lower carbon stock[8];
- **Removals from Forest Enhancement (Restoration) (RS)**, caused by upward shift of a forest land stratum with lower carbon stock to another forest/land stratum with higher carbon stock; and
- **Removals from Forest Enhancement (Reforestation) (RF)**, caused by gain of forest carbon stock due to conversion of non-forest land stratum to a forest land stratum.

In addition, there are two stable types of land/forest classes which do not impact emissions or removals, which are:

- **Stable Forest (SF)**, where there is no change in the forest stratum; and.
- **Stable Non-Forest (SNF)**, where there is no change in the non-forest land stratum.

Accordingly, the AD is derived as amount of changes in forest areas which relate to any of the four sources and sinks (Figure 6). The four sources and sinks and the two stable land/forest classes serve as stratification for collecting reference data to apply reference sampling of AD.



[8] In addition to the use of land/forest cover change data from Forest Type Maps, impact of logging is estimated through field survey of tree stumps. This captures degradation not only caused by downward shift of a forest stratum, but also those in same forest land stratum. Possible double-counting of emissions from degradation arising from the use of two different methods are avoided in the accounting.

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

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

Figure 6: Sources and sinks associated with REDD + activities

Sources and sinks maps

The map which shows the sources and sinks associated with REDD+ activities for 2015-2019 is shown in Figure 7.

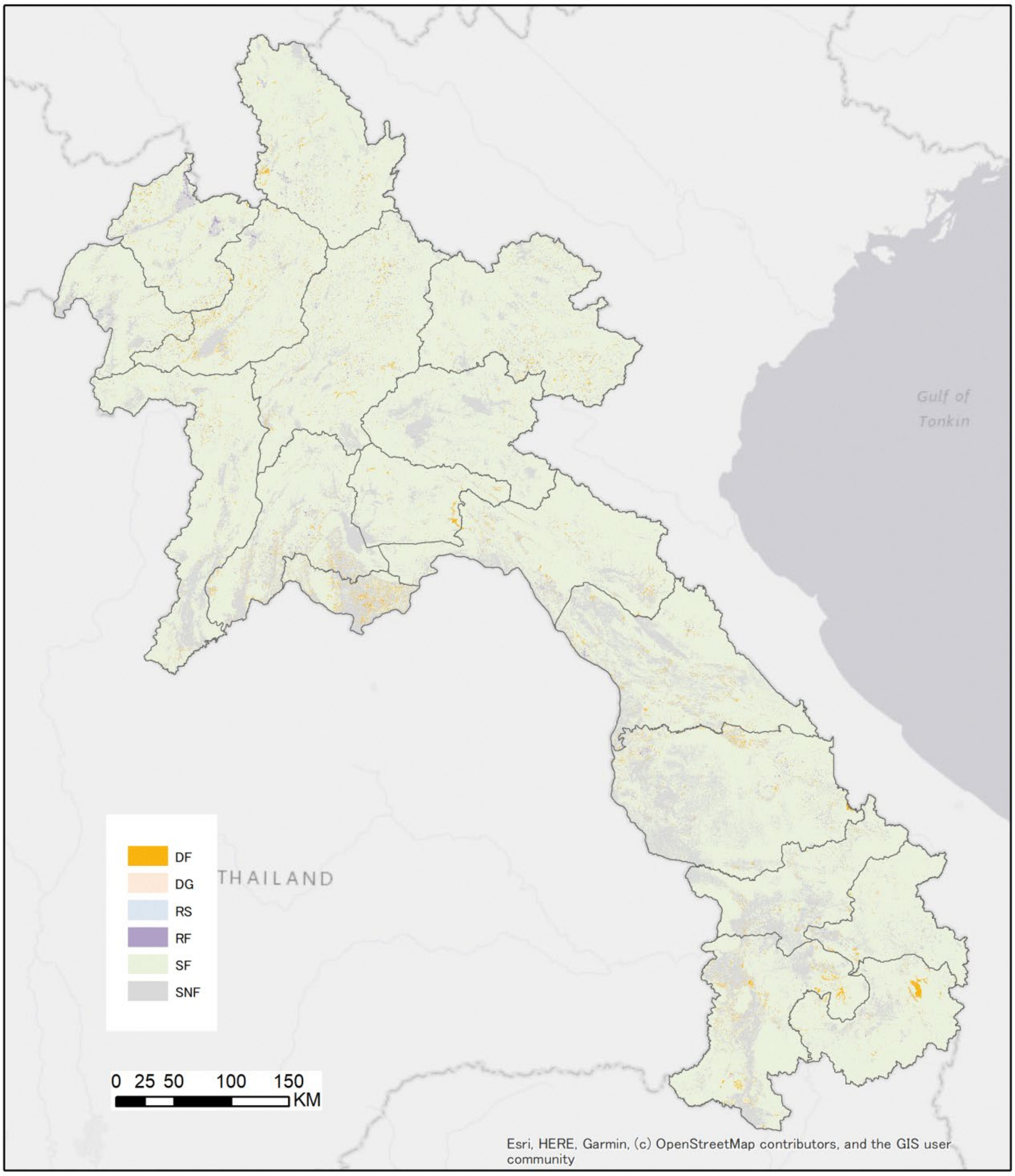


Figure 7: Sources and Sinks Map 2015 - 2019

2.6 Reference sampling ('Design-based area estimation') of Activity Data

Lao PDR decided to apply reference sampling (so called 'design-based area estimation' in the FREL/FREL report) with respect to generating statistically reliable estimates of AD. The following sections explain the methods used for conducting reference sampling using the stratified Forest Type Maps for collecting reference data.

The reference sampling method follows good practice recommended by Olofsson et al. (2014)[9], which regards the stratified Forest Type Map to serve as an initial stratification of the population of interest for the purposes of designing and collecting reference data which is then used to re-estimate the actual changed areas.

2.6.1 Sampling design

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

Where

N = *number of sample points for the stratum of interest*

$S(\widehat{O})$ = *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 sample size was determined by using the formula by Cochran (1977)[10], assuming that the sampling cost of each stratum is the same. The calculation was done using FAO's SEPAL[11] which allows automated calculation of sampling size and distribution. The following values were set as the target for allocating statistically sound sampling size[12]:

- 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.

As a result, the sampling design for the reference data was created as shown in Table 11. The total number of plots sampled was 931 plots, where 30 sampling plots were given to strata DG, DF, RF and RS respectively, to ensure statistical soundness (i.e. otherwise, from proportional allocation, the sample size would be too few). The total number sampled for strata SF and SNF were 689 plots and 122 plots respectively.

[9] Olofsson et al (2014). Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment, 148:42-57.

[10] Cochran, W. G. (1977). Sampling techniques. John Wiley & Sons.

[11] https://sepal.io/

[12] According to Congalton and Green (2008), the minimum sample size for assessing the accuracy of remotely sensed data is recommended to be in the range of 20 – 100 samples.

Table 11: Sampling design per source/sink 2015 - 2019

Source/Sink Category	Degradation	Deforestation	Restoration	Reforestation	Stable forest	Stable non-forest	Total
Stratum	DG	DF	RS	RF	SF	SNF	
Area (ha)	267,746	184,779	155,603	93,916	18,985,447	3,366,767	23,054,258
Expected User's Accuracy	0.70	0.70	0.70	0.70	0.90	0.90	
Wi (Mapped proportion)	0.01	0.01	0.01	0.00	0.82	0.15	
Si (Standard Deviation)	0.46	0.46	0.46	0.46	0.30	0.30	
Wi*Si	0.01	0.00	0.00	0.00	0.25	0.04	0.30
					$S(\hat{P})$	(SE overall accuracy)	0.01
					$\left(\frac{\sum W_i S_i}{S(\hat{P})}\right)^2$		929.15
					Total Number of Samples		931
						Sample size per stratum	Total
Equal	155.17	155.17	155.17	155.17	155.17	155.17	931
Proportional	11	7	6	4	767	136	931
Minimum sample size	30	30	30	30	30	30	
Adjusted	**30**	**30**	**30**	**30**	**689**	**122**	931

2.6.2 Response design

The response design provides the best available interpretation of change for each spatial unit sampled. The spatial assessment unit was set as 1 ha (100 x 100 m). The square plots were visually (manually) interpreted using high and medium resolution satellite imagery as the reference data.

High and medium resolution satellite imagery were obtained from repositories accessible through Planet and Google Earth, as well as the archives available at FIPD (Landsat2000, SPOT 2005, RapidEye 2010, RapidEye 2015, Sentinel-2 2017 and Sentinel-2 2019). Protocols and rules, such as reference labelling, were agreed on before conducting the assessment.

2.6.3 Creation of error matrix

After the sampling design was determined, the sampling plots were interpreted and the resulting reference data were summarized into the error matrix as shown in Table 12.

Table 12: Error matrix per source/sink 2015 - 2019

	Reference data						
	DF	**DG**	**RF**	**RS**	**SF**	**SNF**	Total
DF	26	1	1	0	1	1	30
DG	1	19	2	0	8	0	30
RF	0	24	1	1	0	4	30
RS	1	3	23	2	1	0	30
SF	2	5	5	11	686	21	730
SNF	1	2	1	23	2	1	30
Total	31	33	29	26	692	120	931

2.6.4 Results of design-based estimation of Activity Data

From the error matrix, the areas for the four sources and sinks (Deforestation, Degradation, Restoration, Reforestation) and the two stable land/forest classes (Stable Forest, Stable Non-Forest) were calculated as shown in Table 13 below.

Table 13: Areas per source/sink 2015 - 2019

Class	DF	DG	RF	RS	SF	SNF
DF	0.0229	0.0031	0.0010	0.0000	0.0021	0.0021
DG	0.0004	0.0067	0.0007	0.0000	0.0028	0.0000
RF	0.0000	0.0000	0.0084	0.0000	0.0008	0.0028
RS	0.0001	0.0000	0.0001	0.0031	0.0002	0.0001
SF	0.0023	0.0056	0.0056	0.0124	0.7739	0.0237
SNF	0.0011	0.0022	0.0000	0.0022	0.0090	0.1044
Reference Class Proportion	0.0267	0.0177	0.0159	0.0178	0.7888	0.1331
Standard error	0.00324	0.00357	0.00295	0.00405	0.00808	0.00659
95% CI	0.00635	0.00699	0.00578	0.00793	0.01584	0.01293
Area	616,370	407,553	367,038	409,422	18,186,260	3,067,614

As the AD are the volume of area changed among the five strata, the areas above were proportionally disaggregated back to the changes among the five strata, and the final AD are determined as shown in the tables below:

Table 14: Activity Data 2015 - 2019

		2019				
	ha	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
2015	Stratum 1	2,594,412	891	4	2,593	7,658
	Stratum 2	388	9,173,675	2,125	174,504	86,996
	Stratum 3	0	1,149	1,169,435	4,663	12,951
	Stratum 4	160	91,910	308	6,047,925	160,141
	Stratum 5	0	0	0	155,603	3,366,767
					Total	23,054,258

Legend: Deforestation; Degradation; Restoration; Reforestation; No Change

Table 15: Activity Data 2015 – 2019: annual amount of change

ha/year	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
Stratum 1	648,603	223	1	648	1,914
Stratum 2	97	2,293,419	531	43,626	21,749
Stratum 3	0	287	292,359	1,166	3,238
Stratum 4	40	22,978	77	1,511,981	40,035
Stratum 5	0	0	0	38,901	841,692

Legend: Deforestation; Degradation; Restoration; Reforestation; No Change

2.7 Map accuracy and uncertainty of Activity Data

From the error matrix (shown in Section 2.6.3), user accuracy and producer accuracy of the Forest Type Maps were estimated for the four (4) sources and sinks and the two (2) stable land/forest classes. Finally, the uncertainty of AD was estimated as show in Table 16 below:

Table 16: Map accuracy and uncertainty of Activity Data 2015 - 2019

Class	DF	DG	RF	RS	SF	SNF
AD uncertainty	30.9%	38.5%	44.7%	26.6%	1.6%	9.4%
User accuracy	86.7%	80.0%	76.7%	76.7%	97.4%	82.8%
Producer accuracy	83.9%	72.7%	79.3%	88.5%	97.0%	84.2%
Overall accuracy	93.2%					

3. CONCLUSIONS AND AREAS FOR FUTURE IMPROVEMENT

The Forest Type Map 2019 was developed consistently with the methods applied for the FREL/FRL. Based on the Forest Type Map 2019 and the existing Forest Type Map 2015, the Initial Forest Change Map and Initial Forest Change Matrix was developed. Forest Type Maps are developed applying the 'Level 2' of land/forest classification system which is further stratified into the five land/forest strata. The resulting stratified Forest Type Maps were overlaid to create the Final Forest Cover Change Map and Final Forest Cover Change Matrix. The accuracy of the resulting data was assessed and the change area was adjusted accordingly using the results to derive the Activity Data (AD). From this, the uncertainty of AD was estimated.

The data are made accessible to public through the NFMS Web portal <http://nfms.maf.gov.la:4242/nfms/>[13] to ensure transparency.

Three areas for future improvement are suggested to aim for step-wise improvement as well as to further reduce the uncertainty of AD:

1) Improvement of classification between forest classes "Mixed Deciduous Forests" (MD) and "Regenerating Vegetation" (RV)

Improvement of classification between RV and MD, which often represent different phases of land use in a shifting cultivation cycle continues to be a challenge. The global dataset of Hansen et al. was used to support the classification, however, the dataset has limits for the use of Lao PDR (i.e. using global dataset for Lao PDR). Recently, an alternative dataset which records repeated deforestation in Mekong region has been released[14]. For the future forest mapping exercises, Lao PDR may consider applying this dataset to detect repeated slash and burn events in order to enable further analysis of land/forest cover change over time.

2) Updating the classification of classes "Upland Crop" (UC) and "Other Agriculture" (OA)

As explained in Section 2.3.2, distinguishing UC and OA was also a challenge as they give off very similar texture on satellite imagery. Therefore, in the current mapping method, for land parcels (polygons) interpreted as UC in both of the two latest Forest Type Maps (namely, of years 2015 and 2019), a rule was applied that such parcels would be considered as permanent agricultural land and the classification of polygon for the latter year would be revised to OA. This is an example of challenges of conducting forest mapping with satellite imagery of a single year.

In the future, Lao PDR may explore using options, such as the technologies to analyze 'big data', multi-temporal satellite dataset, and GIS data from different sources (e.g. land concession data), which meet its needs.

3) Further capacity building of the remote sensing, GIS and IT engineers of FIPD

FIPD has been increasing their remote sensing capacity with the technical and financial support from development partners and projects. However, under rapid innovation in remote sensing, GIS and IT technologies and products, demand for competent engineers is increasing. Particularly the skills and knowledge of the skilled senior engineers needs to systematically be passed on to the younger generation. Also, there is an emerging need for IT engineers who can manage and operate database systems which handle large and diverse range of data.

[13] As the web-portal is currently inaccessible due to its system upgrading in progress (as of June 2020), the temporary back-up website can be accessed through <http:/nfms-lao.net/nfms/>

[14] Potapov, P. et al. (2019) "Annual continuous fields of woody vegetation structure in the Lower Mekong region from 2000-2017 Landsat time-series" Remote Sensing of Environment 232: 111278

In order to periodically generate AD, continuous capacity building efforts is inevitable. Development partners can continue to play an important role on systemizing know-how, training on planning, development and analysis of data, and support the FIPD/DOF staff to be updated on innovative technology. It is notable that taking the Forest Type Map 2019 experience, a Standard Operation Procedure for forest mapping has been established within FIPD, in order to standardize the mapping methods and techniques and to allow systematic improvement into the future.

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Lao People's Democratic Republic

1st National REDD+ Results Report for

REDD+ Results Payment under the UNFCCC

Annex 2

Emission/Removal Factors Report

March 2020

Department of Forestry
Ministry of Agriculture and Forestry, Lao PDR

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Acronyms

AE	Allometric Equation
AGB	Above Ground Biomass
B	Bamboo
BGB	Below Ground Biomass
CF	Coniferous Forest
CI	Confidence Interval
DAFO	District Agriculture and forest Office
DBH	Diameter at Breast Height
DD	Dry Dipterocarp Forest
DOF	Department of Forestry
DW	Dead Wood
EF	Emission Factor
EG	Evergreen Forest
E/R F	Emission and Removal Factor
FIPD	Forestry Inventory and Planning Division
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
F-REDD	Sustainable Forest Management and REDD+ Support Project in the LAO PDR
GIS	Geographic Information System
GL	Guideline
IPCC	Intergovernmental Panel on Climate Change
Lao PDR	Lao People’s Democratic Republic
JICS	Japan International Cooperation System
MAF	Ministry of Agriculture and Forestry
MCB	Mixed Coniferous Broadleaved Forest
MD	Mixed Deciduous Forest
NFI	National forest Inventory
NFIS	National Forest Information System project
NTV	Non-Tree Vegetation
PAFO	Provincial Agriculture and Forest Office
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the role of conservation of forests and enhancement of forest carbon stock
RF	Removal Factor
RV	Regenerating Vegetation
StD	Standard Deviation
StE	Standard errors
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

1.1 Objectives

This report aims to describe the methods and the final results of the development of Emission and Removal Factors (E/R factors) used in the estimation of 1st National REDD+ Results achieved by Lao PDR for the national level to be submitted to the United Nations Framework Convention on Climate Change (UNFCCC).

The main inputs for the development of the E/R factors are:

- The 3rd National Forest Inventory (NFI) conducted in 2019 by the Forest Inventory and Planning Division (FIPD) of the Department of Forestry (DOF) under the Ministry of Agriculture and Forestry (MAF).[1] The purpose of the 3rd NFI was to measure forest biomass of the five forest classes: Evergreen Forest (EG), Mixed Deciduous Forest (MD), Dry Dipterocarp Forest (DD), Coniferous Forest (CF) and Mixed Coniferous Broadleaf (MCB) (discussed in Section 2.1).
- A survey for the Regenerating Vegetation (RV) class (which was outside the scope of the 3rd NFI), conducted by FIPD to study the years for a forest fallow (classified as "regenerating vegetation": RV) to reach the forest status according to Lao's forest definition, as well as to measure the biomass of this vegetation class (discussed in Section 2.2).
- To improve the accuracy of forest biomass estimation, Lao PDR developed country-specific allometric equations for the three major forest classes: EG, MD and DD (discussed in Section 2.3). Other land/forest classes use IPCC default values or biomass data from neighboring Vietnam.

In this report, the above results were used applying methodologies to estimate biomass, carbon stock to determine the E/R factors as presented in Section 3. The report also presents actual results of estimation and the final E/R factors in Section 4. The uncertainty of estimated value is analyzed in Section 5. The issues related to the use of the 2nd NFI is discussed in Section 6, and lastly, the conclusion and areas for future improvement are summarized in Section 7.

[1] The 2nd NFI was technically and financially supported by "Sustainable Forest Management and REDD+ Support Project in the Lao PDR (F-REDD)" under JICA.

2. Dataset used

2.1 Forest biomass data from the 3rd NFI[2]

Background

Lao PDR conducted its 1st NFI in 1991-1999, covering the entire country. However, data archiving was weak and insufficient to retroactively manipulate, in addition, methodologies applied for the 1st NFI needed improvement to make the results suitable for use under REDD+. Improved NFI methodologies were developed through field testing in 2013 - 2015[3] and a manual was developed[4]. Based on this, the 2nd NFI was conducted over the two dry seasons of 2015-2016 and 2016-2017 and the results were used for the construction of the FREL/FRL.

Objectives

The objectives of the 3rd NFI was to survey the forest biomass[5] of the five natural forest classes of the whole country. (Excluding the Forest Plantations (P) class due to its relatively small area and possible use of IPCC default factors; and classes of Bamboo (B) and Regenerating Vegetation (RV) which do not currently meet the status of forest under the Lao forest definition[6].) A standardized methodology and sample-based field measurements were applied.

Survey outline

Survey schedule

To meet Lao PDR's target to complete the estimation of 1st National REDD+ Results against the National FREL/FRL, natural forest classes (EG, MD, DD, CF and MCB) were surveyed in the dry season of 2019 using Forest Type Map 2015 for distributing the sample survey plots.

A total of 415 survey plots were distributed across the five forest classes through the stratified-random-sampling approach (see Figure 1). Lands classified as non-forest were not sampled. It is recognized that this may slightly bias the resulting estimates, but the effect of such bias is considered to be small and negligible compared to the cost of their inclusion, thus omitted.

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[2] See DOF, et al. (2019). "The 3rd National Forest Inventory Survey in Lao People's Democratic Republic <http://dof.maf.gov.la/en/home/> for more details.

[3] Capacity Development Project for Establishing National Forest Information System for Sustainable Forest Management and REDD (NFIS) (2013 – 2015) under JICA.

[4] Lao PDR National Forest Inventory Standard Operating Procedures (SOP) Manual for Terrestrial Carbon Measurement.

[5] The main target of the survey was to measure the forest biomass, however, other information, such as observed disturbances were also recorded.

[6] Lao's forest definition includes: Minimum DBH of 10cm, minimum crown density of 20% and minimum area of 0.5ha.

Survey team

The survey teams were composed of different institutions including FIPD as the responsible agency, and Provincial Agriculture and Forest Office (PAFO), District Agriculture and Forest Office (DAFO) and villagers as the partners in each province. In total, six survey teams were formed to execute the field survey.

Plot design

The 'floating cluster design' as described in Figure 2 was used, where the first sub-plot (sub-plot A) was laid out with an anchor point placed in the plot center, and then up to nine additional plots (B, C, D, E,....., J) were randomly placed within a 300 m radius of the anchor point. However, the sub-plot centers could not be closer than 75 m from each other nor the anchor point. One cluster must have at least six tree-plots to provide enough opportunity to the field team to measure four valid tree-plots in forested areas.

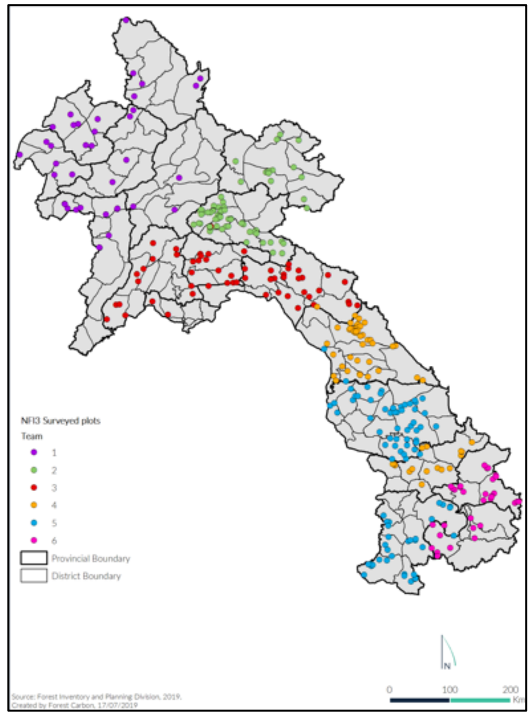

Figure 1: Surveyed plot by forest class in the 3rd NFI

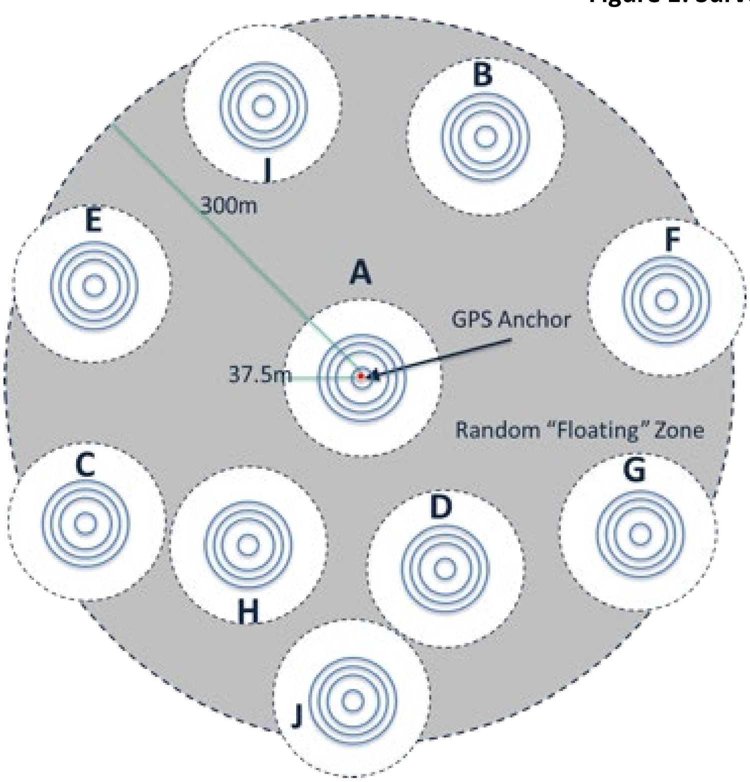

Figure 2: Floating cluster design

The circular nest sizes are shown for each stratum as below. Each stratum was given different tree DBH groups to measure (See Figure 3).

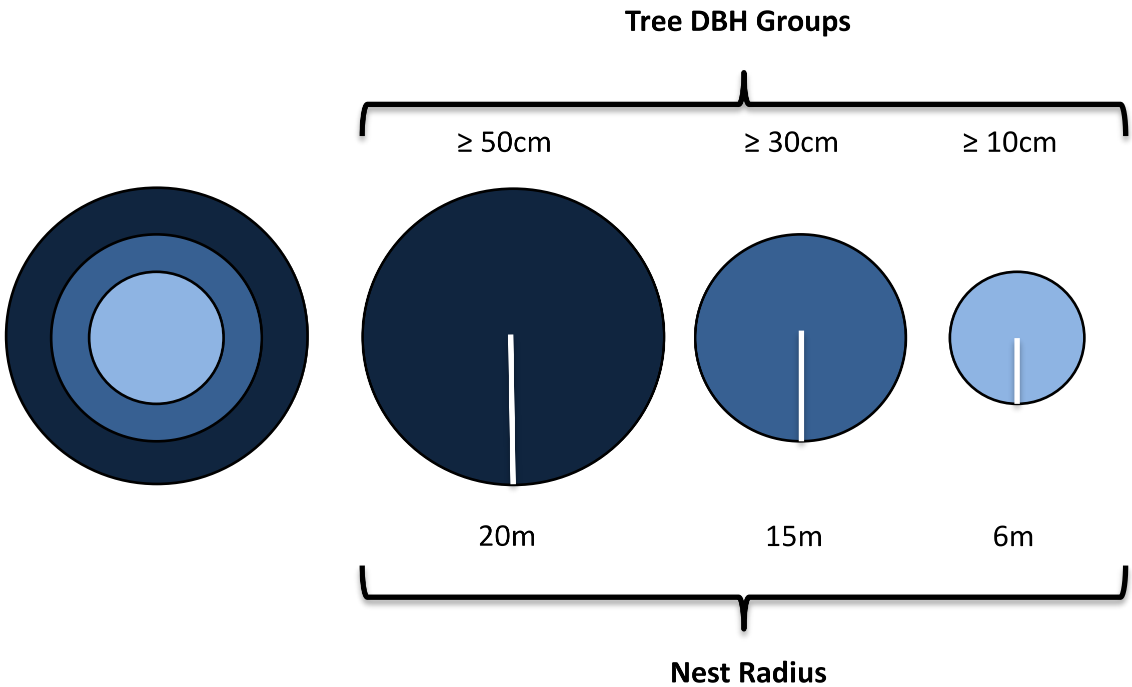

Figure 3: Nested circle plots

Carbon pools measured

Above Ground Biomass (AGB, standing trees) and Dead Wood (standing and tree stumps), were measured. Saplings, Non-Tree Vegetation (NTV), Bamboo and lying deadwood were not measured due its small contribution to the total carbon stock and the significant time requirement for measurement: instead the data from the 2nd NFI are used for the estimation.

Results

Across the five forest classes surveyed, among the 415 plots distributed, a total of 359 plots were included in the estimation of forest carbon stocks. The remaining 56 plots were not included because of their land condition (contrary to the identification from the 2015 maps, the survey found the sites as non-forest), or difficulties in accessing the sites. The resulting average forest carbon stock by forest class, for the national level are shown in the Annex 1.

2.2 Biomass data of Regenerating Vegetation from the "2nd RV survey"[7]

Background

In Lao PDR, annually around 100,000-150,000 ha of forest lands are burned for shifting cultivation (including rotational and pioneering practices). The area is cultivated for a short period, often one year, and then left to as fallow to regenerate as "Regenerating Vegetation (RV)" which covered around 25% of the total area of the country in 2015. Quantification of biomass from this landscape had been a challenge due to limited availability of data and allometric models[8]. Furthermore, distinguishing RV class from forest classes through remote sensing poses a big challenge[9]. The 1st RV survey was conducted in 2017 to address these two issues[10]. The 2nd RV survey was expected to provide updated and improved data.

Objectives

The objective of the 'RV Survey' was to survey the number of years of fallow required to regenerate to meet the forest definition (i.e. the threshold year), and also to survey the biomass of RV of different fallow years to estimate the average biomass.

Survey outline

Survey clusters were selected from the annual vegetation loss dataset of Hansen et al[11] to detect the year of loss on forest loss plots, then conducted ground truth and measured the crown cover to determine whether it had reached the forest status[12] or not.

One survey cluster was laid out for each plot representing 1st to 9th year of fallow (this was limited to 1st to 8th year in the 1st RV survey) in seven provinces; Luang Namtha, Oudomxay, Houaphane, Khammouane, Savanakhet, Salavan and Attapeu. One survey cluster composed of three circular plots. In each plot with 6m radius, trees with Diameter at Breast Height (DBH) of at least 5cm are recorded. Within in each circle plot, four square sub-plots were established and all vegetation except trees with DBH ≥ 5 cm were cut at the base (size of 1m*1m or 2m*2m depending on the vegetation height to weigh the non-tree biomass). Measurement of Dead Wood was added in the 2nd RV survey. At the same time, aerial

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[7] See, DOF, et al. (2019). Update survey of a Lao specific biomass prediction model for regenerating vegetation and confirmation of the threshold number of years since abandonment, as Regenerating Vegetation, before becoming current forest. <http://dof.maf.gov.la/en/home/> for more details.

[8] Kiyono, et.al (2017) developed predicting models of biomass from the data of 'abandoned year' (fallowed year) and 'abandoned year average carbon stocks'. But this survey was conducted only in Luangprabang province, a northern province, thus, not suitable to represent the entire country.

[9] Among the stages of shifting cultivation, RV and Mixed Deciduous Forest (MD) are continuous phases of regeneration in many cases, and old RV and young MD have very similar color tone and texture on satellite imagery, thus, distinguishing the two in a single satellite imagery faces technical challenges. This is in part addressed through analysis using multi-temporal remote sensing imagery.

[10] See, DOF, et al. (2017) Development of a Lao-specific Equation for the Estimation of Biomass of 'Regenerative Vegetation' and Determination of the Threshold Years for its Regeneration into Forest. <http://dof.maf.gov.la/en/home/> for more details

[11] Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest.

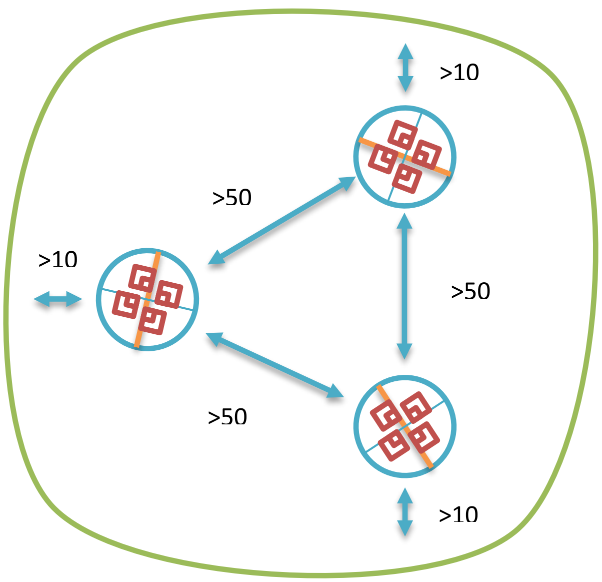
[12] Minimum DBH of 10cm, Minimum crown density of 20%, minimum area of 0.5ha.

photographs of the plots were taken by drones in order to estimate Crown Cover Rate (CCR), which was then used for identifying the threshold year of abandoned RV to regenerate into forest.
A total of 189 survey plots (63 survey clusters with three survey plots each) were surveyed in seven provinces.

Table 1: Number of RV Survey clusters in each region/province

Region	Province	Age of abandoned year	Total number of clusters
North	Luang Namtha	1 - 9	9
North	Oudomxay	1 - 9	9
North	Houaphane	1 - 9	9
Central	Khammouane	1 - 9	9
Central	Savanakhet	1 - 9	9
South	Salavan	1 - 9	9
South	Attapeu	1 - 9	9
		Total	**63**

Since the most common forest type for RV to regenerate into is Mixed Deciduous (MD) forests, the tree biomass of RV was estimated by applying the allometric equation developed for MD forest class (AGB=0.407*DBH^2.069), and the biomass of NTV (DBH < 5cm) were also estimated by using dry-wet ratio calculated from the samples of the MD forest class.



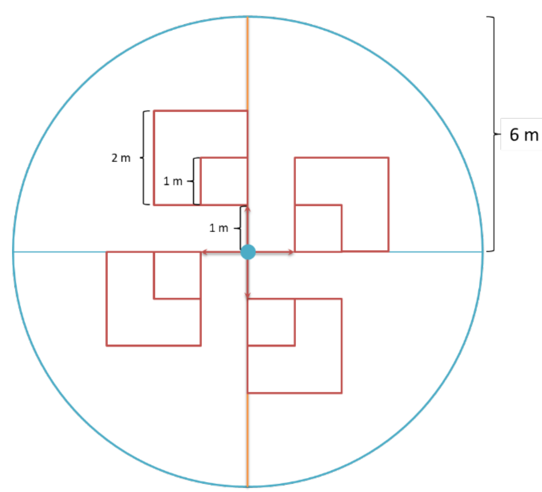


Figure 4: Clusters with three ranged circle plots (Left)

Figure 5: A plot (blue circle) with four square sub-plots (red squares) and transect for lying dead wood measurement (orange line) (Right).

Results

The average carbon stock of RV is used for E/R factors development. The following table shows the result. Only the biomass from RV plots which were below 7 years of fallow was counted in the calculation (i.e. the plots which were already beyond 7 years of fallow were regarded as MD class and not included in the calculation) to maintain consistency with the assessed FREL/FRL.

Table 2: Average carbon stock of RV

2nd RV survey 2019	Carbon stock (Ct/ha)	StD
North	8.95	6.54
Central	8.61	8.42
South	6.42	3.98
Average	**8.13**	6.45

2.3 Allometric equations for the three major forest classes[13]

Note: the use of allometric equations for the estimation of tree biomass was explained in the E/R factors report appended to the FREL/FRL report, which underwent technical assessment by the UNFCCC[14]. The estimation of 1st National REDD+ Results applied these same allometric equations from the FREL/FRL. Description hereunder is reproduced from the FREL/FRL report.

Background

For REDD+, a country is requested, as feasible, to accurately estimate its forest carbon stock and changes, by using country-specific data and periodic measurement of the parameters. Development of country-specific allometric equations enable Lao PDR to improve the estimates of forest biomass in combination with the data collected through the NFI.

Objectives

To improve the accuracy of forest biomass estimation, conduct destructive measurement of trees to develop country-specific allometric equations for the three major forest classes[15]; Evergreen Forest (EG), Mixed Deciduous Forest (MD) and Dry Dipterocarp Forest (DD).

Survey outline

The allometric equations were developed by taking a total of 36 sample trees from each forest class (i.e. EG, MD and DD) with a variety of DBH and regional balance (See Table 3). Deadwood and saplings were also sampled.

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[13] See DOF, et al. (2017). "Development of country-specific allometric equations in Lao PDR" <http://dof.maf.gov.la/en/home/> for more details.

[14] https://redd.unfccc.int/submissions.html?country=lao

[15] The 3 forest classes cover 66% of the total forest land of Lao PDR (EG: 13%, MD: 47%, DD: 6%) in 2015.

All destructive field and laboratory sampling methods for trees, deadwood and saplings are based on Winrock International's standard operating procedures (Walker et al. 2014) and the FIPD/DOF survey teams were trained on the survey methods according to its procedures.

The samples were dried at 100°C using drying ovens to measure the dry weight.

Several regression models were applied to develop the allometric equations with R software.

Table 3: Survey sites for each forest type in AE survey

Forest class	Province	Region	Number of Tree	Minimum DBH(cm)	Maximum DBH(cm)
EG	Xayabouly	North	12	14.0	59.3
	Bolikhamxay	Central	12		
	Attapeu	South	12		
MD	Bokeo	North	12	15.0	85.0
	Khammouane	Central	12		
	Attapeu	South	12		
DD*	Khammouane	Central	18	16.0	67.0
	Attapeu	South	18		
*** DD occurrence in the Northern region is limited.**					

Results

The allometric equations were developed for each forest class as regression lines with a power approximation under the FAO manual (Picard et al. 2012). Among 10 possible regression lines for each forest class, one regression model was selected as below. Compared to the allometric equations developed for other forests in South-East Asia[16], the Lao-specific equations result in estimating lower biomass. Although the original data from this survey show that the highest biomass is approximately 4,300 kg, it seems reasonable and conservative to apply the equations to the obtained data that is out of DBH range.

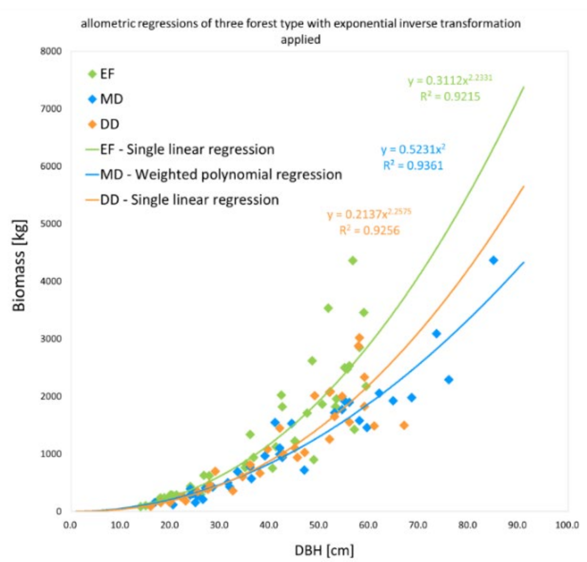

Figure 6: Allometric regressions of three forest types

[16] Allometric equations for Lao(Luang Prabang) Evergreen and Mix deciduous forest (PAREDD+,2015); Cambodia Dry Dipterocarp forest (Monda et al, 2016)

Table 4: Allometric equation for three forest types

Forest Type	Equation	Number of sample trees	R^2	AIC
EG	$AGB = 0.3112\ x\ DBH^{2.2331}$	36	0.9215	18.84
MD	$AGB = 0.5231\ x\ DBH^{2}$	35	0.9081	477.24
DD	$AGB = 0.2137\ x\ DBH^{2.2575}$	35	0.9256	10.53

3. Estimation Methods of biomass and carbon stock

The following parts explain the methodologies applied for converting the measured forest biomass into carbon stock and then to tCO2e.

3.1 Estimation of biomass by land/forest class

Three carbon pools were considered for the measurement of forest biomass: Above Ground Biomass (AGB) from direct measurement and including living trees, saplings, bamboo and other non-timber vegetation (NTV); Dead Wood (DW) from direct measurement and including standing DW, stumps and lying DW; and Below Ground Biomass (BGB) using the IPCC default values.

As explained in Section 2, the biomass of the five forest classes were estimated from the measurement results of the 3rd NFI. Meanwhile, the biomass of RV was estimated separately using the measurement results from the 2nd RV survey. These two results are explained separately in the following sections.

3.1.1 Above Ground Biomass (AGB)

3.1.1.1 AGB of the five forest classes

The biomass of a plot surveyed in the 3rd NFI is calculated as the average stock of its sub-plots. Then, average biomass stock for each forest class is calculated as the average stock of all plots.

<u>LIVING TREES</u>

The calculation of the biomass (kg) for each tree is done by applying the appropriate allometric equations to the measured trees in different forest classes (See Table 5). The allometric equations for EG, MD and DD forest classes were developed for Lao PDR, and the allometric equations developed in neighboring Vietnam were used for CF and MCB forest classes. Secondly, the biomass per tree is then converted into biomass per ha, and summed for sub-plots.

Table 5: List of allometric equation for calculating tree AGB.

C pool	Forest class	Equation	Source
AGB (living trees and dead standing trees)	EG	*AGB (kg/tree) =0.3112 x DBH^2.2331*	JICS (2017), Development of specific allometric equations in Lao PDR.
	MD	*AGB (kg/tree) =0.523081 x DBH^2*	
	DD	*AGB (kg/tree) =0.2137 x DBH^2.2575*	
	CF	*AGB (kg/tree) =0.1277xDBH^2.3944*	Hung et al (2012), Tree allometric equation development for estimation of forest above-ground biomass in Viet Nam.
	MCB	*AGB (kg/tree) =0.1277xDBH^2.3944*	

<u>SAPLINGS</u>

The saplings are defined as trees with height >1.3 m and 0 < DBH <10 cm. The biomass of saplings are estimated from the number of saplings in the first nest multiplied by the average dry weight of saplings of the same forest class (See Table 6). Average dry weight were measured only for the EG, MD and DD forests, and the average value of these three forest classes were used for the other two (i.e. CF, MCB). Due to its small contribution to the carbon stock, measurement of saplings were omitted from the 3rd NFI, and the data of the 2nd NFI are used instead.

Table 6: Average dry weight/tree of saplings by forest type

Forest class	Average dry weight	Source
EG	113 g	JICS (2017), Development of specific allometric equations in Lao PDR".
DD	252 g	
MD	191 g	
Others	184 g	

<u>BAMBOO</u>

For the measurement of biomass of bamboo, average diameter of five bamboo poles sampled per sub-plot was calculated and the allometric equation for bamboo developed in Vietnam was used[17]. Then the biomass of individual poles was multiplied by the number of poles of the clump and an expansion factor (Equation 1) to estimate the bamboo biomass per ha.

Due to its small contribution to the carbon stock, measurement of bamboo were omitted from the 3rd NFI, and the data of the 2nd NFI are used instead.

Equation 1: Allometric equation for bamboo biomass (kg) from Hung et al. (2012) [18]

$$GB\ (kg/pole) = 0.1006 \times D^{2.222}$$

Where:

D = diameter of the bamboo pole (cm)

<u>NON TREE VEGETATION (NTV)</u>

NTV were measured in each sub-plot by establishing a small plot (50cm*50cm). All vegetation, except for the living trees, saplings and bamboo were taken and measured for weight. Samples were brought back to the laboratory to measure the dry-wet ratio.

Due to its small contribution to the carbon stock, measurement of NTV were omitted from the 3rd NFI, and the data of the 2nd NFI are used instead.

[17] Hung et al. (2012). This equation was developed by using the 120 sample trees and expected value of error (%) is 0.327.

Table 7: Average carbon stock of non-timber vegetation (NTV) by forest class

Forest class	Sample size	C stock (tC/ha)	Source
EG	78	1.12	JICA(2017), 2nd National Forest Inventory Survey in Lao PDR
MD	358	1.09	
DD	84	0.50	
CF	133	0.75	
MCB	764	0.57	

3.1.1.2 AGB of Regenerating Vegetation (RV)

The biomass of RV, including trees, NTV, bamboo and saplings, were measured through the "2^{nd} RV Survey" (see Section 2.2). The estimation of carbon stock of RV, however, has a higher degree of uncertainty due to the high diversity of different vegetation species (including bamboo), topographic factors, and human factors associated to the land.

3.1.2 Dead Wood

Dead Wood (DW) consists of standing deadwood, stumps and lying trees.

<u>STANDING DEADWOOD</u>

Standing DW were separated into two categories, i.e. Category 1: dead trees with twigs and branches; and Category 2: dead standing trees without branches, which was further separated into short trees and tall trees. The Category 2 trees were treated as conical cylinders, and the biomass of the Category 1 trees was calculated with respective allometric equations.

<u>STUMPS</u>

The biomass of stumps was calculated assuming a cylindrical shape multiplied by wood density Equation 2):

Equation 2: Equation for the estimation of stump biomass (B_{stump} in kg) [19]

$$B_{stump} = \left(\left(\left(D_{mean}/2 \right)^2 \times \pi \right) \times H_{stump} \right) \times WD \times 0.001$$

Where:

D_{mean} = mean diameter (cm)

H_{stump} = height of the stump

WD = wood density (0.57 g/cm^3)

[19] Goslee, et al (2015), P.37, equation 53.

LYING DEADWOOD

Lying DW was separated into two categories of hollow and solid, and the latter was further separated by three density classes (i.e. sound, intermediate, and rotten; Table 8). The volume of solid dead wood was calculated as a cylinder, whereas hollow dead wood was calculated as the difference between the outer cylinder and inner cylinder.

Table 8: Lying deadwood densities (g/cm^3) by density class and forest type

Forest type	Density class	Density (g/cm^3)	Source
EG	Sound	0.39	JICS (2017), Development of specific allometric equations in Lao PDR.
	Intermediate	0.34	
	Rotten	0.26	
DD	Sound	0.44	
	Intermediate	0.35	
	Rotten	0.32	
MD	Sound	0.45	
	Intermediate	0.3	
	Rotten	0.29	
Other	Sound	0.44	
	Intermediate	0.33	
	Rotten	0.3	

3.1.3 Below Ground Biomass (BGB)

The BGB was estimated by using the best available Root-to-Shoot (R/S) ratio corresponding to each forest class and their average AGB.

Table 9: Root-to-Shoot ratio by forest type and AGB threshold

Forest type	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	
Forest Plantation	AGB<50t/ha	0.46	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)
	AGB=50-150t/ha	0.32	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)

	AGB>150t/ha	0.23	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)
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)

3.2 Conversion of biomass to carbon stock

The estimated biomass was converted into carbon stock with the generic formula below:

$$Ci = TBi \times CF$$

Where:
TBi = total biomass of plot *i* (include AGB and BGB), expressed in kg.
CF = IPCC default carbon fraction value 0.46 or 0.47 depending on the land/forest class (2006 IPCC GL Volume 4, Chapter 4)

The detailed table summarizing the results is shown in the Annex 2 of this report.

3.3 Conversion of carbon stock (tC) into tCO2e

The generic formula suggested in the IPCC GL 2006 below was used to convert carbon stock (tC) into tCO2e, and then the final E/R factors were determined.

$$EF\ or\ RFij\ (\text{tCO2e/ha}) = (Ci - Cj) \times 44/12$$

Where:
EF or RFij = is EF or RF when the change incurred from land use *i* to land use *j*.
Ci and *Cj* = is carbon stock per ha of land/forest class *i* and *j* corresponding to the changes;
44/12 is the ratio of carbon mass to CO2 mass.
If C*i* > C*j*, such change is considered emissions;
If C*i* < C*j*, such change is considered removal.

3.4 Estimation of carbon stock after stratification

Echoing the process from the FREL/FRL, to reduce uncertainty of emissions and removals while taking into account the accuracy from sampling and the cost and efforts required, the land/forest classification was further stratified into five strata as below. The same stratification is applied for estimating the carbon stock from the 3rd NFI result.

The average carbon stock for the new strata was calculated by using weighted value as follows:

$$Cstrata\ (tC/ha) = (C1 * A1 + C2 * A2 + \ldots + Cn * An)/(A1 + A2 + \ldots + An)$$

Where:

Cstrata = average carbon stock (tC/ha) of new strata calculated from biomass and area of land/forest class;

Ci = carbon stock of land/forest class (tC/ha);

Ai = area (ha) of land/forest class in 2019.

4. Result

4.1 Average carbon stock

The average carbon stock of the five forest classes from the 3rd NFI data are shown in Table 10. Only AGB and BGB were selected as the carbon pools to be accounted and DW is not accounted. The average carbon stock (and tCO2e) for the remaining land/forest classes are calculated based on the IPCC default value (IPCC GL 2006) and other available sources, except for RV which uses the results of the "2nd RV Survey".

Table 10: Average carbon stock (tC/ha and tCO2/ha) of the 5 strata

Strata	tC/ha	tCO2/ha
Stratum 1 (EG)	205.8	754.5
Stratum 2 (MD/CF/MCB)	87.8	321.8
Stratum 3 (DD)	50.8	186.3
Stratum 4 (P/B/RV)	11.5	42.1
Stratum 5 (NF)	4.7	17.2

4.2 Emission/Removal Factors

The E/R Factors are developed by taking the difference in average carbon stock (as tCO2e) of each forest/land strata as shown in Table 11.

Table 11: Emission/Removal 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	-169.1
Stratum 4 (P/B/RV)	712.4	279.6	144.1	0.0	-25.0
Stratum 5 (NF)	737.4	304.7	169.1	25.0	0.0

5. Uncertainty analysis

5.1 Method of uncertainty assessment

5.1.1 Sources of uncertainty of Emission/Removal factors

The IPCC GL 2006 for National Greenhouse Gas Inventories (Volume 1, Chapter 3), lists out eight broad causes of uncertainties. Some cause of uncertainty (e.g. bias) may be difficult to identify and quantify[20]. Accordingly, the causes of uncertainties for the E/R factors and their application in the uncertainty assessment are summarized in following Table 12.

Table 12: Cause of uncertainty and relevance for the estimation of Emission/Removals factor

Cause of Uncertainty	Relevance for the EF?	Applied (yes/no) and explanations
Lack of completeness	Considered not relevant. The 3rd NFI was complete. The survey followed the SOP.	No
Model	Relevant and significant. Affects estimation of biomass. Uncertainty in statistical models used to estimate biomass as function of tree parameters, models to estimate BGB, and models to convert from biomass to carbon.	Yes (No.2 below)
Lack of data	Relevant, but, minor. Data do not exist to estimate emissions/removals from several pools (litter and soil) which are assumed to be insignificant (< 10%).	No
Lack of representativeness of data	Partially relevant to the data of the 3rd NFI. Emission factors come from statistically sound random sampling plots distributed across the entire country but applied to the 6 provinces. As discussed in Section 5.2, the difference is not expected to be significant. Relevant to the RV data due to limited number of plot data.	Partially relevant to the 3rd NFI data Yes for RV
Statistical random sampling error	Relevant and significant. Affects estimation of Emission factors from forest inventory samples.	Yes Errors of forest carbon stock estimation are assessed (No.1 below)
Measurement error	Relevant. Measurement of tree DBH assumed to be with minor error according to the quality control (QC) results, although reference data is limited	Yes (No.3 below)
Misreporting or misclassification	Considered not relevant. Field data were collected following the SOP, and the data were	No

[20] Rypdal and Winiwarter, 2001

	recorded through a tablet-based survey application to eliminate data loss and reduce data input errors. Field survey teams were well trained before conducting survey.	
Missing data	Considered not relevant. Sampling and forest cover mapping covers 100% of the area of interest. Field data were collected following the SOP, and data were recorded through a tablet-based survey application to eliminate data loss and reduce data input errors.	No

5.1.2 Assessment of uncertainty related to estimation of Emission/Removal Factors

From the analysis described, the main causes of uncertainty of E/R factors are considered as follows:

1. Uncertainty of AGB originating from sampling error (3rd NFI data)
2. Uncertainty of AGB originating from biomass equation (See Allometric Equation development report)
3. Uncertainty of Root-to-Shoot ratios due to the use of IPCC default values (IPCC GL 2006)
4. Uncertainty of Carbon Fraction factor due to the use of IPCC default values (IPCC GL 2006)
5. Uncertainty of AGB originating from measurement error (QC of 3rd NFI)

<u>Estimation method for uncertainty of AGB originating from sampling error</u>

First, estimate the mean Standard Deviation (StD) and 95% Confidential Interval (CI) of the measured carbon stock of all inventory plots for each forest class. Then, divide the CI (95%) by mean AGB (t/ha) to derive the level of uncertainty of each AGB caused by sampling error[21].

<u>Estimation of uncertainty of AGB originating from biomass equation</u>

The following generic formula was used to estimate the uncertainty of the allometric equations developed for Lao PDR for the three forest classes (i.e. EG, MD and DD).

Equation 5-1

$$StD = \frac{100}{N}\sum_{i=1}^{n}\frac{|\widehat{Yi} - Yi|}{Yi}$$

$$StE = \frac{StD}{\sqrt{N}}$$

Where:

N = number of sample trees

$\hat{Y}i$ and Yi = the predicted and measured AGB of the tree.

StD = Standard Deviation.

[21] Goslee, et al (2015), page 4, equation 5

StE = Standard Error.

The following Table 13 shows the results of assessment.

Table 13: Uncertainty of AGB originating from the allometric equations

Forest class	Sample size	StD	CI (95%)	StE
EG	36	23.6	7.7	3.9
MD	35	22.8	7.4	3.8
DD	35	21.7	7.1	3.6

CI: Confidence Interval

Uncertainty of AGB originating from measurement error

For estimating the uncertainty of AGB originating from measurement error, Standard errors (StE) were calculated based on the standard deviations (StD) and number of sample trees by using the equation 5-1 above. The same allometric equation was used to estimate the biomass measured through QC Survey, and the following table shows the result of AGB measurement error based on the QC Survey. Note that the QC survey was not able to re-measure sufficient numbers of EG plot (e.g. QC teams unable to find the exact QC plots).

Table 14: Uncertainty of AGB originating from measurement error

	Number of QC survey plot	Average difference between primary plot and QA plot	StD	StE
EG	1	N/A	N/A	N/A
MD	13	9.9	18.8	5.2
DD	10	8.2	15.3	4.8
CF	7	3.7	9.1	3.5
MCB	8	4.1	9.7	3.4

Estimation of total uncertainty

After the uncertainty of each parameter are assessed, the total uncertainty of carbon stock was calculated through 'propagation of error approach' and by using the following generic equations given in the IPCC GL 2006.

EQUATION 3.1
COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2}$$

Where:

U_{total} = the percentage uncertainty in the product of the quantities (half the 95 percent confidence interval divided by the total and expressed as a percentage);

U_i = the percentage uncertainties associated with each of the quantities.

EQUATION 3.2
COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + \ldots + (U_n \bullet x_n)^2}}{|x_1 + x_2 + \ldots + x_n|}$$

Where:

U_{total} = the percentage uncertainty in the sum of the quantities (half the 95 percent confidence interval divided by the total (i.e., mean) and expressed as a percentage). This term 'uncertainty' is thus based upon the 95 percent confidence interval;

x_i and U_i = the uncertain quantities and the percentage uncertainties associated with them, respectively.

In addition, there are potential systematic uncertainties listed below which are included in the approach applied, however, their impact on uncertainty are difficult to assess or reduce immediately through practical approaches, therefore, considered as an issue for future improvement:

- Unknown age class and growth rates of forests, influencing both removals and emission estimates; and
- Application of strata-specific E/R factors which do not explicitly estimate the emissions and removals based on their true dynamics. The resulting over-estimation of emissions from deforestation and degradation is addressed through the analysis of time-series (Section 4.3.1 of the submission) to the extent possible.

5.2 Uncertainty assessment of carbon stock

The following table shows the total uncertainty of carbon stock for each forest class estimated through the propagation of error approach.

Table 15: Total uncertainty assessment of carbon stock

Forest class	Sources of uncertainty					Uncertainty (AGB+BGB) (%)
	1.	2.	3.	4.	5.	
EG	10.2	3.9	11.5	2.7	-	16.1%
MD	4.8	3.8	11.5	2.7	5.2	14.3%
CF	11.1	18.0	20.3	2.7	3.5	29.6%

MCB	14.1	18.0	11.5	2.7	3.4	25.9%
DD	8.2	3.6	11.5	2.7	4.8	15.6%
P	-	18.0	20.3	2.7	-	27.3%
B	15.7	0.3	-	2.7	-	15.9%
RV	22.2	-	0.9	2.7	-	22.4%
NF	N/A	N/A	N/A	N/A	N/A	20.0%

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

5.3 Estimation of uncertainty after stratification

In order to reduce uncertainty of emissions and removals while balancing the accuracy of sampling and the cost/efforts required, the land/forest classification explained in Section 2.2 was collapsed into five strata.

The uncertainty of average carbon stock for the new strata was calculated by using weighted value as follows:

$$Ustrata\ (\%) = (U1*A1 + U2*A2 + ... + Un*An)/(A1 + A2 + ... + An)$$

Where:

Ustrata = uncertainty (%) of strata calculated from uncertainty of respective land/forest class and carbon stock;

Ui = uncertainty of land/forest class (%);

Ai = total carbon stock (tC/ha) of each land/forest class in 2015.

5.4 Uncertainty by stratum

As explained in Section 3.4, as the land/forest classification was stratified into five strata, the uncertainty for each stratum was calculated by using weighted value based on the area proportion. The following table shows the uncertainty for each stratum.

Table 16: Uncertainty in carbon stock/ha by stratum

Strata	Mean (tCO_2e/ha)	Uncertainty range (tCO_2e/ha)	Uncertainty (%)
1	754.5	±121.3	16.1%
2	321.8	±44.9	13.9%
3	186.3	±29.0	15.6%

4	42.1	±8.2	19.6%
5	17.1	±3.4	20.0%

5.5 Uncertainty of Emission/Removal Factors

The uncertainty of the E/R factors was calculated using abovementioned Equation 3.2 and the result is shown in Table 17 below.

Table 17: Emission/Removal Factors (Uncertainty (%))

	Stratum 1 (EG)	Stratum 2 (MD/CF/MCB)	Stratum 3 (DD)	Stratum 4 (P/B/RV)	Stratum 5 (NF)
Stratum 1 (EG)		12.0%	13.3%	15.3%	15.7%
Stratum 2 (MD/CF/MCB)	12.0%		10.5%	12.5%	13.3%
Stratum 3 (DD)	13.3%	10.5%		13.2%	14.4%
Stratum 4 (P/B/RV)	15.3%	12.5%	13.2%		15.1%
Stratum 5 (NF)	15.7%	13.3%	14.4%	15.1%	

From above Table 17, uncertainty of E/R factors per source and sink are estimated as below.

Table 18: Uncertainty of Emission/Removal Factors per source and sink

	Uncertainty (%)
Deforestation	10.1%
Forest Degradation	6.5%
Reforestation	10.1%
Restoration	6.5%

6. Analysis for determination of dataset use from the two NFI surveys

Taking into account the availability of datasets from two NFI surveys (i.e., 2nd and 3rd NFIs), an analysis was undertaken to consider the best option for use of either, or both of the NFI survey results for the generation of E/R factors.

6.1 Comparability: 3rd NFI and 2nd NFI

The 3rd NFI conducted in 2019 measured the forest biomass of the entire country applying the same methodology as that of the 2nd NFI.

The 2nd NFI result indicated that all the sub-components of the AGB carbon pool except for Living Trees were small in its contribution to the total carbon stock. It is also generally understood that such carbon pools do not change drastically within two years (i.e. years from the 2nd NFI to the 3rd NFI). For these reasons, Sapling, Non-Timber Vegetation (NTV) and Bamboo were excluded from the 3rd NFI survey. The 2nd NFI results for these pools are considered complementary.

Table 19 shows the comparison of survey contents and design between the 2nd and 3rd NFIs.

Table 19: Comparison of the 2nd and 3rd NFIs

	2nd NFI	3rd NFI
Main Objectives	- Estimate forest biomass/carbon stock	- Estimate forest biomass/carbon stock
Target area	Nation wide (areas of five natural forest classes covering 13,231,443ha (57.4% of the national land area), random sampling)	Nation wide (areas of five natural forest classes covering 13,231,443ha (57.4% of the national land area), random sampling)
Implementation Year	2016-2017	2019
Number of plots	Forest: 420 plots	Forest: 359 plots
Survey class	5 natural forests	5 natural forests
Plot design, shape, location, etc.		
Single plots		
Cluster plots	X	X
Circular plots	X	X
Forest classification	X	X
Location information (Latitude/longitude coordinates)	X	X
Photographs of the plots	X	X
Living trees	X	X
DBH	X	X
Diameters at middle and top of bole		
Tree height		
Tree quality		
Population of saplings	X	

Canopy density		
Non-forest class	X	X
Forest structure		
Species (local name)	X	X
Species (Scientific name)	X	X
Slope	X	X
Stumps	X	X
Diameter	X	X
Height	X	X
Non-tree vegetation	X	
Fresh mass	X	
Dry mass	X	
Standing dead trees	X	X
DBH	X	X
Height	X	X
Lying Dead Wood	X	
Diameter	X	
Density	X	
Decomposition class	X	
Litter		
Fresh mass		
Dry mass		
Soil		
Soil type		
Bulk density		
Organic carbon content		
NTFP	X	X
Rattan		
Bamboo	X	X

6.2 Comparability: 1st RV survey and 2nd RV survey

A minor modification was made to the plot design of the 2nd RV survey compared to the 1st RV survey, however, the resulting data are considered as comparable. The uncertainty of the results of the 2nd RV survey has reduced (i.e. accuracy improved) compared to the 1st RV survey.

6.3 Usability of the resulting data set for E/R factors for the 1st National REDD+ results

The UNFCCC "Decision 14/CP.19 Modalities for measuring, reporting and verifying" encourages improvement of data and methodologies, while maintaining consistency with the established FREL/FRL:

> 5. *Encourages* Parties to improve the data and methodologies used over time, while maintaining consistency with the established or, as appropriate, updated, forest reference emission levels and/or forest reference levels in accordance with decision 1/CP.16, paragraph 71(b) and (c);

and requires the REDD+ results (submitted as a technical annex) to be consistent with the assessed FREL/FRL:

> 11. *Further decides* that, as part of the technical analysis referred to in decision 2/CP.17, annex IV, paragraph 4, the technical team of experts shall analyse the extent to which:
>
> (a) There is consistency in methodologies, definitions, comprehensiveness and the information provided between the assessed reference level and the results of the implementation of the activities referred to in decision 1/CP.16, paragraph 70;

As shown in the following table, uncertainty of E/R factors estimated from the 3rd NFI data set and 2nd RV survey is lower than the ones from the 2nd NFI for all sources and sinks.

Table 20: Uncertainty of Emission/Removal Factors per source and sink estimated from the 2nd NFI and 1st RV survey

	Uncertainty (%)
Deforestation	11.4%
Forest Degradation	7.4%
Reforestation	11.4%
Restoration	7.4%

Table 21: Uncertainty of Emission/Removal Factors per source and sink estimated from the 3rd NFI and 2nd RV survey

	Uncertainty (%)
Deforestation	10.1%
Forest Degradation	6.5%
Reforestation	10.1%
Restoration	6.5%

Notably, the implementation period of 3rd NFI and 2nd RV survey are more aligned with the period represented through the Forest Type Map (FTM) 2019 when comparing with the 2nd NFI survey and the 1st RV survey for estimating the result against FREL/FRL.

Thus, mainly for the two reasons of temporal proximity to the FTM 2019 and lower uncertainty as encouraged by UNFCCC Decision 14/CP.19, estimated carbon stocks from the 3rd NFI and 2nd RV survey were used for generating Emission/Removal factors for the 1st national REDD+ results.

7. Conclusion and areas for future improvement

This report presents the E/R factors estimated by the 3rd NFI data, 2nd RV survey and allometric equations including country-specific ones for Lao PDR.

Potential improvements in future E/R factors as below.

- Carbon stock of RV

  The carbon stock of 2nd Regenerating Vegetation (RV) survey was calculated from the average carbon stock of each fallow year. The uncertainty reduced in the 2nd RV survey (i.e. accuracy improved) compared to the 1st RV survey. Since this survey distributed seven clusters for each year of fallow, variations in the area of RV for each year are not considered. Therefore, there is still a limitation in the representativeness of data and resulting uncertainty was still relatively high. For future NFI surveys, the number of years after abandonment is suggested to be included as a survey item with support from remote sensing.

- Continuous improvement of E/R factors

  Default values from the IPCC guidelines were used to estimate carbon stock for some of the land/forest classes where country-specific data do not exist. These are potential areas for improvement in order to reduce the uncertainty of E/R factors. As allometric equations for minor forest classes applied ones from neighboring country (i.e. Vietnam), developing country-specific allometric equation for minor forest classes contribute to reducing the uncertainty into the future. Also, as Lao PDR is considering accounting for non-CO2 gases from field burning, developing a country-specific biomass combustion factor which can be applied for slash and burn activities can also be considered.

8. References

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Annex 1: Carbon Stocks per Land/Forest classes and sources of data

IPCC definitions	Level 1	Level 2	tC/ha	tCO2/ha	Data source
Forest Land	Current Forest	Evergreen Forest	205.8	754.5	3rd NFI_Lao original AE
		Mixed Deciduous Forest	87.9	322.3	3rd NFI_Lao original AE
		Dry Dipterocarp Forest	50.8	186.3	3rd NFI_Lao original AE
		Coniferous Forest	77.1	282.7	3rd NFI_Vietnam AE
		Mixed Coniferous and Broadleaved Forest	87.6	321.2	3rd NFI_Vietnam AE
		Forest Plantation	37.2	136.5	GPG GL(2003) Anx_3A_1_Data_Tables(Other species)
	Potential Forest	Bamboo	24.4	89.5	Vietnam modified REL report
		Regenerating Vegetation	10.4	38.2	2nd RV survey
Grassland	Other Vegetated Areas	Savannah	16.4	60.0	IPCC EF DB 513130
		Scrub	38.6	141.7	2006 IPCC guideline V4 Chp4 Table4.7
		Grassland	7.4	27.2	LULUCF Sector Good Practice Guidance P3.109 Table3.4.2
Wetland		Swamp	0	0	No default value
Cropland	Cropland	Upland Crop	5.0	18.3	LULUCF Sector Good Practice Guidance P3.88 Table3.3.8 (Annual)
		Rice Paddy	5.0	18.3	LULUCF Sector Good Practice Guidance P3.88 Table3.3.8 (Annual)
		Other Agriculture	2.6	9.5	LULUCF Sector Good Practice Guidance P3.88 Table3.3.8 (Perenial)
		Agriculture Plantation	38.8	142.3	IPCC EF DB 511318 other species
Settlements/ Other land /Wetlands	Non Vegetated Areas	Non Vegetated Areas/Other/Water	-	-	-

Annex 2: List of equation, root shoot ratio and carbon fraction

		AGB		AGB→BGB			Biomass→Carbon	
Level 1	**Level 2**	Allometric Equation	Data source	Condition	Conversion Factor	Data source	Conversion Factor	Data source
Current Forest	Evergreen Forest	AGB=0.3112 x DBH^2.2331	JICS Forest Preservation Programme TA6 Final report	AGB<125t/ha	0.20	2006 GL(V4_04_Ch4_Table4.4)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB>125t/ha	0.24	2006 GL(V4_04_Ch4_Table4.4)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Mixed Deciduous Forest	AGB=0.523081 x DBH^2	JICS Forest Preservation Programme TA6 Final report	AGB<125t/ha	0.20	2006 GL(V4_04_Ch4_Table4.4)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB>125t/ha	0.24	2006 GL(V4_04_Ch4_Table4.4)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Dry Dipterocarp Forest	AGB=0.2137 x DBH^2.2575	JICS Forest Preservation Programme TA6 Final report	AGB<125t/ha	0.20	2006 GL(V4_04_Ch4_Table4.4)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB>125t/ha	0.24	2006 GL(V4_04_Ch4_Table4.4)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Coniferous Forest	AGB=0.1277xDBH^2.3944	UN-REDD Programme, Hanoi, Viet Nam(2012).	AGB<50t/ha	0.46	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB=50-150t/ha	0.32	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB>150t/ha	0.23	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Mixed Coniferous and Broadleaved Forest	AGB=0.1277xDBH^2.3944	UN-REDD Programme, Hanoi, Viet Nam(2012).	AGB<125t/ha	0.20	2006 GL(V4_04_Ch4_Table4.4)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB>125t/ha	0.24	2006 GL(V4_04_Ch4_Table4.4)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Forest Plantation	Use IPCC default value	IPCC EF DB 511220 Broad leaf)	AGB<50t/ha	0.46	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB=50-150t/ha	0.32	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB>150t/ha	0.23	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)	0.47	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
Potential Forest	Bamboo				0.82	Junpei Toriyama(http://www.ipcc-nggip.iges.or.jp/EFDB/main.php)	0.46	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Regenerating Vegetation	AGB = 1.7573e0.4107Y Where: Y is abandoned years after cropland	FPP TA6 Final report	AGB<20t/ha	0.56	2006 GL(V4_04_Ch4_Table4.4)	0.46	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
				AGB>20t/ha	0.28	2006 GL(V4_04_Ch4_Table4.4)	0.46	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
Other Vegetated Areas	Savannah				0.50	GPG(Chp3_4_Grassland_Table3.4.3)	0.46	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Scrub				2.80	GPG(Chp3_4_Grassland_Table3.4.3)	0.46	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Grassland				1.60	GPG(Chp3_4_Grassland_Table3.4.3)	0.46	2006 IPCC GL for National GHGi_V4_04_Ch4_Forest_Land
	Swamp							
Cropland	Upland Crop			According to GPG2000 Chp4 p.4.63, In the IPCC Guidelines' method for incorporation of crop residues, the contribution from root biomass from the harvested crop is not accounted for. Ideally, both the aboveground and the root biomass should be accounted for to include nitrogen from the total plant, but the root biomass cannot readily be estimated.				
	Rice Paddy							
	Other Agriculture							
	Agriculture Plantation			AGB<50t/ha	0.46	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)		
				AGB=50-150t/ha	0.32	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)		
				AGB>150t/ha	0.23	2003 GPG(Anx_3A_1_Data_Tables3A.1.8)		