**Emissions and Removal Factor Report
for the ER Program of Lao PDR**

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**Department of Forestry
Lao PDR**

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Acronyms

Acronym	Name
AE	Allometric Equations
AGB	Above Ground Biomass
B	Bamboo
BGB	Below Ground Biomass
CF	Coniferous Forest
CI	Confidential 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
ER	Emission Reduction
FCPF	Forest Carbon Partnership Facility
FIM	Forest Information Program
FIPD	Forestry Inventory and Planning Division
FREL/ FRL	Forest Reference Emission Level /Forest Reference Level
F-REDD	Sustainable Forest Management and REDD+ Support Project in the LAO PDR
GIS	Geological Information System
GL	Guidelines
GOL	Government of the Lao PDR
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
REL	Reference Emission level
RF	Removal Factor
RV	Regenerating Vegetation
StD	Standard Deviation
StE	Standard errors
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

1.1 Introduction

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 construction of Reference Emission Level (REL)[1] for

    i.   the national level REL to be submitted to the United Nations Framework Convention on Climate Change (UNFCCC); and

    ii.   the REL for the Emission Reduction Program Accounting Area (ER-P area) which Lao PDR proposes to the FCPF Carbon Fund (i.e. ER-P areais the 6 northern provinces of Houaphan, Bokeo, Louangnamtha, Louangphabang, Oudomxai and Xaignabouly).

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

- The 2nd National Forest Inventory (NFI) conducted between 2015 and 2017 by the Forest Inventory and Planning Division (FIPD) of the Department of Forestry (DOF) under the Ministry of Agriculture and Forestry (MAF).[2] The purpose of the 2nd 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) (Section 2.1).
- A survey for the Regenerating Vegetation (RV) class (which was outside the scope of the 2nd 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 type (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 (Section 2.3). Other land/forest classes use IPCC default values or biomass data from neighboring Vietnam.

In this report, the above results were combined under the methodologies to estimate biomass, carbon stock to determine the E/R factors as prestend in Chapter 3. The report also presents actual results of estimation and the final E/R factors in Chapter 4. Uncertainty of E/R factors is assessed in Chapter 5. The issues related to the use of the 1st NFI[3], usability of national dataset for the ER Program, and

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[1] The term "REL" is used differently by UNFCCC and FCPF CF, where the former calls it "Forest Reference Emission Level/Forest Reference Level (FREL/FRL), and the latter calls it "Reference Level (RL)". As the two are basically the same in its definition, this report uses the term "REL" as the common term unless otherwise specifically distinguished.

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

[3] Lao PDR conducted its 1st NFI in the late '90s, however, the results are decided not to be used in the development of E/R F. See Section 5.1 for the details.

accounting of Dead Wood (DW) are discussed in Chapter 6, and lastly, the conclusion and areas for future improvement are summarized in Chapter 7.

1.2 Notes on analytical considerations

This report is written based on the following understandings (details are discussed in Chapter 6):

a) Lao PDR conducted its 1st NFI in 1990s. Review of the 1st NFI data found that they are not suitable due to the limititation in data representativeness, and the gap of nearly 20 years between the 1st NFI and the 2nd NFI. Therefore, only the data from the 2nd NFI are used for the development of E/R factors.

b) Usability of the national dataset for the ER Program was assessed. It was concluded that due to the limited sample of measurement data collected from the ER Program area for some forest classes, using the national dataset for the ER Program area will be more robust. This also has an advantage in terms of consistency between the national REL an that of the ER Program. A further analysis showed small bias of using the national dataset for the ER Program.

c) The 2nd NFI measured Dead Wood (DW) in the five forest classes (EG, MD, DD, CF, MCB). The result showed that DW are not significant source of emissions (approx. 1.7% of the total emissions. Also, the biomass survey of RV (different from the 2nd NFI) did not measure DW which makes the estimation inconsistent. Therefore, it was concluded not to account DW in the development of E/R factors.

2. Dataset used

2.1 Forest biomass data from the 2nd NFI[4]

Background

Lao PDR conducted its 1st NFI in 1991-1999, covering the entire country. However, the 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 the use under REDD+. Improved NFI methodologies were developed through field testing in 2013 - 2015[5] and a manual was developed[6]. Then, a full NFI campaign was conducted over the two dry seasons of 2015-2016 and 2016-2017.

Objectives

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[4] See DOF, et al. (2017). "The 2nd National Forest Inventory Survey <http://dof.maf.gov.la/en/home/> for more details.
[5] Capacity Development Project for Establishing National Forest Information System for Sustainable Forest Management and REDD (NFIS) (2013 – 2015) under JICA.
[6] Lao PDR National Forest Inventory Standard Operating Procedures (SOP) Manual for Terrestrial Carbon Measurement

The objectives of the 2nd NFI was to survey the forest biomass[7] of the five natural forest classes of the whole country. (Excluding forest plantations due to its relatively small area and possible use of IPCC default factors; and bamboo (B) and regenerating vegetation (RV) which do not currently meet the status as forest under the Lao forest definition[8].) A standardized methodology and sample-based field measurements were applied.

Survey outline

Survey schedule

To meet Lao PDR's target to complete both RELs for the national level and for the ER Program by the end of 2017:

- A part of the three natural forest classes (EG, CF, MCB) were surveyed in the dry season of 2015-16 with Forest Type Map (FTM) 2010 for distributing the sampling plots (as FTM 2015 was not yet completed); and

- Remaining part of EG, CF and MCB plus all MD and DD natural forest classes were surveyed in the dry season of 2016-17 with FTM 2015 for distributing the sampling plots.
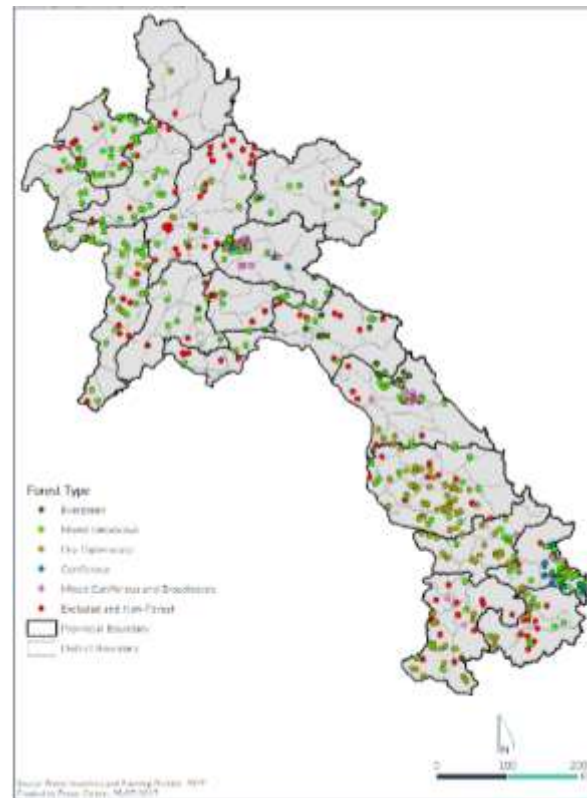
Figure 2-1: Surveyed plot by forest type in 2nd NFI

A total of 559 survey plots were distributed across the five forest classes through stratified-random-sampling (See
Figure 2-1). Lands classified as non-forest were not sampled. It is recognized that this may bias the resulting estimates, but the bias is not expected to be significant.

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

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[7] The main target of the survey was to measure the forest biomass, however, other information, such as observed disturbances were also recorded.
[8] Lao's forest definition includes: Minimum DBH of 10cm, Minimum crown density of 20%, minimum area of 0.5ha.

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 2-2** was used, where the first sub-plot (sub-plot A) was laid out with an anchor point placed in the plot center, and three additional sub-plots (B, C, D) 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.
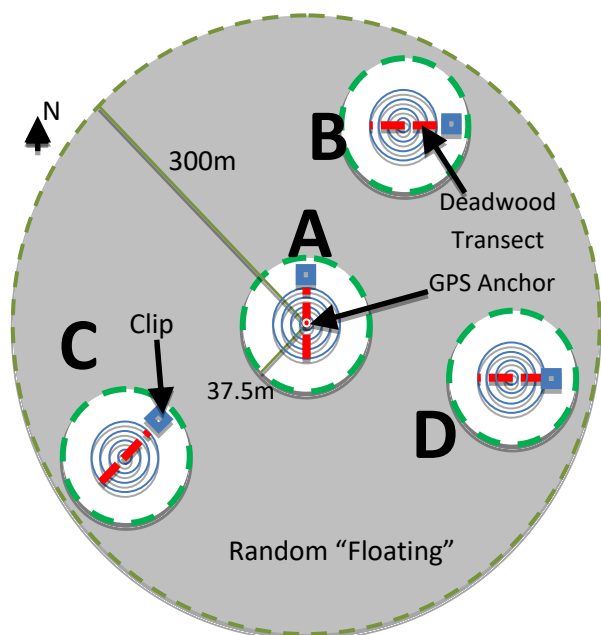
Figure 2-2: Floating cluster design

The following circular nest sizes are shown for each stratum as below. Each stratum was given different tree DBH groups to measure (See Figure 2-3).
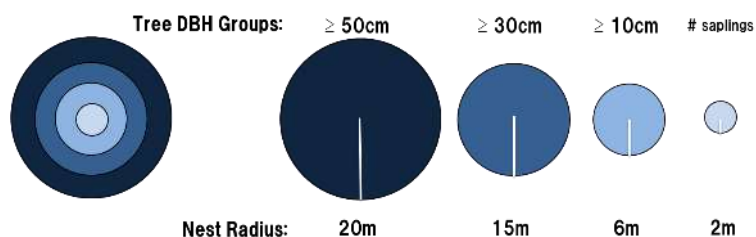
Figure 2-3: Nested circle plots

Carbon pools measured

AGB (standing trees, saplings, non-tree vegetation (NTV), bamboo) and Dead Wood (standing and lying deadwoods, tree stumps), were measured.

Results

Across the five forest classes surveyed, among the 559 plots distributed, a total of 420 plots were included in the estimation of forest carbon stocks. The remaining 139 plots were not included because of their land condition (contrary to the identification from the FTM, the land was actually found as non-forest in the field survey), and conflict in forest classes (the plots with 2 x forest class A and 2 x forest class B were excluded). 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 "RV survey"[9]

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 Laos in 2015. Quantification of biomass from this landscape had been a challenge due to limited availability of data and allometric models[10]. Furthermore, distinguishing RV class from 'forest' classes through remote sensing poses a big challenge[11].

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

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[9]See, 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/home/> for more details.

[10] 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.

[11] 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.

Survey clusters were selected from the annual vegetation loss dataset of Hansen et al[12] to detect the year of loss on forest loss plots, then ground truthed and measured the crown cover to determine whether it had reached the forest status[13] or not. For each survey plot, the year of forest loss was further verified by interviewing the villagers. Only the plots confirmed as RV were measured.

A total of 120 survey plots (40 survey clusters with three survey plots each) were surveyed in five provinces (includingin three provinces in the ER-P area) (**Table 2-1**).

Table 2-1: Number of RV Survey clusters in each region/province

Region	Province	Years after cropping	Number of Cluster	Subtotal
North	Bokeo	1,2,3,4,5,6,7,8	1 x 8	8
North	Xayabouly	1,2,3,4,5,6,7,8	1 x 8	8
North	Xiengkhouang	1,2,3,4,5,6,7,8	1 x 8	8
Central	Bolikhamxay	1,2,3,4,5,6,7,8	1 x 8	8
South	Xekong	1,2,3,4,5,6,7,8	1 x 8	8
			Total	**40**

Below figure shows the plot design.
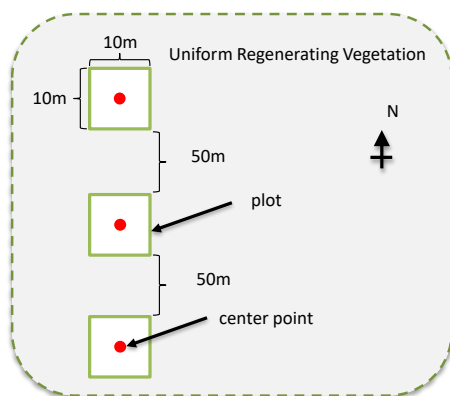
Figure 2-4: Clusters with three ranged square plots

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[12] Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 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.

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

In each plot (10 m*10 m square design)and DBH ($\geqq$5 cm) for all trees was recorded, and all other vegetation were cut at their base in the four corners of the sub-plots (size of 1m*1m or 2m*2m, depending on the vegetation height to weigh the non-tree biomass).

Since the most common forest type for RV to regenerate into is 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 originating from the samples of the MD forest class.

Unmanned aerial vehicles (UAV) were used to take aerial photographs of the plots in order to estimate the crown cover rate, which was then used for identifying the number of years for RV to reach the forest threshold[14]. 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).

Results

The following model using the number of years under fallow was developed.

AGB = 1.7573e$^{0.4107Y}$ (R^2 = 0.7224)

The results of survey showed that the number of years for RV to reach the forest threshold was on average 7 years. By adding one year for cropping (classified as "UC"), it was assumed that a land slashed and burnt could potentially regenerate into forest status in 8 years if left undisturbed.
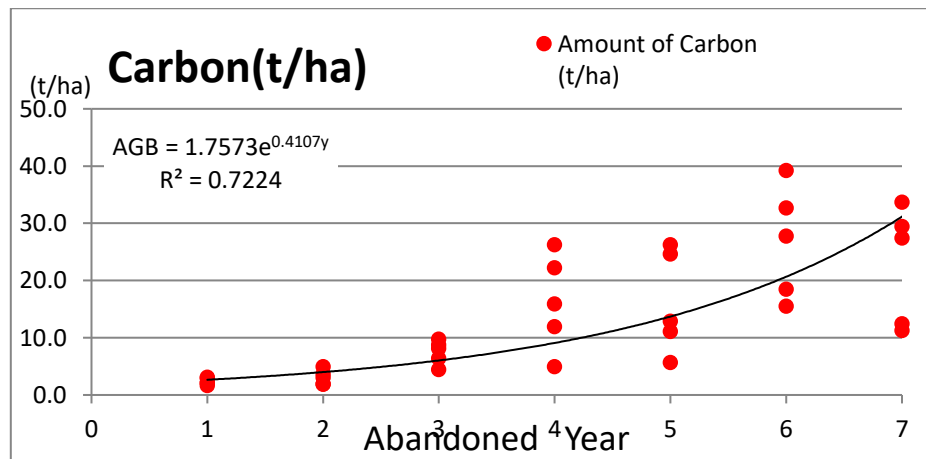
Figure 2-5: Carbon stock of plots

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

The total area of each age class of RV (1 year, 2 year, etc) is not even, since different amount of lands are subject to slash and burn every year. This survey distributed an equal number of 5 clusters for each year of the RV age class without considering variations in size of age classes.

2.3 Allometric equations for the three major forest classes[15]

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 2nd 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[16]; Evergreen Forest (EG), Mixed Deciduous Forest (MD) and Dry Dipterocarp Forest (DD).

Survey outline

The allometric equationss 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 2-2). Deadwood and saplings were also sampled.

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 accordingly.

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 2-2: 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

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[15]See DOF, et al. (2017). "Development of country-specific allometric equations in Lao PDR" <http://dof.maf.gov.la/en/home/> for more details.
[16] The 3 forest classes cover 66% of the total forest land of Lao PDR (EG: 13%, MD: 47%, DD: 6%) in 2015.

	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 equationss deveoped for other forests in South-East Asia[17], 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.
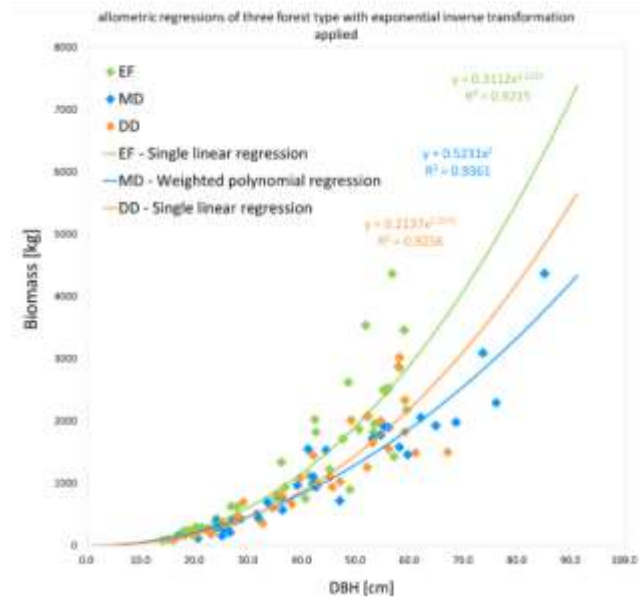
Figure 2-4: Allometric regressions of three forest types

Table 2-3: 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

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

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 Chapter 2, the biomass of the five forest classes were estimated from the measurement results of the 2nd NFI. Meanwhile, the biomass of RV was estimated separately using the measurement results from the 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 2nd NFI is calculated from the average stock of sub-plots. Then, average biomass stock for each forest class is calculated from the average stock of all plots.

LIVING TREES

The calculation of the biomass in kg for each tree by applying the appropriate allometric equations to the trees in different forest classes (See Table 3-1). The allometric equations for EG, MD and DD forest class were developed for Lao PDR, and the allometric equations developed in neighboring Vietnam were used for CF and MCB forests. Secondly, the biomass per tree is then converted into biomass per ha, and summed for subplots.

Table 3-1: 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*	

SAPLINGS

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 3-2). 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).

Table 3-2: 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	

BAMBOO

For the measurement of biomass of bamboo poles, average diameter of five bamboo poles sampled per sub-plot was calculated and the allometric equation for bamboo developed in Vietnam was used[18]. 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.

Equation 1: Allometric equation for bamboo biomass (kg) from Hung et al. (2012) [19]

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

Where:
D = diameter of the bamboo pole (cm)

NON TREE VEGETATION (NTV)

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

Table 3-3: 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 People's Democratic Republic
MD	358	1.09	
DD	84	0.5	
CF	133	0.75	
MCB	764	0.57	

3.1.1.2 AGB of Regenerating Vegetation (RV)

The of biomass of RV, including trees, NTV, bamboo and saplings, were measured through the "RV Survey" (see Section 2.2). The estimation of carbon stock of RV, however, has a higher degree of

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

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 Woods (DW) consists of standing trees, stumps and lying trees.

STANDING DEADWOOD
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 (See Table 3-1).

STUMPS
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) [20]

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

Where:
D_{mean} = mean diameter (cm)
H_{stump} = height of the stump
WD   = wood density (0.57 g/cm^3)

LYING DEADWOOD
Lying DW was separated into 2 categories, i.e. hollow and solid, and the latter was further separated by three density classes (i.e. sound, intermediate, and rotten; Table 3-4). 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 3-4: Lying deadwood densities (g/cm^3) by density class and forest type

Forest type	Density class	Density (g/cm³)	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	

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

	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) ratios corresponding to each forest class and their average AGB.

Table 3-5: Root-to-Shoot rations 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	
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:

$$C_i = TB_i \times CF$$

Where:
TB_i = 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 CO2 mass to carbon mass.

If Ci > Cj, such change is considered emissions;

If Ci < Cj, such change is considered removal.

3.4 Estimation of carbon stock 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 as below:

- Evergreen Forest (EG) has distinctly high carbon stocks (200.0tC), thus, separated as an independent stratum – Stratum 1 (expanse: 481,380ha, 5.9% of the ER-P area).

- Mix Deciduous Forest (MD), Conifer Forest (CF) and Mixed Coniferous and Broadleaved Forest (MCB) will form one stratum on the basis of similarity in carbon stocks per hectare (87.7tC, 92.6tC, 114.7tc). – Stratum 2 (expanse: 3,799,415ha, 46.8% of the ER-P area).

- Dry Dipterocarp Forest (DF) will form one stratum due to the difference in carbon stock from other forest classes (43.2tC), and also due to the fact that they are mostly distributed in the low-lands and prone to conversion to other land use – Stratum 3 (expanse: 17,351ha, 0.2% of the ER-P area).

- Plantation (P), Bamboo (B) and Regenerating Vegetation (RV) will form one strata on the basis of similarity in average carbon stock (37.2tC, 24.4tC, 17.4tC) and the limited area in the ER-P area – Stratum 4 (expanse: 2,974,904ha, 36.6% of the ER-P area).

- The remaining 12 non-forest classes will form one stratum – Stratum 5 (expanse: 850.100ha, 10.5% of the ER-P area). The values of carbon stocks of respective class are mostly taken from IPCC GL 2006 and combined into a single area-weighted estimation.

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

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

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 2015.

4. Result

4.1 Average carbon stock

The average carbon stock of the five forest classes from the 2nd NFI data are shown in **Table 4-1**. 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 "RV Survey".

Table 4-1: Average carbon stock (tC/ha) of the 5 strata

Strata	tC/ha
Stratum 1 (EG)	200.0
Stratum 2 (MD/CF/MCB)	88.1
Stratum 3 (DD)	43.2
Stratum 4 (P/B/RV)	17.9
Stratum 5 (NF)	4.9

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 following Table 4-5.

Table 4-2: 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)		-410.5	-575.1	-667.6	-715.4

Stratum 2 (MD/CF/MCB)	410.5		-164.6	-257.1	-304.9
Stratum 3 (DD)	575.1	164.6		-92.6	-140.3
Stratum 4 (P/B/RV)	667.6	257.1	92.6		-47.8
Stratum 5 (NF)	715.4	304.9	140.3	47.8	

5. Uncertainty analysis

5.1 Method of uncertainty assessment

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[21]. Accordingly, the causes of uncertainties for the E/R factors and their application in the uncertainty assessment are summarized in following**Error! Reference source not found.**.

Table 5-1: 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 2nd 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 2nd 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 2nd 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)

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[21] Rypdal and Winiwarter, 2001

Measurement error	Relevant. Measurement of tree DBH assumed to be with minor error according to the 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 recorded through the tablet-based survey application to eliminate data loss and reduce data input errors. Field survey teams were well trained before conducting survey.	No
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 the tablet-based survey application to eliminate data loss and reduce data input errors.	No

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 (2nd 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 2nd NFI)

Estimation method for uncertainty of AGB originating from sampling error

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[22].

Estimation of uncertainty of AGB originating from biomass equation

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

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

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

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

Where:

N = number of sample trees

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

StD = Standard Deviation.

StE = Standard Error.

The following **Error! Reference source not found.** shows the results of assessment.

Table 5-2 : 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 number of EG and CF plots (e.g. QC teams unable to find the exact QC plots).

Table 5-3 : Uncertainty of AGB originating from measurement error

	Number of QC survey plot	Average difference between primary plot and QA plot	StD	StE
EG	0	N/A	N/A	N/A
MD	14	9.5	11.7	3.1
DD	11	6.6	13.5	4.1
CF	0	N/A	N/A	N/A
MCB	3	7.9	15.1	8.7

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.

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.

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.

5.2 Uncertainty assessment of carbon stock

The following**Error! Reference source not found.** shows the total uncertainty of carbon stock for each forest class estimated through the propagation of error approach.

Table 5-4: Total uncertainty assessment of carbon stock

Forest class	Sources of uncertainty					Uncertainty (AGB+BGB) (%)
	1.	2.	3.	4.	5.	
EG	14.0	3.9	11.5	2.7	-	18.7%
MD	5.0	3.8	11.5	2.7	3.1	13.7%
CF	13.2	18.0	20.3	2.7	-	30.3%
MCB	22.3	18.0	11.5	2.7	8.7	32.2%
DD	8.7	3.6	11.5	2.7	4.1	15.6%
P	-	18.0	20.3	2.7	-	27.3%
B	15.5	0.3	-	2.7	-	15.7%
RV	27.0	-	0.9	2.7	-	27.1%
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:

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

Ustrata = uncertainty (%) of new strata calculated from biomass and area of land/forest class;
Ui = uncertainty of land/forest class (tC/ha);
Ai = area (ha) of 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 **Error! Reference source not found.** shows the uncertainty for each stratum.

Table 5-5: Uncertainty in carbon stock/ha by stratum

Stratum	Uncertainty (%)
Stratum 1 (EG)	18.7
Stratum 2 (MD/CF/MCB)	12.4
Stratum 3 (DD)	15.6
Stratum 4 (P/B/RV)	25.4
Stratum 5 (NF)	20.0

5.5 Uncertainty of Emission/Removal Factors

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

Table 5-6 : 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)		13.5%	15.6%	17.3%	18.2%
Stratum 2 (MD/CF/MCB)	13.5%		9.8%	11.2%	11.8%
Stratum 3 (DD)	15.6%	9.8%		13.3%	14.2%
Stratum 4	17.3%	11.2%	13.3%		20.4%

(P/B/RV)						
Stratum 5 (NF)	18.2%	11.8%	14.2%	20.4%		

6. Discussion

6.1 Usability of the 1st NFI data

The 1st NFI conducted in 1991-1999 measured the forest biomass of the entire country, however, applying a different methodology from the 2nd NFI.

Table 6-1 shows the comparison of survey contents and design between the 1st and 2nd NFIs. Some surveyed items are comparable, however, many others are not, and some of the results from the 1st NFI are not sufficient against the requirements under REDD+.

The major shortcoming of the 1st NFI is that the survey plots were selected only from easily accessible area, thus have significant problems in data representativeness. Also, there is a gap of nearly 20 years between the 1st NFI and the 2nd NFIs, and the forests of Lao PDR have experienced significant changes during this period.

For the reasons above, Lao PDR considered that the 1st NFI shall not be used in the construction of both, the national REL and the ER Program REL.

Table 6-1: Comparison of the 1st and 2nd NFIs

	1st NFI		2nd NFI
Main Objectives	- Estimate growing stock - Development of volume functions - Use for reviewing the forest definition		- Estimate forest biomass/carbon stock
Target area	Nation wide (Only easily accessible areas, 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	1991-1999		2016-2017
Number of plots	Forest: 2,368 plots		Forest: 420 plots
Survey class	6 natural forest, 4 potential forests and others		5 natural forests
Plot design, shape, location, etc.			
Single plots			

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Cluster plots	X	X
Rectangular plots	X	
Circular plots		X
Forest classification	X	X
Location information (Latitude/longitude coordinates)	Province name only	X
Photographs of the plots		X
Living trees	X	X
DBH	X	X
Diameters at middle and top of bole	X	
Tree height	X	
Tree quality	X	
Population of saplings	X	X
Canopy density	X	
Non-forest class	X	X
Forest structure	X	
Species (local name)	X	X
Species (Scientific name)		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
DBH		X
Height		X
Lying Dead Wood		X
Diameter		X
Density		X
Decomposition class		X
Litter		
Fresh mass		
Dry mass		
Soil	X	
Soil type	X	

Bulk density		
Organic carbon content		
NTFP	X	X
Rattan	X	
Bamboo	X	X

6.2   Usability of national E/R factors for the ER Program

E/R factors for the five forest classes

For the E/F factors for the five forests classes (stratified into three strata) to be used for the ER Program, two options were considered:

    a) Using national E/R factors derived from the national NFI data for plots from the entire country.

    b) Using E/R factors derived from only the NFI data for plots within the ER-P area.

Option b) was considered a weak option, as there were only as few as four plots for the EG class and 10 for the DD class, available. The following Table 6-2 shows the number of NFI plots from the ER-P area. Meanwhile, due to the limited area of DD, CF and MCB classes (and no sample plots for CF and MCB) in the ER-Program area, it was considered reasonable to use the national E/R factors for these three forest classes.

Table 6-2: Number of NFI plots for the five forest classes in the ER Program area surveyed in the 2ⁿᵈ NFI

	Area(ha) (2015)	Number of NFI plots	Ave (tC/ha)	StD	CI (95%)	Uncertainty (%)
EG	481,380	4	169.5	57.8	56.7	33.4
MD	3,771,453	100	93.6	37.3	7.3	7.8
DD	17,351	10	67.4	39.9	24.7	36.7
CF	25,782	0	-	-	-	-
MCB	2,180	0	-	-	-	-
Total	4,298,146	114				

In order to further assess the level of bias and judge the usability of national data (i.e. option a) above), the plot data of the entire country and that of the ER-P area were compared and analyzed. The following figures show the carbon stock variance of EG, MD and DD between the national and that of the ER-P area (i.e. "6 province"). The figure shows that the plots of EG, MD and DD in the 6 provinces are not outside the range as that for the rest of the country, instead, they are well within the range of the national data set. Thus, the bias arising from the use of national E/R factor for the ER-P is considered as limited.

For the MD and DD classes, the number of plots for the ER-P area is enough for developing a specific E/R factor for the area. As Table 6-2 and shows, the average carbon stock and uncertainty is very close

to the national data shown in **Table 4-1**. Taking the above into account, and to enhance consistency between the national and ER-P FREL, for MD also, Lao decides to use the nationally constructed E/R for the ER program.

What is a box plot?

Box plots allow you to visualize and compare the distribution and central tendency of numeric values through their quartiles. Quartiles are a way of splitting numeric values into four equal groups based on five key values: minimum, first quartile, median, third quartile, and maximum.The box portion of the chart illustrates the middle 50 percent of the data values, also known as the interquartile range, or IQR. The median of the values is depicted as a line splitting the box in half. The IQR illustrates the variability in a set of values. A large IQR indicates a large spread in values, while a smaller IQR indicates most values fall near the center. Box plots also illustrate the minimum and maximum data values.

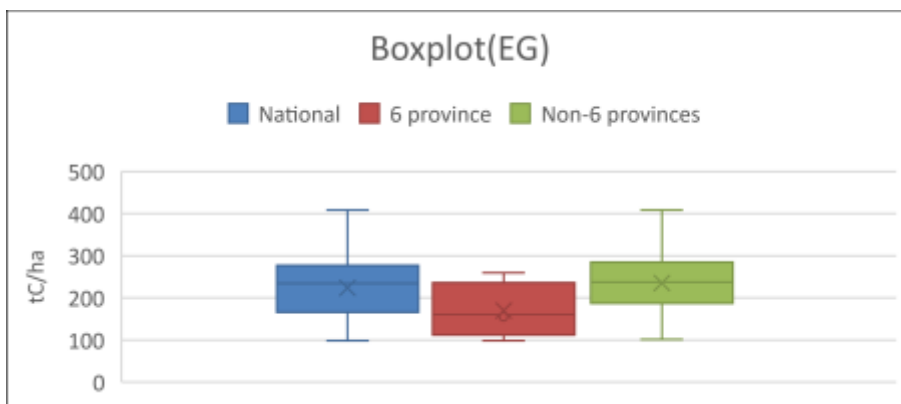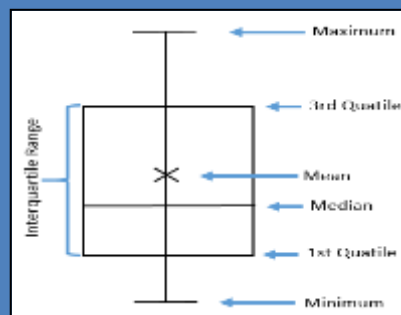Source: https://pro.arcgis.com/en/pro-app/help/analysis/geoprocessing/charts/box-plot.htm

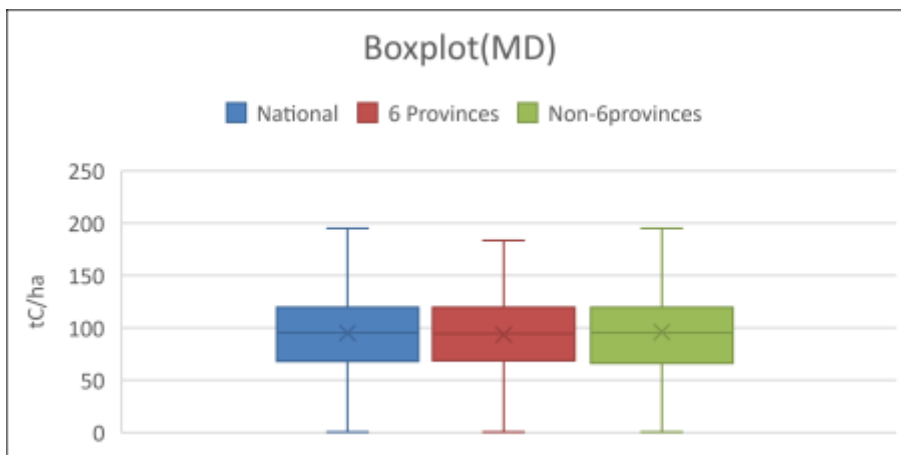Figure 6-1: Comparing carbon stocks between national and 6 provinces (EG)

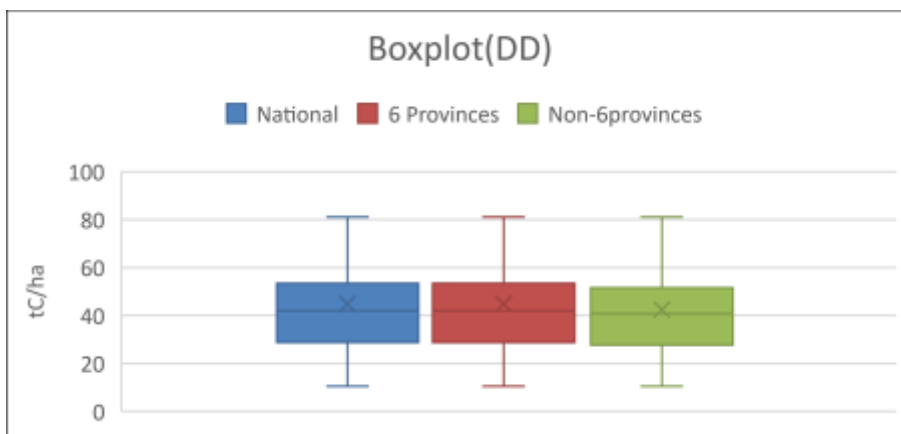Figure 6-2: Comparing carbon stocks between national and 6 provinces (MD)

Figure 6-3: Comparing carbon stock between National and 6 provinces (DD)

E/R factors for RV

Usability of the national E/R factor of RV for the ER program was also examined. The survey plots for RV were distributed in three provinces in the northern region including two of the ER Program provinces (i.e. Bokeo and Xayabouly), one province in the central region and one province in the southern region. Therefore, it generally is possible to apply regional E/R factors for the ER program area.

However, it was determined that the value of the ER Program E/R factor is higher compared to that of the nationally constructed E/R factor, while the standard deviation is also higher. Therefore, in order to avoid possible overestimation, it was considered suitable to use the nationally constructed E/R factor for RV for the ER Program. This has another advantage in terms of consistency between the national REL and that of the ER Program.

Table 6-3: Comparison of average carbon stock of RV by region

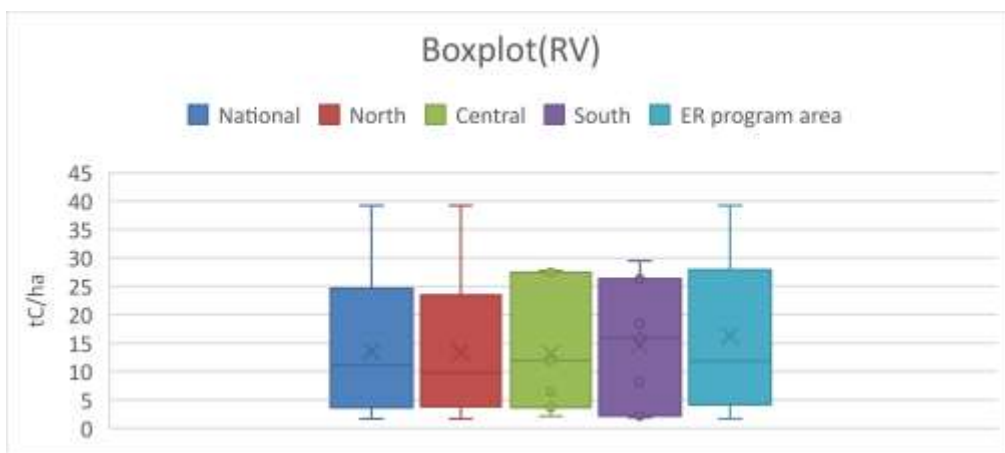|	National	ER program area (Bokeo, Xayabouri)	North	Central	South
Number of plots	40	16	24	8	8
Average Carbon / ha	13.6	16.2	13.4	14.6	13.2
StD	11.1	13.2	11.7	11.0	10.6

Figure 6-4: Comparing carbon stocks among national, ER-P area, North,Central and South (RV)

6.3 Exclusion of Deadwood from the carbon pool

The 2nd NFI included measurement of DW. As shown in Table 6-5, historical results showed that emissions from DW through deforestation accounts for only 1.7% of the sum of the AGB, BGB, and DW, therefore, considered insignificant. It should also be noted that the uncertainty of DW was relatively high.

Table 6-4: Carbon stock and uncertainty by different pools

	AGB+BGB	DW		DW/(AG+BG+DW)
	Average (tC/ha)	Average (tC/ha)	Uncertainty (95%)	Ratio (%)
EG	200.0	10.4	28.5	4.9
MD	87.7	6.4	21.7	6.8
DD	43.2	2.4	20.5	5.3
CF	92.6	3.0	64.3	3.1
MCB	114.7	9.0	49.8	7.3

Table 6-5: Emission from deforestation and forest degradation by DW pool

	AG+BG MtCO2/year	DW MtCO2/year	DW/ (AG+BG+DW)
National	25.02	0.59	2.3%
6 province	10.57	0.17	1.6%

Emission from DW pool shown in Table 6-5 does not include emission from forest degradation for the reason that main source of emission from forest degradation is caused by conversion of forest to RV. Nevertheless, there is no measurement data of DW in RV (therefore, not accounted). There is a concern that inclusion of DW in forest degradation may result in inconsist estimation and causing possibility of overestimation.

Therefore, DW is determined not to be included in the current estimation of E/R factors.

7.   Conclusion and areas for future improvement

This report presented the E/R Factor estimated by the 2nd NFI data, RV survey and allometric equations including country-specific ones for Lao PDR. The potential use of a) data from the 1st NFI, b) specific E/R factors for the ER program area and c) inclusion of DW as a carbon pool were considered.

As a result, from the perspective of data representativeness of the 1st NFI and the time gap between the 1st and the 2nd NFI, Lao PDR considers that the 1st NFI data should not be used for constructing E/R factors. Regarding specific E/R factors for the ER Program area, use of the nationally constructed E/R factors were considered as the more robust option considering the small number of sample size for the ER Program area, and conservativeness principle. Emissions from DW have historically been recorded to be insignificant and therefore omitted.

Potential improvements in future E/R factor as below.

- Secure sufficient number of survey plots per forest and non-forest classes

  In the 2nd NFI, there was low congruence between the predicted and actual classification of forest classes for the NFI plots. This resulted in lower than desired samples for non-MD forest classes. As such, for the future iteration of the NFI, it is recommended to increase the number of non-MD plots, to ensure minimum thresholds are met for all forest classes. Also, since the lands other than those categorized as currently stocked (i.e. EG, MD, DD, CF, MCB, P) in the forest type maps were not sampled, there is a concern of bias (although not significant). Thus, future NFIs should sample whole landscapes and verify forest as well as non-forest.

- Carbon stock of RV

  The carbon stock of Regenerating Vegetation (RV) was calculated from the average carbon stock of each year. Since this survey distributed five clusters for each year of fallow, variations in the area of RV for each year are not considered. Therefore, there is a limitation in the representativeness of data and resulting uncertainty was relatively high. For future NFIs, the number of years after abandonment is suggested to include as survey item with support from remote sensing. The future survey of the carbon stock of RV should also consider including measurement of DW.

- Continuous improvement of E/R factors

  Default value from the IPCC GLs 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 used ones from neighboring country (i.e. Vietnam), developing country-specific allometric equation for minor forest classes shall contribute to reducing the uncertainty. Also, as Lao PDR consideres to account non-CO2gas from field burning, developing a country-specific biomass combustion factor which can be applied for slash and burn activities shall be considered

8. References

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9. Annex

Annex 1: Carbon Stocks per Lao's Land/Forest classification and sources of data for constructing carbon stock estimates

IPCC definitions	Level 1	Level 2	tC/ha	tCO2/ha	Data source
Forest Land	Current Forest	Evergreen Forest	200.0	733.4	2nd NFI_Lao original AE
		Mixed Deciduous Forest	87.7	321.5	2nd NFI_Lao original AE
		Dry Dipterocarp Forest	43.2	158.3	2nd NFI_Lao original AE
		Coniferous Forest	92.6	339.6	2nd NFI_Vietnam AE
		Mixed Coniferous and Broadleaved Forest	114.7	420.7	2nd 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	17.4	63.8	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	-	-	-

Annex2: List of equation, root shoot ratio and carbon fraction

Level 1	Level 2	AGB — Allometric Equation	AGB — Data source	AGB→BGB — Condition	AGB→BGB — Conversion Factor	AGB→BGB — Data source	Biomass→Carbon — Conversion Factor	Biomass→Carbon — 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)		