Bhutan's Proposed National Forest Reference Emission Level and National Forest Reference Level

Submission for technical assessment to UNFCCC

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Acronyms

AD	Activity Data
AGB	Aboveground Biomass
AFOLU	Agriculture, Forestry and Other Land Use
AR5	IPCC Fifth Assessment Report
Ba	Basal Area
BEF	Biomass Expansion Factor
BCEF	Biomass Conversion and Expansion Factor
BGB	Belowground Biomass
C	Carbon
CWD	Coarse Woody Debris
CE	Collect Earth
CF	Carbon Fraction
CFs	Community Forests
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
COP	Conference of Parties
DD	Drivers of Deforestation and Forest Degradation
DoFPS	Department of Forests & Park Services
d.m	dry matter
DW	Dead Wood
EDP	Economic Development Policy
EF	Emission Factor
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FIRMS	Forest Information Reporting and Monitoring System
FMU	Forest Management Units

FNCA	Forest and Nature Conservation Act of Bhutan
FNCRR	Forest and Nature Conservation Rules and Regulations of Bhutan
FREL	Forest Reference Emission Level
FRMD	Forest Resources Management Division
FRL	Forest Reference Level
FYP	Five Year Plan
ha	hectare
GCF	Green Climate Fund
GFC	Global Forest Change
GFOI	Global Forest Observation Initiative
GHG	Greenhouse Gas
GLC	Global Land Cover
GNH	Gross National Happiness
GWP	Global Warming Potential
HFLD	High Forests Low Deforestation
IPCC	Intergovernmental Panel on Climate Change
LCMP	Land Cover Mapping Project
LFMA	Local Forest Management Area
LULC	Land Use and Land Cover
LUPP	Land Use Planning Project
m	million
m^3	cubic meter
m.a.s.l	Meters above sea level
MoAF	Ministry of Agriculture & Forests
MRV	Monitoring, Reporting and Verification
MW	Megawatt
NDC	Nationally Determined Contribution
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NFP	National Forest Policy

NSB	National Statistical Bureau
PA	Protected Areas
RBP	Result Based Payment
RBS	Randomized Branch Sampling
REDD+	Reducing Emissions from Deforestation and forest Degradation and the role of Conservation, Sustainable management of forests and Enhancement of forest carbon stocks
RGOB	Royal Government of Bhutan
RPP	REDD+ Readiness Preparation Proposal
SEPAL	System for Earth Observation Data Access, Processing and Analysis for Land Monitoring
SIS	Safeguard Information System
SMF	Sustainable Management of Forest
SNC	Second National Communication
SOC	Soil Organic Carbon
SRFL	State Reserved Forest Land
t	tonne
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Degradation in developing countries
WD	Wood Density

1. Summary

As per the Warsaw Framework on Reducing Emissions from Deforestation and Forest Degradation (REDD+), countries implementing REDD+ need to have a REDD+ architecture in place consisting of a National REDD+ Strategy, a National Forest Monitoring System (NFMS), a National Forest Reference Emission Level (FREL) and/or National Forest Reference Level (FRL) and a Safeguard Information System. Developing countries are encouraged to develop a FREL and/or FRL in accordance with the national circumstances, to serve as a benchmark for assessing performance of implementation of REDD+ activities.

Bhutan has developed the FREL and FRL mainly to take stock of emissions and removals from the forest sector and set a baseline to measure future performances. The data collected is also expected to provide overall guidance for planning and implementation of activities in forestry and other relevant sectors. The FREL and FRL submission is made to strengthen Bhutan's position and commitment under its Nationally Determined Contribution (NDC) by revalidating the forest cover, instituting a system to quantify and monitor carbon stocks and establishing a benchmark for tracking its performances in terms of forest management.

Bhutan's FREL and FRL includes only four REDD+ activities which are Reducing Emission from Deforestation, Sustainable Management of Forests (SMF), Conservation of Forest Carbon Stocks and Enhancement of Forest Carbon Stocks. Carbon Pools include Above Ground Biomass (AGB), Below Ground Biomass (BGB), Dead Wood, Litter and Soil Carbon. Besides CO_2 emission, non-CO_2 emissions, namely CH_4, CO and N_2O from forest fire have also been included as CO_2 equivalent (CO_2-e).

For transparency, consistency and future reporting, separate reference levels for emission (FREL) and removal (FRL) is reported. The FREL and FRL construction followed the guidance and guidelines of Intergovernmental Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC) Decisions 4/CP.15, 1/CP.16, 12/CP.17 and 13/CP.19. The FREL for deforestation is constructed by calculating the historical average emissions from deforestation and adding an upward adjustment of 0.1% of biomass carbon applicable for countries with high forest and low deforestation and adjustment from delayed emission from soil. Bhutan being a developing country and country with high forests and low deforestation, an adjustment for FREL construction was required and is justifiable. The adjustment was determined based on assessment of the national circumstances and future projections of developmental activities in the country.

The total annual historical emission from the deforestation is 159,781 tCO_2-e yr^{-1}, the 0.1% adjustment from biomass carbon is 335,331 tCO_2-e yr^{-1} and adjustment from delayed emission from SOC is 10,725 tCO_2-e yr^{-1}. Therefore, the proposed FREL for Bhutan is 505,837 tCO_2-e yr^{-1}.

The total average annual net sequestration from SMF, Conservation and Enhancement is -8,539,085 tCO_2-e yr^{-1}. Therefore, the proposed FRL for Bhutan is -8,539,085 tCO_2-e yr^{-1}.

The historical data used to construct the national FREL and FRL are result of the large and successful efforts in implementing conservation and sustainable management of forest in the past. The data, therefore, allow the country to objectively demonstrate the positive contribution to global climate change mitigation objectives.

Further, the benchmark set by the FREL and FRL demonstrates that the continuation of the efforts to maintain the status-quo can be considered as a good performance and positive contribution to mitigation of global climate change.

2. Introduction

Reducing Emissions from Deforestation and Forest Degradation and the role of Conservation of Forests Carbon Stock, Sustainable Management of Forests (SMF) and Enhancement of Forest Carbon Stocks in developing countries (REDD+) was negotiated under the United Nations Framework Convention on Climate Change (UNFCCC) to reduce carbon dioxide (CO_2) emissions and enhance sequestration through five activities; i) reducing deforestation, ii) reducing forest degradation, iii) conservation of forest carbon stock, iv) sustainable management of forest and v) enhancement of forest carbon stock.

The 19th Conference of the Parties (COP) to the UNFCCC completed the guidance for REDD+, known as the Warsaw REDD+ Framework. As per this Framework, countries implementing REDD+ need to have a REDD+ architecture in place consisting of a National REDD+ Strategy, a National Forest Reference Emission Level (FREL) and/or National Forest Reference Level (FRL), a Safeguards Information System (SIS) and a National Forest Monitoring System (NFMS). Developing countries are encouraged to develop a FREL and/or FRL, in accordance with the national circumstances, to serve as a benchmark for assessing performance of implementation of REDD+ activities. A country which undertakes only actions to reduce emissions from the forest sector, by controlling deforestation and forest degradation, will be using a FREL as the benchmark to assess its performance. The term FRL is generally used when a country undertakes actions both to reduce emissions and to increase removals by increased carbon sequestration by its forests. In the case of Bhutan, both terms are used; the FREL is used to describe the benchmark for emissions, and the FRL is used to describe the benchmark for removals.

In response to the Warsaw REDD+ framework, Bhutan has developed the FREL and FRL mainly to take stock of emissions and removals from the forest sector and set a baseline to measure future performances. The data collected is also expected to provide overall guidance for planning and implementation of activities in forestry and other relevant sectors. Therefore, Bhutan would like to submit its national FREL and FRL to the UNFCCC in accordance with Decision 12/CP.17 and 13/CP.19 and its Annex.

3. National Context

Bhutan has a geographical area of 38,394 square kilometer and is characterized by fragile mountainous ecosystems with elevation ranging from about 130 m.a.s.l in the foothills to over 7,500 m.a.s.l in the North; within a distance of 170 km from the northern to the southern border. Bhutan has a wide geographic diversity contributing to diverse climatic conditions, making it a rich repository of biological diversity and ecosystems. The topographical and climatic features of the whole country result in a mosaic of watersheds with wide array of ecosystems and rich biodiversity, making Bhutan part of the Himalayan global biodiversity hotspot (Mittermeier et al., 2004). Forests provide various ecosystem goods and services which are important source of livelihood and national development.

Environmental conservation constitutes an important part of Bhutan's national planning strategic framework and has always enjoyed a high priority on the country's development agenda. Bhutan`s protection and conservation of the environment and the safeguarding of forest and wildlife is ensured under the Constitution of the Kingdom of Bhutan (RGoB, 2008). The Constitution directs every Bhutanese citizen to protect the environment and natural resources. The Constitution of the Kingdom of Bhutan (2008) under Article 5, Section 3 mandates Bhutan to maintain 60% forests cover for all the time (RGoB, 2008). Over the years, a set of strong laws and policies have evolved to ensure the protection, management and sustainable use of forests (RGoB, 2010). These legislations are essentially geared towards contributing to the Gross National Happiness (GNH) - the central development concept for Bhutan. This unique and singular commitment with strong legitimacy, long-term policies and approaches of sustainable management of forest and utilization are in line with the vision of REDD+ mechanism. This positions the country as a strong candidate to be recognized for its past and present actions and continued financial support for conservation of its forest for various ecosystem goods and services.

As per the development priorities, forest management in Bhutan has evolved over the years with management approach gradually shifting from a primary focus on protection and conservation towards balancing conservation with sustainable management and utilization in the context of climate change and livelihoods. To operationalize the provisions of the Constitution, the National Forest Policy of Bhutan, 2011 (RGoB, 2011) defines the overarching goal of sustainable management of forest resources, and biodiversity conservation for meeting the long-term needs of people. The Forest and Nature Conservation Act of Bhutan1995 (FNCA) provides a legal framework for appropriate forest uses, social and community forestry programs (RGoB, 1995). The Forest and Nature Conservation Rules and Regulations of Bhutan (FNCRR), 2017 (RGoB, 2017b) cover general aspects of managing State Reserved Forest Land (SRFL) and defines detailed management requirements for Forest Management Units (FMU), Community Forests (CFs), Protected Areas (PA), watersheds and Local Forest Management Area (LFMA). About 51.44 % of the country's total area is managed under the PA network system, while some forests are managed under FMU (around 5%), CFs (804 number), and LFMA (49 number). The remaining forests not covered under above management regimes are managed as per FNCRR, 2017. PA focuses on the conservation of biological diversity and integrated conservation development for the people residing within the parks. FMUs are the areas prescribed for sustainable timber harvesting based on sustainable forest management plans. CFs are managed by the local communities for meeting their requirement for forest produce. All areas outside these existing management regimes are being brought under LFMA and other silvicultural interventions. Timber harvesting in forest areas without any management plan is done using single tree selection following the scientific principle of forest management as required under FNCRR, 2017 (RGoB, 2017b).

Considering that the goal of the REDD+ mechanism is in line with the conservation efforts and the sustainable forest management practices of Bhutan, the REDD+ program was formally initiated in 2010. Bhutan envisages that REDD+ implementation could contribute to Bhutan's sustainable development through improved management of forest resources, forest law enforcement and governance. Bhutan is currently implementing actions described under the REDD+ Readiness Preparation Proposal (R-PP).

At the 15th COP of UNFCCC in 2009, Bhutan made a commitment to remain carbon neutral. Bhutan's Nationally Determined Contribution (NDC) reaffirmed the commitment by ensuring to maintain the GHG emissions below the sink capacity of its forests with support from global community. Hence, forest conservation and management are the cornerstone of fulfilling Bhutan's carbon neutrality commitment. The NDC emphasizes the importance of adaptation and mitigation for Bhutan's forests, given future climate change impacts on its mountainous ecosystems. Specifically, the NDC focuses on ensuring sustainable management of forest and institutionalization of a NFMS. REDD+ can contribute to the forest component of the NDC and to the overall development philosophy of GNH.

The FREL and FRL submission is made to strengthen Bhutan's position and commitment under its NDC by revalidating the forest cover, instituting a system to quantify and monitor carbon stocks and establishing a benchmark for tracking its performances in terms of forest conservation and management based on national circumstances. Further, REDD+ serves to renew Bhutan's vision and commitment to the conservation and sustainable management of its forest resources.

4. Definition of Forests

The National Forest Policy (NFP) of Bhutan 2011 (RGoB, 2011) and FNCRR, 2017 (RGoB, 2017b) defines forests as "land with tree spanning more than 0.5 ha with trees higher than 5 meter and a canopy cover of more than 10 percent". This definition of forest is used for development of the FREL and FRL for Bhutan.

This definition of forests is consistent with the criteria thresholds of 2006 Intergovernmental Panel on Climate Change's (IPCC) forest definition (Good Practice Guidance) (IPCC, 2006a) and UNFCCC decision 11/CP.17. It is also consistent with definition of forest adopted for National Forest Inventory (NFI) of Bhutan (FRMD, 2016), Land Use and Land Cover (LULC) mapping of Bhutan (FRMD, 2017) and technical definition of forest adopted in Global Forest Resources Assessment (FAO, 2015a).

5. Scale

Bhutan has decided to submit a national level FREL and FRL pursuant to the decision 12/CP.17. Having FREL and FRL at the national level, avoids the issue of internal displacement or leakage (Angelsen *et al*., 2011; Hirata *et al*., 2012; Meridian Institute, 2011) of emissions and facilitates the assessment of the impact of national-level policies and measures. The NFI and LULC data used in this report are generated and available at the national level. Therefore, development of FREL and FRL at sub-national level as an interim measure for Bhutan is neither justified nor necessary.

6. FREL and FRL Historical Reference Period

The historical reference period for Bhutan is for 10 years from 2005-2014. This historical period is further divided into 2 contiguous periods (2005-2009, 2010-2014). The reference period has been decided based on the Forest Carbon Partnership Facility (FCPF) Carbon Fund Methodological Framework 2016 (FCPF, 2016) and freely available land use and land cover datasets.

7. Scope (Activities, Pools, Gases)

7.1 REDD+ Activities

Bhutan's FREL and FRL includes four REDD+ activities: Reduced Deforestation; Sustainable Management of Forests (SMF); Conservation of Forest Carbon Stocks; and Enhancement of Forest Carbon Stocks. It does not include Reduced Forest Degradation, however, all carbon fluxes from the forest are covered through these four REDD+ activities. Definitions and rationale for inclusion and exclusion of these activities are as follows:

7.1.1 Deforestation

The definition of deforestation is adopted from the National Forest Policy of Bhutan (RGoB, 2011) which defines deforestation as "clearing an area of forest on a non-temporary basis for another use". Forest areas which are temporarily un-stocked as a result of human intervention such as harvesting or natural causes but which are expected to revert back to forest are not considered as deforestation.

Therefore, conversion of forest land to any other land category, including land with tree cover not meeting minimum threshold of 10% canopy cover, 0.5 ha and 5 meter height is considered as deforestation for the purposes of this FREL and FRL.

This definition of deforestation is consistent with the IPCC's Good Practice Guidance (IPCC, 2006a) which states that deforestation is "the direct human-induced conversion of forested land to non-forested land". Small patches of cleared lands, forest areas which are temporarily un-stocked as a result of human intervention such as harvesting or natural causes are expected to revert back to forest and hence not considered as deforestation.

The patches of forest loss not detected by satellite imageries (e.g. farm roads, narrow power transmission lines) are also not included in deforestation.

7.1.2 Forest Degradation

Forest degradation is considered as source of greenhouse gas (GHG) emissions resulting from activities in forest remaining as forest i.e. that does not result in a land use change. Bhutan's Drivers of Deforestation and Degradation study (DD) (WMD, 2017) considered the timber harvested from forests as a source of degradation. However, according to the definitions of SMF and conservation referred in section 7.1.3. and 7.1.4, all emissions resulting from timber harvesting (degradation) in any forest type are accounted under these two activities. Therefore, forest degradation is not included as a separate activity in this FREL and FRL.

7.1.3 Sustainable Management of Forests

The definition of SFM is adopted from the NFP, 2011 (RGoB, 2011), which is "to manage Bhutan's forests for sustainable production of economic and environmental goods and services and to meet the long-term needs of society". In operational terms, SMF concerns all forest land remaining forest outside the PA. PA shall mean the area under National Parks, Wildlife Sanctuaries and Strict Nature Reserve.

7.1.4 Conservation of Forest Carbon Stocks

In the NFP 2011, nature conservation is defined as the means 'to maintain species persistence and ensure long-term sustainability of Bhutan's biodiversity, ecosystem services and natural habitats through a network of PA and management of other parts of the forest landscape for positive environmental outcomes'(RGoB, 2011). In the context of this FREL and FRL, conservation of carbon stocks concerns forest remaining forest inside the PA.

7.1.5 Enhancement of Forest Carbon Stocks

Enhancement of forest carbon stock is defined as the establishment of forest on land which was not previously forested, or which had earlier been converted from forest to other land use. In the context of this FREL and FRL, afforestation and reforestation are considered as the enhancement of forest carbon stocks.

7.2 Carbon Pools included in the FREL and FRL of Bhutan

All carbon pools are included for the development of FREL and FRL (*Table 1*).

Table 1: Carbon pools considered for FREL and FRL

Sl. No	Pools	Definitions	Justification	Data Sources
1	Above Ground Biomass (AGB)	All biomass of trees, saplings, shrubs, and herbs.	AGB is major carbon pool with biomass density of 269.32 t ha^{-1} and represent 53.64 % of total forest carbon stock.	National Forest Inventory Report (FRMD, 2018)
2	Below Ground Biomass (BGB)	Live root biomass of trees and saplings	The biomass density of BGB is estimated to be 73.34 t ha^{-1} and constitute 13.08 % of the carbon stock.	National Forest Inventory Report (FRMD, 2018)
3	Dead Wood (DW)	Coarse woody debris	Biomass density of DW is 6.44 t ha^{-1} and constitute 1.32 % of carbon stock.	National Forest Inventory Report (FRMD, 2018)
4	Litter	Litter	Biomass density of litter is 13.25 t ha^{-1} and constitute 2.84 % of forest carbon stock	National Forest Inventory Report (FRMD, 2018)
5	Soil Organic Carbon (SOC)	Organic carbon in mineral and organic soils up to 30cm depth	SOC is 64.07 t ha^{-1} and constitute 29.12 % of carbon stock and it is second largest carbon pool for Bhutan.	National Forest Inventory Report (FRMD, 2018)

7.3 Gases included in the FREL and FRL

Besides CO_2 emission, non-CO_2 emissions, namely CH_4, CO and N_2O from forest fire have also been included in this FREL and FRL as CO_2 equivalent. Non-CO_2 emissions constitute about 43% of emissions during the reference period, which is significant.

8. Data and Methods

Historical emissions from deforestation are estimated through analysis of remote sensing data. Deforested area estimated for the reference period is spatially explicit. Historical emissions from Conservation of Forest Carbon Stocks and SMF are estimated using timber harvested records for the reference period, maintained with Department of Forests and Park Services (DoFPS). Historical removals for Conservation of Forest Carbon Stocks and SMF are estimated based on biomass increment in forest land remaining forest. The historical removals from enhancement of carbon stock is estimated using the plantation record and biomass growth for natural forest. The biomass increment and growth rate are derived from the NFI data. Non-CO_2 emissions from forest fire are estimated using the forest burnt area record and IPCC default emission and combustion factor.

8.1 Deforestation

8.1.1 Activity Data

In order to generate the activity data for deforestation, all available national land use and land cover (LULC) datasets were examined and consolidated. At the moment, Bhutan has three national LULC datasets; namely Land Use Planning Project (LUPP) 1995 (MoA, 1995), Land Cover Mapping Project (LCMP) 2010 (MoAF, 2010) and Land Use Land Cover (LULC) 2016 (FRMD, 2017). All three LULC datasets were derived from different satellite imageries with different methodology. LUPP 1995 was based on aerial photo and SPOT imageries, LCMP 2010 was derived from ALOS Imageries and LULC 2016 was based on Landsat 8. Therefore, due to data inconsistency, national LULC datasets were not used to generate activity data. The possibilities of using different global datasets (**Error! Reference source not found.**) were explored to generate activity data. Stepwise flow chart for generation of activity data is described in *Figure 1*.

Table 2: List of LULC Data assessed for Activity Data generation of Bhutan

Product	Producer	Resolution	Classes	Forest Types	Tree Canopy Cover	Year
LUPP 1995	MoAF, Bhutan	10m, 20m, VHR	13	5	0-100	1995
LCMP 2010	MoAF, Bhutan	10m	16	5	-	2010
LULC 2016	MoAF, Bhutan	30m	12	4	-	2016
CCI	ESA	300m	38	18	0-15-40-100	1992-2016
GLC	China	30m	10	1	0-100	2000 & 2010
GFC TC	UMD	30m	-	-	0-100	2000
GFC LY	UMD	30m	0-1	-	-	2000-2017

Taking the reference period and spatial resolution of satellite image into consideration, it was found that the Global Forest Change (GFC) product (Hansen *et al*., 2013) produced by University of Maryland most suitable for Bhutan to generate the activity data. The GFC dataset has annual tree cover loss for 2000 to 2016, tree canopy cover percentage in 2000 and gain for the period 2000-2012 at the pixel level. In order to align the pixel level analysis with definition of forest in Bhutan, fine scale level information on disturbance (pixel level gain and losses) were aggregated to the minimum mapping unit resulting larger scale element. The process was executed within a systematic grid by down sampling the product to reach the minimum mapping unit (Stibig *et al*., 2016).

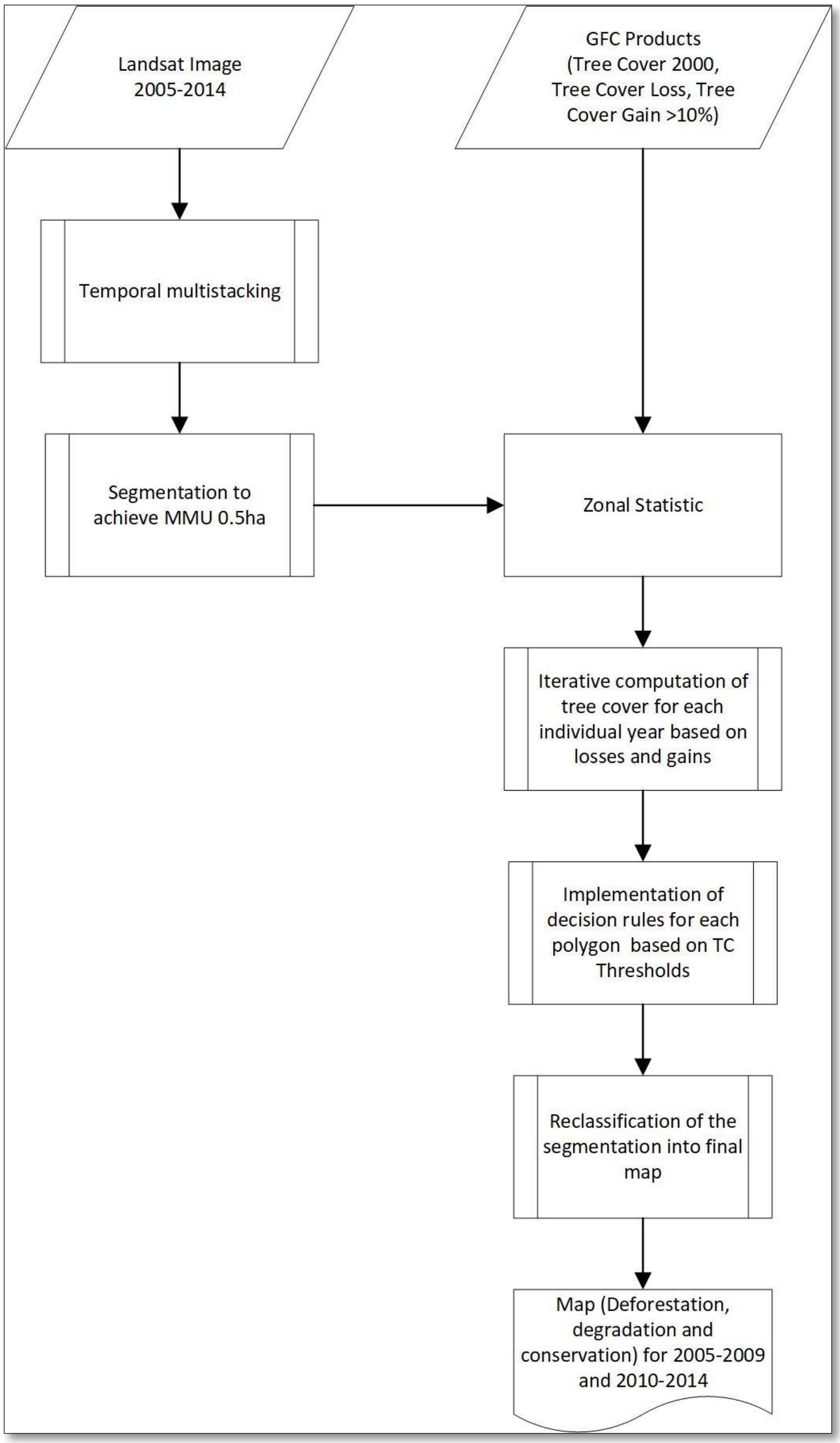

Figure 1: Deforestation activity data generation flow chart

Two multi-temporal layers were created by stacking Landsat imageries of 2005-2009 (Landsat 7) and 2010-2014 (Landsat 7 & 8). The segmentation for the two multi-layer stacked image was carried out in eCognition v.9.2 to achieve the minimum mapping unit of 0.5 ha. The yearly loss GFC dataset was combined with multi- temporal segmentation using zonal statistics to produce information at the polygon level. This process was executed in SEPAL (FAO, Rome) through a decision tree, using full set of available libraries.

The iterative computation of data for the tree canopy cover for each year was based on the following formula. Since the gain in GFC is available only for the whole period (2000-2012), the changes were assumed to be equally distributed between the different years.

$$TreeCover_{n+1} = TreeCover_n - Losses_{n+1} + \frac{Gain}{14} \quad \text{(Equation 1)}$$

8.1.1.1 Sampling Design

This methodological component encompasses sample size determination and allocating the overall sample size to each of the map classes. The target standard error for overall accuracy was α = 0.01 and the expected user's accuracy for each class was 50%, the most conservative estimate of user accuracy. The resulting overall sample size is 450 samples with minimum sample size of 50 samples per class. The samples for each class were spatially distributed using a stratified random sampling approach.

Points for loss and gains were carefully assessed through a visual assessment using a time series of Landsat images, vegetation indices and very high-resolution imagery available in the Google Earth and Bing Maps, all assessed using the Open Foris Collect Earth interface. The change was further verified using archived forestry clearance data from annual Forestry Facts and Figures maintained by the DoFPS.

Only points with a high level of confidence of land use change were applied for estimating the area. Collect Earth (CE) is one of the tools that was developed by Food and Agriculture Organization of United Nations (FAO) under the Open Foris Initiative where software tools are open source and freely available. Open source software allows any party to verify the assessment conducted and, therefore, improves the transparency of REDD+ process.

Within the CE, the point samples were assessed for land use conversion based on IPCC categories (Bey et al., 2016) (*Figure 2*). Two land use change maps for the period 2005-2009 and 2010-2014 (*Figure 3* and *Figure 4* respectively) was developed and area of change were estimated for the reference period.

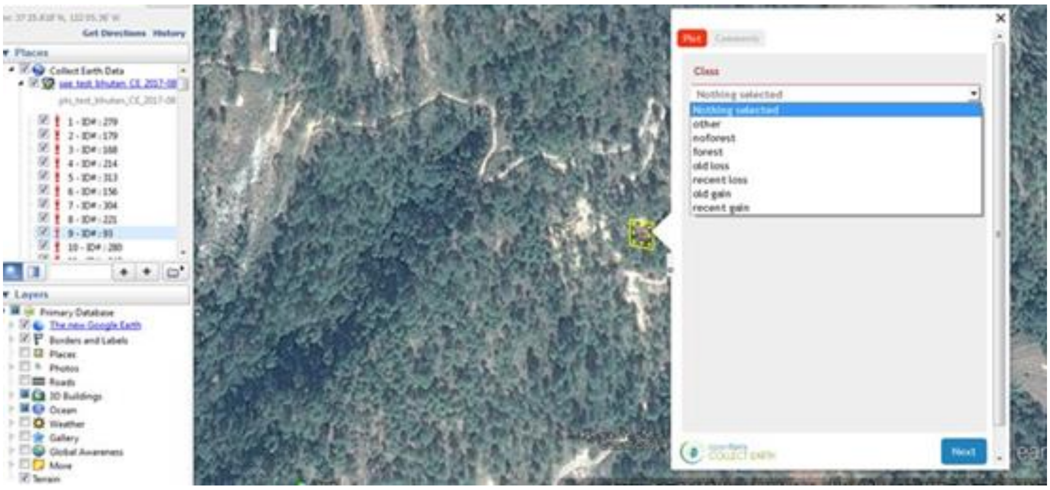

Figure 2: Validation of data products in Collect Earth

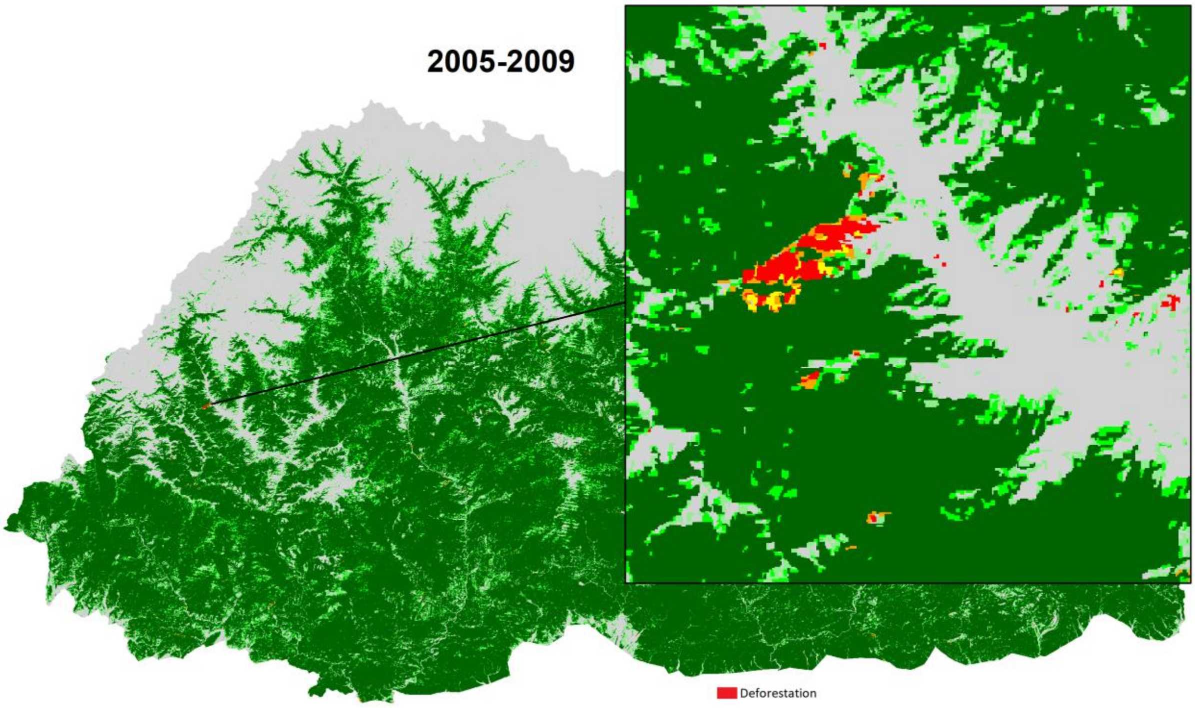

Figure 3: Deforestation Map (2005-2009)

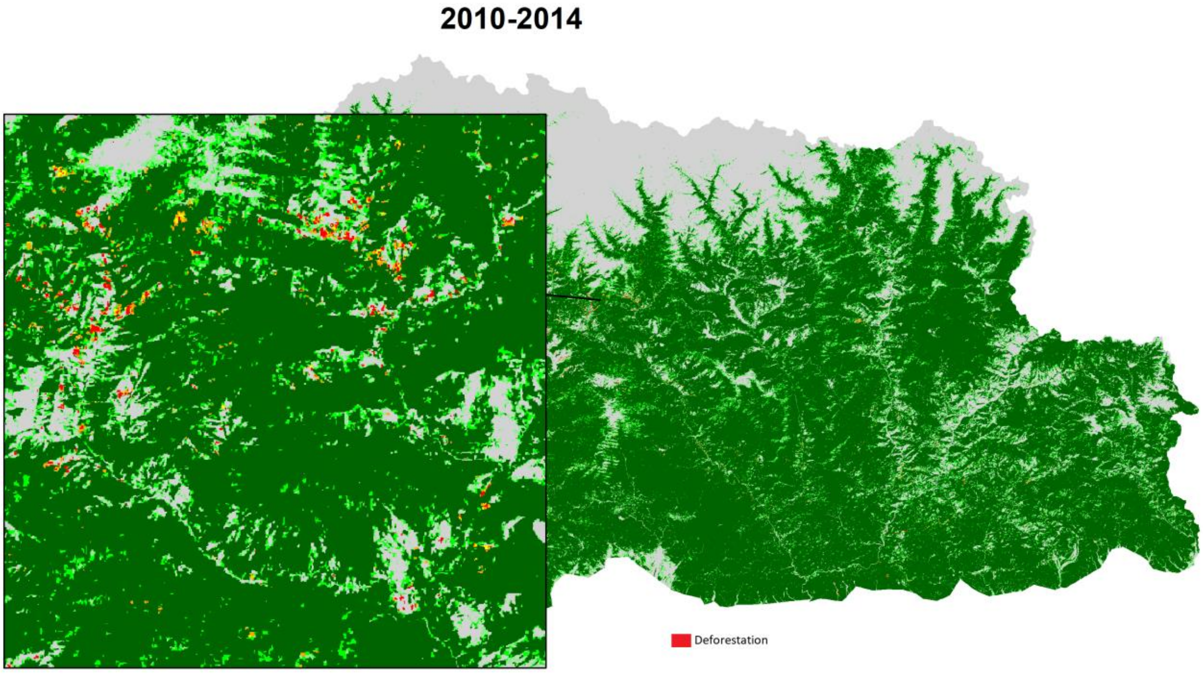

Figure 4: Deforestation Map (2010-2014)

8.1.1.2 Accuracy Assessment of the Maps

The overall accuracy of the map and area estimates was carried out using the STRATIFIED AREA ESTIMATOR-ANALYSIS tool in SEPAL. The scientific background for the accuracy assessment methodology can be found in the publication on good practices for estimating area and assessing accuracy of land change (Olofsson et al., 2014).

An error matrix was used to compare the map classes against the reference data. The overall accuracy of the map is calculated by dividing the samples where the map and reference data agree (the bold sample counts in diagonal) divided by the total number of samples (sum of sample counts in all cells in the matrix). The overall map accuracy for 2005-2009 and 2010-2014 is 70% and 72% respectively.

8.1.1.3 Stratified Area Estimation

According to IPCC, it is good practice to produce emission estimates which: 1) neither over- nor underestimate actual emissions as far as can be judged, introducing a systematic error (or bias), and 2) reduce uncertainties as far as practicable given national circumstances. It is also good practice to quantify uncertainties and report them in a transparent manner.

Classification errors were identified by collecting sample point data. The sample data verifies whether the classification is correct or incorrect at the location of the sample points. Based on the verification and validation of sample points, the STRATIFIED AREA ESTIMATOR – ANALYSIS tool in SEPAL estimates the bias corrected area of deforestation, referred to as stratified area estimates (*Table 3* and *Table 4*) and average annual deforested area in *Table 5.*

Table 3: Biased corrected estimate of deforested area (2005-2009)

Forest land converted to	Samples	Proportion	Area estimates (ha)
Cropland	4	0.13	125.00
Grassland	10	0.33	312.47
Settlement	10	0.33	312.47
Other land	6	0.20	187.48
	30	**1.00**	**937.42**

Table 4: Biased corrected estimate of deforested area (2010-2014)

Forest land converted to	Samples	Proportion	Area estimates (ha)
Cropland	3	0.17	272.34
Grassland	4	0.22	363.12
Settlement	7	0.33	607.11
Other land	5	0.28	453.90
	19.00	**1.00**	**1696.47**

Table 5: Average Annual Deforested Area (ha) during reference period

Forest land converted to	2005-2009 (ha)	Annual Average (ha)	2010-2014 (ha)	Annual average (ha)
Cropland	125.00	25.00	272.34	54.47
Grassland	312.47	62.49	363.12	72.62
Settlement	312.47	62.49	607.11	121.42
Other land	187.48	37.50	453.90	90.78
Total	**937.42**	**187.48**	**1696.47**	**339.29**

8.1.1.4 Estimated Deforestation Area vs. GFC Forest Loss Area

It was found that area of forest loss indicated by GFC was much higher than the deforestation area estimated through STRATIFIED AREA ESTIMATOR-ANALYSIS tool in SEPAL.

Majority of the agriculture land and alpine grassland were misclassified as forests in the GFC (*Figure 5* and *Figure 6*).

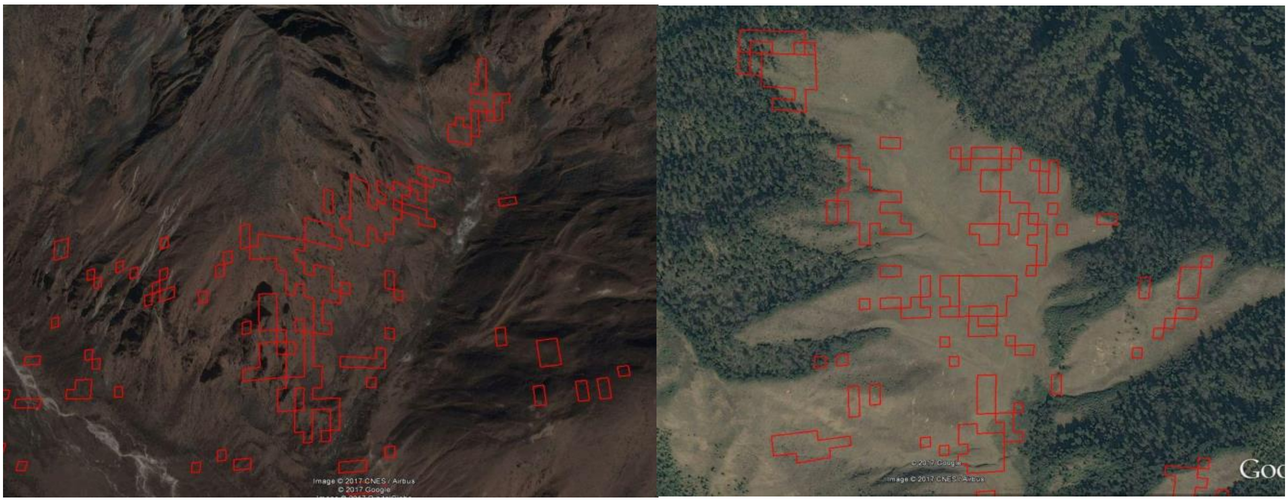

Figure 5: GFC misclassification of alpine grassland as forests in Bhutan

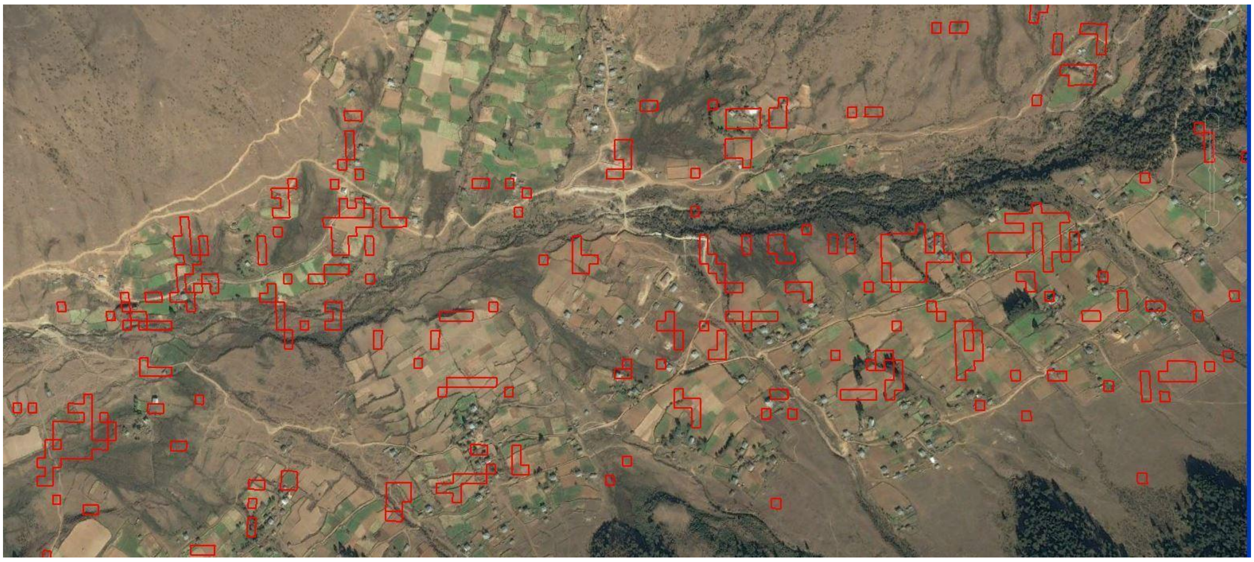

Figure 6: GFC misclassification of permanent agriculture land as forests in Bhutan

8.1.2 Emission Factors

Emission factors (EF) for deforestation was mainly estimated using methodological guidance provided by the Global Forest Observations Initiative (GFOI) which defines deforestation as the change of forest land to other land category (GFOI, 2016). In IPCC terms, the possibilities of Forest Land replacing land uses are Cropland, Grassland, Wetlands, Settlements or Other Land (GFOI, 2016). The change in biomass/carbon density from forest land to each of the other land categories were estimated using the corresponding methodological guidance available under IPCC latest guidelines 2006GL (IPCC, 2006b). Generally, the following equation was used for estimating the emission factor for each land conversion category.

$$\hat{\mu}_{EF} = \hat{\mu}_B - \hat{\mu}_A \qquad \text{(Equation 2)}$$

Where, $\hat{\mu}_B$ and $\hat{\mu}_A$ represents biomass carbon density for land before conversion and for land after conversion respectively.

The emission of SOC is calculated as difference between SOC density in forest land and forest land converted to corresponding different land category. In absence of land category specific SOC density for Cropland, Settlement, Grassland and Other Land, the SOC density for new land use category was estimated using IPCC default stock change factor and 20 years transition period (IPCC, 2006b). The soil emission is estimated using the following equation, which is an adaptation of equation 2.25, Chapter 2, Volume 4 of IPCC 2006 (IPCC, 2006b).

$$SOC_{emission} = \frac{SOC_{Forest} - SOC_{non-forest}}{20_{years}} \qquad \text{(Equation 3)}$$

Emissions from deforestation in the year in question are, therefore, the sum of conversions that occurred in the current year. EF for each conversion category has been estimated as shown in the *Table 6*.

Table 6: Emission factor for forest land converted to other land categories

Initial land category	**Final land Category**	**EF (tCO_2 equivalent with SOC)**	**EF (t CO_2 equivalent without SOC)**
Forest Land	Cropland	626.45	624.45
Forest Land	Grassland	483.32	482.96
Forest Land	Settlement	626.80	624.45
Forest Land	Other Land	636.20	624.45

The difference in the EF between Forest Land converted to Cropland, Settlement and Other Land, and; Forest Land converted to Grassland is due to the assumptions made for the two conversions. In case of conversion from Forest land to Cropland, Settlements and Other Land, it was assumed that there would be complete loss of biomass carbon, which includes AGB of trees, shrubs and herbs, BGB, litter and DW.

In case of conversion from Forest land to Grassland, no loss of biomass of shrubs, herbs, DW and BGB is considered. The carbon transfer matrix on land conversion is provided in Annexure I. Due to lack of data on carbon stock transfer between the carbon pools, the same EF is applied to SMF and Conservation.

Emissions from all carbon pools have been considered for Bhutan's proposed FREL and FRL and the estimates of biomass/carbon density are generated from plot level measurements of the NFI of Bhutan. The EF for a land conversion category has been multiplied with corresponding area of change to estimate the total emission. The 14 species-specific models and two general models have been applied onto the plot measurements of trees to estimate the AGB carbon density of trees (list of equations provided in Annexure II). For the other carbon pools (herbs, shrubs, litters and SOC), about 20% of the 2,424 NFI plots were systematically sub-sampled for actual collection of samples. The collected samples were oven-dried in the laboratory for calculating the dry matter and analyzed for organic carbon content for soil samples.

The summary of sampling design of the NFI, tree biomass allometric model development process, estimation of biomass and carbon are discussed below:

8.1.2.1 Sampling Design of the National Forest Inventory

The NFI of Bhutan has systematic sampling design with sample plots laid at 4 km by 4 km grid. The design for the NFI was determined through two technical exercises. Exercise I was the remote sensing exercise, wherein classification of land into forests and non-forests was done using Land Cover Map of Bhutan from the Land Use Planning Project (MoA, 1995). The forests were then classified into homogenous categories of forest types.

In Exercise II, the data of forest resource inventory plots (approximately 4,500 plots of 0.05 ha) from 13 FMU were referred for determining the sampling intensity required for achieving 15% Margin of Error at 90% confidence level at Geog level[1]. The sampling intensity was thus used to estimate the total number of cluster plots, which came to 26,935 cluster plots at 1.2 km systematic spacing. However, considering the human resource and financial limitations, it was decided on 4 km by 4 km grid as NFI framework, following numerous consultations with experts from within the DoFPS, the School of Forestry and Environmental Studies of Yale University and the US Department of Agriculture-Forest Service. This framework allows one sample location for every 160 ha and comes to 2,424 cluster plots covering all land cover classes as decided by the stakeholders during the Data User Consultation Workshop held in January, 2009. This framework will provide reliable estimates at 15% Margin of Error for basal area at 90% confidence level at Dzongkhag[2] and greater precision at the national level (FRMD, 2012).

At each plot location, the inventory plot consisted of cluster of 3 circular plots on an L-shaped transect spaced 50 m apart. These circular plots are referred to as Elbow Plot, North Plot and East Plot as shown in Figure 7.

Each circular plot is of 12.62 m radius with an area of 0.05 ha for collecting tree and sapling data. A circular plot of 3.57 m radius was laid inside the Elbow Plot for regeneration data, and circular plot of 0.57 m radius was laid in North and East Plot for collecting herb data with same plot center.

A separate plot for the understory carbon assessment was laid at 20 m south-west of the Elbow Plot (Figure 7). It consisted of 5 m by 5 m square plot for shrubs and 1 m by 1 m square plot within it for herbs. Both shrubs and herbs falling within the plots were harvested and bagged for laboratory analysis for dry matter.

Litter falling within the 20 cm by 20 cm square plot were also collected. Soil samples were excavated to a depth of 30 cm using 10 cm by 10 cm by 10 cm soil frame.

Only 20 percent of the total 2,424 plots were systematically sub-sampled for forest understory carbon assessment.

[1] Geog is the smallest administrative unit
[2] District

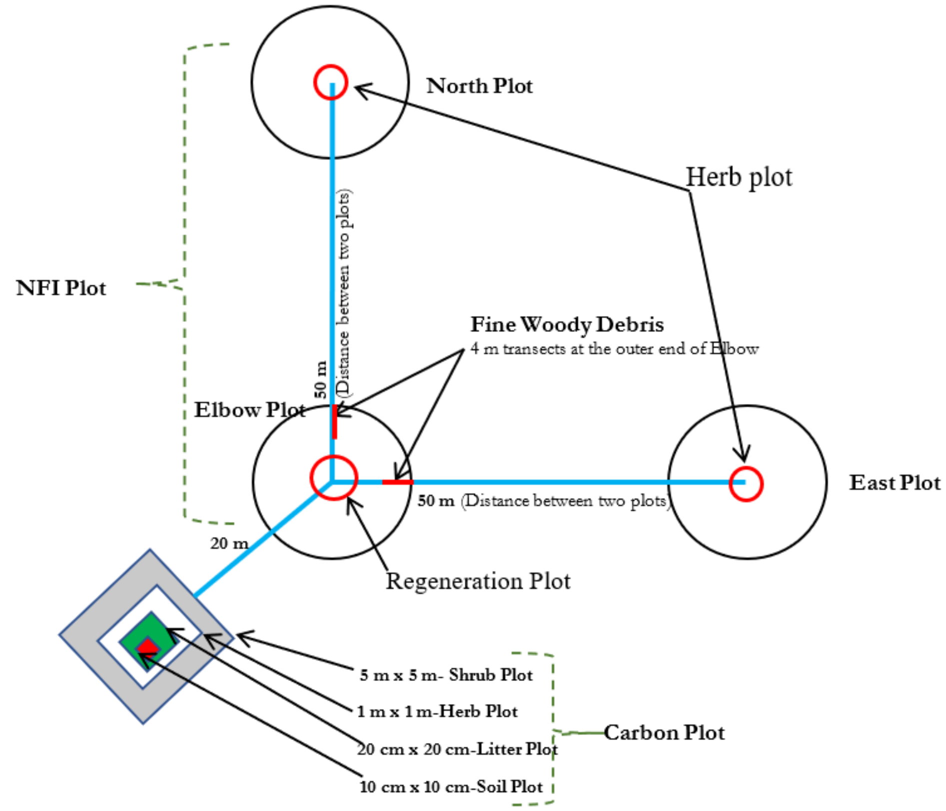

Figure 7: NFI Sampling Design

8.1.2.2 Allometric Model Development

Eight number of samples per species spread across the diameter class was selected from each region (Eastern, Western, Southern and Central region) and thus a minimum of 32 trees was selected for each of the 14 tree species and destructively sampled. The list of biomass model is provided in Annexure II. For each destructively sampled tree, two discs from the bole through stratified random sampling and other segment/parts of tree along the pathway defined by randomized branch sampling (RBS) technique were collected and brought to the laboratory for oven drying.

The dry weights of the samples were used for fitting the regression model for the 14 tree species. Two mixed species model; one for conifer and another for broadleaf was developed and applied to species without species specific biomass model.

For all 14 species and the two mixed species data, total tree biomass was found best predicted by the basal area of the tree in cubic spline model as shown below.

$$g(X_1) = (X_1 - t_1)^3 - (X_1 - t_2)^3 \times \left(\frac{t_3 - t_1}{t_3 - t_2}\right) + (X_1 - t_3)^3 \times \left(\frac{t_2 - t_1}{t_3 - t_2}\right) \qquad \text{(Equation 4)}$$

Where, X_1 =basal area (Ba), X_2=g(X_1), and t_1, t_2 and t_3 corresponds to the knots at 10th, 50th and 90th quantiles of the X_1(Ba) values.

8.1.2.3 Estimating Carbon Density

The aboveground biomass density of trees and saplings was estimated by applying the biomass models on to the NFI tree and sapling data, while the aboveground understory vegetation biomass, mainly, shrubs and herbs was estimated based on the oven-dried weights of the samples taken from the NFI plots.

BGB was estimated for the trees and saplings at stand level following the formula described in equation 5 (Mokany et al., 2006):

$$BGB = 0.489 * AGB^{0.89} \qquad \text{(Equation 5)}$$

Coarse woody debris (CWD) biomass was estimated from the NFI CWD data following Gregoire and Valentine (2007). The methodology estimates inclusion probabilities per piece and expands them from the line to the hectare level. National wood density values (UNIDO, 1994) was applied to estimate the biomass of the CWD sampled during the NFI which was further multiplied by a correction factor that assumes a wood degradation of level 2.

SOC density is estimated from the NFI soil samples that were analyzed for the organic carbon content in laboratory.

Biomass density was converted to carbon density using carbon fraction of 0.47 (IPCC 2006 given in Table 4.3 of 2006 IPCC Guidelines for Forest Land) and, biomass and carbon density for each carbon pools are provided in *Table 7*.

Table 7: Biomass and carbon density of carbon pools

Biomass/carbon pool	t d.m. ha^{-1}	t C ha^{-1}	Margin of Error (%)
Aboveground Biomass	269.32	127.10	6.4
Belowground Biomass	74.34	34.47	4.01
Dead Wood (Coarse Woody Debris)	6.44	3.03	46.5
Litter	13.25	6.23	15
Soil Organic Carbon (Forest land)	NA	64.07	4.2
Soil Organic Carbon (Non forest land)	NA	57.95	6.8

8.1.3 Estimating Emission from Deforestation

As per GFOI methodological guidance, the total emission from deforestation is estimated by multiplying the forest land converted into non-forest land by EF. Table 8 and 9 shows emission during two reference period of 2005-2009 and 2010-2014 respectively.

$$\text{Emission} = \text{Activity Data x Emission Factor} \qquad \text{(Equation 6)}$$

Table 8: Total Emission from Deforestation during the period 2005-2009

a) Emission due to biomass carbon loss

Initial land category	Final land Category	Activity data (ha)	Emission Factor (tCO_2-e ha^{-1})	Total emission ($t\ CO_2$-e)
Forest Land	Cropland	124.99	624.45	78,048.97
Forest Land	Grassland	312.47	482.96	150,912.26
Forest Land	Settlement	312.47	624.45	195,122.42
Forest Land	Other land	187.48	624.45	117,073.45
	Total	**937.41**		**541,157.09**

b) Emission due to change in SOC stock[3]

Initial land category	Final land Category	Activity data (ha)	Emission Factor ($t\ CO_2$-e ha^{-1})	Total emission ($t\ CO_2$-e)
Forest Land	Cropland	124.99	1.997	748.88
Forest Land	Grassland	312.47	0.35	329.95
Forest Land	Settlement	312.47	2.35	2,201.84
Forest Land	Other land	187.48	11.75	6,607.13
	Total	**937.41**		**9887.78**

Table 9: Total emission from deforestation during 2010-2014

a) Emission due to biomass carbon loss

Initial land category	Final land Category	Activity data (ha)	Emission Factor ($t\ CO_2$-e ha^{-1})	Total emission ($t\ CO_2$-e)
Forest Land	Cropland	272.33	624.45	170,064.32
Forest Land	Grassland	363.12	482.96	175,375.65
Forest Land	Settlement	607.12	624.45	379,109.70
Forest Land	Other land	453.90	624.45	283,440.53
	Total	**1,696.48**		**1,007,990.21**

b) Emission due to change in SOC stock[4]

Initial land category	Final land Category	Activity data (ha)	Emission Factor ($t\ CO_2$-e ha^{-1})	Total emission ($t\ CO_2$-e)
Forest Land	Cropland	272.34	2.00	2,879.78
Forest Land	Grassland	363.12	0.35	933.35
Forest Land	Settlement	607.11	2.35	7,947.96
Forest Land	Other land	453.90	11.75	27,006.40
Total		**1,696.47**		**38,767.49**

[3] The SOC loss is estimated using 20 years transition period and total emission report is not exact product of AD and EF.

[4] The SOC loss is estimated using 20 years transition period and total emission report is not exact product of AD and EF.

8.2 Sustainable Management of Forests

SMF includes all emissions associated with wood extraction (Table 10) and removals through growth and increment in areas outside the PA network in forest remaining forest. These areas are mainly managed scientifically as FMU, CFs and LFMA. The timber harvesting in areas not yet managed under these forest management regimes are still regulated through the Forest and Nature Conservation Act of Bhutan, 1995 (RGoB, 1995) and Forest and Nature Conservation Rules and Regulations of Bhutan, 2017 (RGoB, 2017b) under the principles of sustainability.

The timber harvested from the aforementioned management regimes were considered as degradation (WMD, 2017). However, since all the harvesting are based on the principles of sustainability, it does not result in net reduction in long term biomass/carbon density and are accounted under SMF and conservation of forest carbon stock (Section 8.3). The short-term reduction in biomass density through extraction of timber is replenished through incremental growth and regenerations.

Table 10: Volume of timber extracted from SMF area

Timber Type	Timber Harvest Volume (m^3)	
	2005-2009	2010-2014
Broadleaf	401,320.17	364,583.76
Conifer	601,980.25	546,875.64

8.2.1 Emission and Removal from SMF

The method for estimating carbon stock changes in biomass for SMF is based on the gain loss method using equation 2.7, Chapter 2, Volume 4, IPCC 2006

$$\Delta C_B = \Delta C_G - \Delta C_L \qquad \text{(Equation 7)}$$

Where ΔC_B is annual change in carbon stock in biomass, ΔC_G is the gain through annual increase in carbon stock due to biomass growth, and ΔC_L is the annual decrease in carbon stock due to biomass loss.

8.2.1.1 Annual Decrease in Carbon Stock from Timber Harvesting

Emissions from timber harvesting is calculated using adapted equation 2.12, Chapter 2, Volume 4, IPCC 2006 with the assumption that there are no changes in BGB.

$$SMF_{Timber\_emission} = H \times WD \times BEF \times CF \times 44/12 \qquad \text{(Equation 8)}$$

Where, $SMF_{Timber\_emission}$ is emission from SMF in tCO_2, H is the volume of harvested timber (m^3), WD is wood density (tm^{-3}), CF is carbon fraction of 0.47 and BEF is biomass expansion factor.

BEF is estimated using biomass data collected for development of species-specific biomass models used in calculation of AGB. Two BEF, one for conifer and another for broad-leaved timber were developed using the Equation 9.

$$BEF = \frac{W_{aboveground}}{W_{bole}} \qquad \text{(Equation 9)}$$

Where, BEF is biomass expansion factor (dimensionless), $W_{aboveground}$ is total AGB of tree (kg) and W_{bole} is bole biomass (kg).

The BEF for conifer is estimated at 1.29 and BEF for broadleaf is at 1.83.

The average wood density of 0.623 tm^{-3} and 0.483 tm^{-3} for broadleaf and conifer species respectively (UNIDO, 1994) is applied to Equation 8. The biomass and emissions from timber harvested are presented in Table 11 and 12 respectively.

Table 11: Biomass loss from the timber harvest (SMF)

Timber type	**Biomass (t d.m.)**		
	2005-2009	**2010-2014**	**Total**
Broadleaf	457,704.42	716,573.50	1,174,277.92
Conifer	375,777.77	341,379.48	717,157.26
Total	833,482.20	1,057,952.98	1,891,435.18

Table 12: Emission from timber harvest (SMF)

Timber type	**Emission CO_2-e (t d.m.)**		
	2005-2009	**2010-2014**	**Total**
Broadleaf	788,777.29	716,573.50	1,505,350.79
Conifer	647,590.36	588,310.65	1,235,901.01
Total	1,436,367.65	1,304,884.15	2,741,251.80

8.2.1.2 Annual Decrease in Carbon Stock through Forest Fire

Forest fire is one of the major forests disturbances factors in Bhutan. The area of forest damaged by fires has been recorded and published by the DoFPS annually. Forest fire is usually prevalent in SMF area and non-CO_2 emission from fire is accounted under this activity.

Non-CO_2 emission from forest fire is included under SMF and not under deforestation, as forest fire doesn't lead to permanent land use change. Non-CO_2 is estimated using adapted Equation 2.27, IPCC 2006, Vol.4, and Chapter 2 (Equation 10).

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3} \qquad \text{(Equation 10)}$$

Where,

L_{fire} is the amount of GHG emission from fire tonnes of each GHG (e.g. CH_4, N_2O);
A is the area burnt, ha;
M_B is mass of fuel available for combustion, t/ha;
C_f is combustion factor, dimensionless; and
G_{ef} is emission factor, (g/kg) dry matter burnt.

Forest fire burnt area for reference period is obtained from annual forest fire statistics maintained by DoFPS. M_B is obtained from NFI estimates, C_f is from Table 2.6 (All "other" temperate forests), and G_{ef} for Extra Tropical forests from Table 2.5 of IPCC 2006 is applied to Equation 10.

Non-CO_2 emission are converted into CO_2 equivalent, using Global Warming Potential (GWP) Table 8.7, Chapter 8, Anthropogenic and Natural Radiative Forcing, IPCC AR 5 (IPCC, 2014). Table 13 shows area affected by forest fire while Table 14 and 15 shows combustion factor, emission factor, GWP and GHG emissions for two reference period of 2005-2009 and 2010-2014 respectively.

Table 13: Forest area burnt during reference periods

Activity data	**Area burnt (ha)**	
Forest area burnt	**2005-2009**	**2010-2014**
	39,512.49	36,415.77

Table 14: Non-CO_2 emission during 2005-2009 from fire

Particulars	**CO**	**CH_4**	**N_2O**
Biomass	267.00	267.00	267.00
Combustion factor	0.45	0.45	0.45
Emission factor	107.00	4.70	0.26
Global Warming Potential	1.80	28.00	265.00
Emission (t CO_2-e)	**914,354.25**	**624,761.26**	**327,097.65**

Table 15: Non-CO_2 emission during 2010-2014 forest from fire

Particulars	**CO**	**CH_4**	**N_2O**
Biomass	267.00	267.00	267.00
Combustion factor	0.45	0.45	0.45
Emission factor	107.00	4.70	0.26
Global Warming Potential	1.80	28.00	265.00
Emission (t CO_2-e)	**842,693.34**	**575,796.69**	**301,461.95**

The total emission from SMF is the sum of emission from timber harvest and non-CO_2 forest fire (Table 16).

Table 16: Total emission (t CO2-e) from SMF (2005-2014)

Parameters/reference period	**Emission (t CO_2-e)**	
	2005-2009	**2010-2014**
Emission from Timber Extraction	1,436,367.650	1,304,884.145
Emission from fire	1,866,213.224	1,719,951.922
Total Emission	3,302,580.874	3,024,836.067

8.2.1.3 Removal from SMF

The removal (carbon sequestration) in SMF is estimated based on the forest area under SMF area. The removal from SMF is calculated using equation 2.9, Chapter 2, Volume 4 of IPCC 2006 (Equation 11).

$$SMF_{Removal} = A_{smf} \times G_{mean} \times CF \times 44/12 \qquad \text{(Equation 11)}$$

Where, $SMF_{Removal}$ is removal by SMF ($tCO_2\ yr^{-1}$), A_{smf} is the area under SMF (ha), G_{mean} is mean annual biomass increment ($t\ d.m\ ha^{-1}yr^{-1}$), CF is carbon fraction and 44/12 is CO_2-e fraction.

The A_{smf} and annual biomass growth of 2.01 t. d.m. $ha^{-1}\ yr^{-1}$ from NFI and carbon fraction of 0.47 is applied to Equation 11. The total removals from SMF is described in Table 17.

The A_{smf} for each year of reference period is derived through interpolation (FAO, 2018) of forest area using four land use and land cover data sets for the year 1990, 2000, 2010 (Gilani *et al*., 2015) and 2016 (FRMD, 2017) generated from Landsat images.

Table 17: Removal from SMF

Reference period	Removal (tCO_2-e)	Removal (tCO_2-eyr^{-1})
2005-2009	-33,515,934.37	-6,703,186.87
2010-2014	-32,220,601.16	-6,444,120.23
Total	-65,736,535.53	-13,147,307.10

8.3 Conservation of Forest Carbon Stock

Conservation of forests carbon stocks concerns forest remaining forest inside the PA. PA includes area under National Parks, Wildlife Sanctuaries and Strict Nature Reserve. PA constitute 51.44% of the country area and provides opportunity for long term conservation of forest carbon stocks. As per the FNCRR (RGoB, 2017b), any form of commercial harvesting of timber is prohibited inside the PA. Although the PA network is primarily managed for biodiversity conservation, in Bhutan's context, there are local communities residing within the area. People residing within the PA are granted user right over timber and other resources with approved permit system for their bonafide domestic use. Timber is harvested on selection or thinning basis in accordance with FNCA 1995 and FNCRR, 2017 (RGoB, 1995, 2017b) as part of habitat management.

Therefore, timber harvested for meeting the requirements of local residents are considered as source of emission from the conservation areas and are estimated and reported.

The carbon stock changes in biomass for conservation area is estimated using Equation 7 as described in section 8.2.1 for SMF.

8.3.1 Annual Decrease in Carbon Stock from Timber Harvested from the Conservation Area

The emission resulting from timber harvesting in conservation is calculated using adapted equation 2.12, Chapter 2, Volume 4 of IPCC 2006 (Equation 12) on the assumption that there is no change in below ground biomass. The quantity of timber harvested within conservation area over the reference period is based on the official record maintained with the DoFPS.

$$Conservation_{Emission} = H \times WD \times BEF \times CF \times 44/12 \qquad \text{(Equation 12)}$$

Where, $Conservation_{Emission}$ is emission from conservation in tCO_2, H is the volume of harvested timber (m^3), WD is wood density ($t\ m^{-3}$), CF is carbon fraction and BEF is biomass expansion factor. Values for BEF and Wood density is same as the values taken for SMF under section 8.2.1.1. Table 18 and 19 shows the biomass loss and emission from timber harvested respectively in conservation.

Table 18: Biomass loss from the timber harvest in conservation

Timber type	Biomass (t d.m.)		
	2005-2009	**2010-2014**	**Total**
Broadleaf	65,725.41	57,926.58	123,652.00
Conifer	53,960.92	47,558.04	101,518.96
Total	119,686.34	105,484.62	225,170.96

Table 19: Emission from timber harvest in conservation (2010-2014)

Timber type	Emission (tCO_{2}-e)		
	2005-2009	**2010-2014**	Total
Broadleaf	113,266.80	99,826.81	213,093.61
Conifer	92,992.66	81,958.36	174,951.02
Total	206,259.46	181,785.17	388,044.63

8.3.2 Removal from conservation

The removal (carbon sequestration) from conservation was estimated using equation 2.9, Chapter 2, Volume 4 of IPCC 2006 (Equation 13).

$$\text{Conservation}_{\text{Removal}} = A_{con} \times G_{mean} \times CF \times 44/12 \qquad \text{(Equation 13)}$$

Where, $\text{Conservation}_{\text{Removal}}$ is removal from Conservation ($t\ CO_2\ yr^{-1}$), A_{con} is the forest area under conservation (ha), G_{mean} is mean annual biomass increment ($t\ d.m\ ha^{-1}yr^{-1}$), CF is carbon fraction and 44/12 is CO_2-e fraction. A_{con} and average annual biomass growth of 2.01 t d.m. $ha^{-1}\ yr^{-1}$ from NFI is applied to Equation 13.

The A_{con} for each year of reference period is derived by interpolation (FAO, 2018) of forest area using four land use and land cover datasets for the year 1990, 2000, 2010 (Gilani *et al*., 2015) and 2016 (FRMD, 2017) generated from Landsat images. The detail estimate of removal from conservation activity is given in Table 20.

Table 20: Removal from conservation

Reference year	Removal (tCO_2-e)	Removal (tCO_2-eyr^{-1})
2005-2009	-12,116,130.40	-2,423,226.08
2010-2014	-14,161,386.35	-2,832,277.27
Total	-26,277,516.76	-5,255,503.35

8.4 Enhancement of Forests Carbon Stock

In order to maintain consistency with the GHG reporting and not to omit any significant activities, Bhutan estimates the sequestration of carbon from afforestation and reforestation (plantation).

Bhutan has been carrying out afforestation since the establishment of DoFPS with plantation records dating back to 1950's. The total area of afforestation carried out within the reference period and 20 years prior to start of reference period was obtained from data maintained with DoFPS. The total area of successful afforestation was computed based on its survival percentage at respective plantation site.

8.4.1 Removal from Enhancement of Forest Carbon Stock

Plantations require certain time to establish as forests. The default transition period, prescribed by IPCC (2006), of 20 years was used. The annual biomass growth rate of 2.01 t d.m. ha^{-1} yr^{-1} derived from NFI data was applied to estimate the CO_2 removal through land converted to forest. Equation 14 is used for estimating carbon sequestration from plantations.

$$\text{Plantation}_{tCO2\text{-}e} = (\text{Age of plantation (yr)} \times \text{Biomass growth (t d.m } ha^{-1}yr^{-1})$$
$$\times \text{ Successful Plantation (ha)} \times .047 \times 44/12) \qquad \text{(Equation 14)}$$

A total of 3,675.54 ha was planted over the reference period, of which 1,826.84 ha were successful, indicating an overall survival rate of 49.7 %. The details of cumulative survived plantation area for reference period is given in Table 21 while Table 22 shows removal by plantations. Plantation area from 1985 to 2014 is provided in Annexure III and detail calculations in Annexure IV.

Table 21: Successful plantation area (2005-2014)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Successful plantation area (ha)	2,914.24	2,543.76	2,625.11	2,614.78	2,192.01	2,332.01	,2715.82	2,816.52	2,959.33	2,920.32

Table 22: CO_2 Removals by plantations during 2005-2014

Reference Period	Enhancement	
	Total removal (tCO_2)	Annual removal (tCO2-e yr^{-1})
2005-2009	-44,649.34	-8,929.87
2010-2014	-47,607.84	-9,521.57
Total	-92,257.18	-18,451.44

8.5 Consistency between FREL & FRL and GHG Inventory

The methodology adopted for calculation of the emission and removal for FREL and FRL is consistent with the GHG inventory report submitted in the second national communication (SNC) to UNFCCC. However, the emission factor used in FREL and FRL is combination of Tier 1 and Tier 2 approach while it is entirely Tier 1 approach in SNC. The consistency in terms of method and data use will be maintained for future GHG inventories.

9. FREL and FRL Construction Approach

For transparency, consistency and future reporting, separate reference levels for FREL (emission) and FRL (removal) is developed considering the national circumstances.

9.1 Bhutan's National Circumstances and the Increasing Pressure on Forest Resources

Considering the fact that Bhutan has minimal long-term historical deforestation across the country, the deforestation rate is likely to underestimate the future rate of deforestation. Therefore, Bhutan assessed its national circumstances to explore whether an adjustment would be appropriate.
Bhutan has a unique position, as a developing country with a very high forest cover and a past history of limited deforestation. Bhutan has rich species diversity with highest fraction of land under PA networks (51.44 %), as well as the highest proportion of forest cover (71%) amongst any Asian nation (FRMD, 2016, 2017; MoAF, 2009).

However, with growing population and economic development, there is growing pressure on forests and natural resources. Rural development is a national priority and effort to reduce timber extraction and deforestation may result in trade-offs with economic development and poverty alleviation.

Bhutan continues to evolve into a modern economy with an average economic growth rate of 5% (2012 – 2016). It follows a five-year socio-economic development planning cycle starting with the 1st Five Year Plan (FYP) in 1961. The FYPs articulate the socio-economic development priorities and programs of the country. The 12th FYP (2018-2023) with a theme of "Just, Harmonious and Sustainable Society through enhanced Decentralization" recognizes the importance of improving productive capacity of the economy and prioritizes economic diversification as one of the 17 National Key Result Areas (RGoB, 2017a). With the expected commissioning of three new hydro-electricity projects during the 12th FYP, the total proposed outlay (Nu. 300 billion) is 39.3% more than 11th FYP, indicating more developmental activities in the 12th FYP period (2018-2023). Further, the 12th FYP will also see the implementation of the Bhutan's Economic Development Policy (EDP) of 2016 (RGoB, 2016b). The EDP is the overriding policy document that sets the agenda for economic development of the country, with the aim to double the economic growth rate from 5% to 10% by 2020. The EDP focuses on five priority sectors known as "Five Jewels" which are hydropower, agriculture, cottage & small industries, tourism and mining. The focus on developing the five jewels which were identified as the major drivers of deforestation (WMD, 2017) will again lead to further loss of forests. The Land Act of Bhutan 2007 also allows for both leasing and allotment of SRFL for different purposes.

Since historic baselines are not adequate to capture future risk of forest loss, this section presents evidences supporting the argument that future development will be much greater than what was recorded during the Reference Period (2005-2014). The projection of annual emission of CO_2 from various activities are calculated as per Equation 15.

$$Emission = Area * EF \qquad \text{(Equation 15)}$$

Where

Emission is CO_2 emission from expected forest loss;
Area is the area expected to be lost due to various developmental activities; and
EF is the emission factor of the subsequent land use change from section 8.1.3 for biomass carbon loss

9.1.1 Population Growth

Population has been increasing over the years with the increase in life expectancy due to availability of free health care services, increasing literacy rates and improvement of health facilities. The population of Bhutan increased from 634,982 in 2005 (NSB, 2005) to 779,666 in 2016 (NSB, 2017) with the population growth rate of 1.8 %. The increase in population is rapid in urban areas due to rural to urban migration, which led to construction booms and expansion of urban area. This exerts immense pressure on forests resulting in loss of forest area and depletion of forest resources. As observed in other parts of the world, increasing population is correlated with higher deforestation rate. Hence, in Bhutan, deforestation rates in the future is likely to increase because of growing population.

9.1.2 Allotment of State Reserved Forests Lands (SRFL)

Under various planned programs, the Government allots SRFL for developmental activities such as agriculture, hydropower, roads, mining, and transmission lines which are the major drivers of deforestation in the country (WMD, 2017). Based on the figures from 2008-2014, around 28,845 ha (approximately 1,923 ha annually) of forest is projected to be allotted for various purposes (excluding hydropower, transmission lines and roads) between 2015 and 2030 (WMD, 2017). The annual loss of 1,923 ha of forests, would result in emission of 1,200,817 tCO_2 (Table 23).

However, the records maintained with the DoFPS, shows that during the last three years (2015, 2016 and 2017), the actual annual average allotment of SRFL for various purposes is around 2,800 ha (DoFPS, 2015, 2016, 2017b) which is much higher than the predicted allotment of SRFL (1,923 ha).

9.1.3 Hydropower

The Bhutanese economy is mainly driven by hydropower. Bhutan has an estimated hydropower potential of 30,000 megawatt (MW) (DHPS, 2008) of which 23,760 MW is techno-economically feasible (World Bank, 2007). Development of hydropower is estimated to remain a top priority into the future, given development plans underway. Based on the average forest area loss of 0.5 ha for every MW of hydropower capacity developed, the development of all planned hydropower plants with potential of 18,380 MW could result in the loss of about 39,760 ha of forest (WMD, 2017). This is a conservative estimate as the forest loss due to the construction of transmission lines and power grids is not included. The planned construction of 600 MW hydropower project in 12th FYP would result in loss of 300 ha of forests and emission of 37,467 tCO_2 annually (Table 23).

9.1.4 Roads

The road infrastructure is also linked to other development priorities such as hydropower projects, urban and rural area developments. Road access is intended to improve social services and economic prospects by linking almost every village in the country. In order to provide road access to rural areas for market and development access, expansion of the road network will continue in the country (RGoB, 2013). The road network across the country increased from 4,392 km in 2005 to 5,982 km in 2009 to 12,348 km in 2016 (NSB, 2004, 2007, 2017). In the 12th FYP, there are plans to upgrade existing national highways and build new roads to hydropower projects, Dzongkhags (districts) and villages. Approximately 1,200 km of farm roads are planned to be constructed during the 12th FYP. Taking 5 m standard width of farm road (RGoB, 2009), total area of about 600 ha of forest is expected to be cleared resulting in emission of 74,994 tCO_2 annually (Table 23). This is a conservative estimate as forest loss due to construction of national highways and widening of existing roads are not included in estimated emission. During the period from 2015 – 2017, an average of about 3,895 ha of SRFL was allotted annually for construction of roads (DoFPS, 2015, 2016, 2017a) and it is projected that about 4,100 ha of forests will be lost between 2015 and 2020 and up to 12,300 ha by 2030 due to road construction (WMD, 2017).

9.1.5 Agriculture

Agriculture is one of the most important sectors in the economy, contributing 16.8% of GDP, employing around 59.4% of the population, and accounting for 4.3% of exports (RGoB, 2013, 2016b). The government places agriculture at the centre of the development agenda. The sector's growth is insufficient to address poverty issues, food security and sustained GDP growth (RGoB, 2013). Thus, the 12th FYP prioritizes investments in boosting the enabling environment for increased agriculture production (RGoB, 2017a). Currently, only around 3% of total land is under agriculture cultivation (MoAF, 2011). The planned focus to boost agricultural production will lead to expansion of agriculture areas which might exert pressure on forest land. The trend for commercial agriculture is increasing as evident from the large number of applications for forest land lease. It is projected that about 3,890 ha between 2015 and 2020, and up to 11,670 ha by 2030 would be lost due to conversion of forest land to agriculture (WMD, 2017).

9.1.6 Mining

Mining is one of the fastest growing industries in the country with a growth rate of 17% in 2014 and contributing about 3.4% to GDP(NSB, 2016). National Land Commission data from 2009-2014 indicates that the highest demand for land lease was for mining at 1,550 ha (RGoB, 2016a). It is reasonable to expect that mining will continue to exert pressure on forest resources and deforestation is expected to increase in the future. Assuming the rate of forest area lost due to mines and quarries in the period 2008-2014 continues, deforestation is predicted to be about 3,165 ha between 2015 and 2020, and up to 9,495 ha by 2030. The annual loss of 633 ha of forest will result in emission of 395,278 tCO_2 annually.

9.1.7 Allotment of Forest Resources

Forest resources, in the form of timber, firewood or non-wood forest products, are sustainably harvested for domestic consumption. As per the FNCRR 2017, every household in the rural areas is entitled for round wood of 4,000 cft (≈113 m^3) for house construction once in 25 years and 700 cft (≈20 m^3) for repair/renovation/extension once in 12 years (RGoB, 2017b). With increasing trend of rural households (NSB, 2003, 2007, 2012, 2017), the allotment of forest resources is expected to increase. As per the records with the DoFPS, the total annual average timber allotted (commercial & concessional) from the year 2015 – 2017 is 315,432.58 m^3 (DoFPS, 2015, 2016, 2017b).

Firewood is an important source of energy and contributes about 34% of total energy consumed in the country (Gyeltshen, 2015). According to Dhital (2009), the major categories of firewood consumers are: residential, i.e., both rural and urban; institutions including hotels, schools, restaurants, industries, and agriculture. In the short and medium term, firewood will continue to be the main source of energy, and is readily available in most parts of the country. Based on historical trends, about 424,680 m^3 between 2015 and 2020, and up to 1,274,041 m^3 by 2030 will be harvested for firewood (WMD, 2017).

9.1.8 Forest Fire

Forest fire is common phenomenon in Bhutan, particularly in winter seasons and largely occurs in conifer forest. Statistics shows both increasing number of fire incidences and extent of fire. For instance, between 2015 and 2017, about 136 fire incidences were recorded, which burnt approximately 19,992 hectares of forests (DoFPS, 2015, 2016, 2017b). Forest fire incidences is likely to continue under projected warmer and drier future climate (NCHM, 2017). The country's rugged terrain, coupled with limited firefighting equipment and capacity, will affect fire control and suppression.

Assuming that the annual average forest area damaged by fires (6,260 ha) continues under future climates, about 93,800 ha of forest is predicted to be damaged between 2015 and 2030 (WMD, 2017).

9.2 Proposed Adjustment

In summary, based on the assessment of national circumstances and development projections (section 9.1.1-9.1.8), future emissions from deforestation are predicted to increase to around **1,708,495 tCO_2** annually in the next 5 years (2018 – 2023) (Table 23), which is significantly higher than the historical average. While the historical deforestation rate is 0.01%, the deforestation rate is expected to increase to 0.10 as a result of the increased pressure from development activities (Table 23). This is below the regional rate of deforestation, which was 0.24% for Asia for the period 1990-2015 (FAO, 2015a). The projections do not include possible increases in emissions from agriculture, forest fires and harvesting of timber and firewood and thus can be considered as conservative estimate. The projected emission from planned activities in 12th FYP is described in Table 23.

Table 23: Total projected emission from various developmental activities in the 12th FYP

Activities	Area (annual) (ha)	Emission Factor (t CO_2 ha^{-1})	Annual emission (tCO_2)
SRFL allotment	1,923	624.45	1,200,817.03
Hydropower	60	624.45	37,466.99
Roads	120	624.45	74,933.98
Mining	633	624.45	395,276.74
TOTAL	**2,736**		**1,708,494.74**

However, Bhutan honours the limit proposed by the FCPF Methodological Framework (FCPF, 2016) and Green Climate Fund (GCF) Results-Based Payment (RBP) pilot programme and associated scorecard (GCF, 2017). The FCPF Methodological Framework allows a High Forest, Low Deforestation (HFLD) country to apply an annual upward adjustment of 0.1% of the total forest carbon stock over their average annual historical emissions (FCPF, 2016). Further, the GCF guidelines also allows upward adjustment of 0.1% of the total forest carbon stock spread over the results reporting period (GCF, 2017).

Table 24 shows the calculation of 0.1% adjustment from biomass carbon stock and the adjustment determined at 335,331.33 tCO_2 per annum. The adjustment is conservative estimate as the carbon from the SOC (which accounts for 29.12% of the total carbon stock) is not included in this adjustment.

Further, the delayed emission of soil from the deforestation during the reference period will overlap in the reporting period. The estimated delayed annual average emission of 10,725.21

tCO_2 (Table 24) during reporting period is taken into account as adjustment for the construction of the FREL.

Table 24: Calculation of the 0.1% adjustment for Bhutan and delayed emission from soil

Carbon Pool	Total carbon (t)
AGB	346,040,000.00
BGB	84,360,000.00
Litter	18,340,000.00
CWD	8,530,000.00
Soil	187,850,000.00
TOTAL	645,120,000.00
Only AGB, BGB, DW and litter is considered for adjustment	457,270,000.00
Conversion of carbon stock to million tCO_2 emission	1,676,656,667.00
0.1% of the carbon stock in t CO_2-e	1,676,656.67
0.1% of tCO_2 emission divided over 5 years validation	335,331.33
Delayed emission from soil	10,725.21
Total Adjustment	346,056.55

Applying the 0.1% adjustment applicable for HFLD countries under FCPF CF and GCF Methodological Framework and adjustment from delayed emission of soil, the total adjusted emissions (346,057 tCO_2) is significantly lower than the projected emission (**1,708,495** tCO_2). The comparison of emissions using regional deforestation rate, projected developmental activities based on national circumstances, average historical emission and proposed FREL with adjustment is provided in Figure 8. Therefore, an annual upward adjustment of 0.1% biomass carbon stock divided over the validation period and delayed emission from soil is justifiable and has been applied for construction of Bhutan's National FREL (Figure 9).

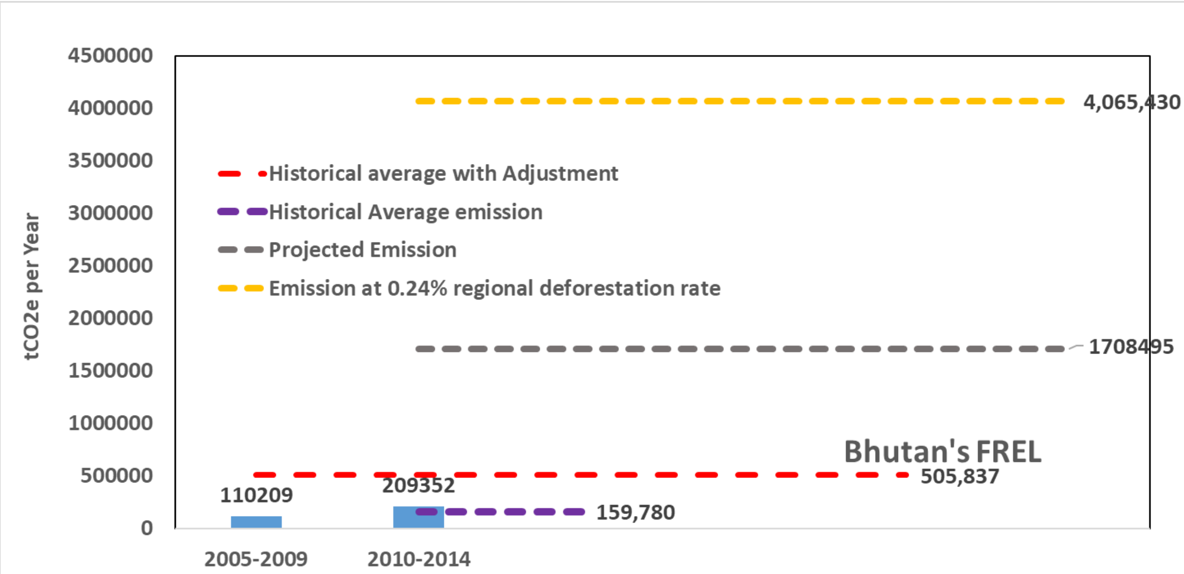

Figure 8: Historical Average emission from Deforestation and adjustment

9.3 National Level Forest Reference Emission Level

The national FREL is constructed by calculating the historical average emissions from deforestation and adding an upward adjustment of 0.1% of biomass carbon stock applicable for countries with HFLD and delayed emission from soil for deforestation occurred during reference period (Figure 9 and Table 25).

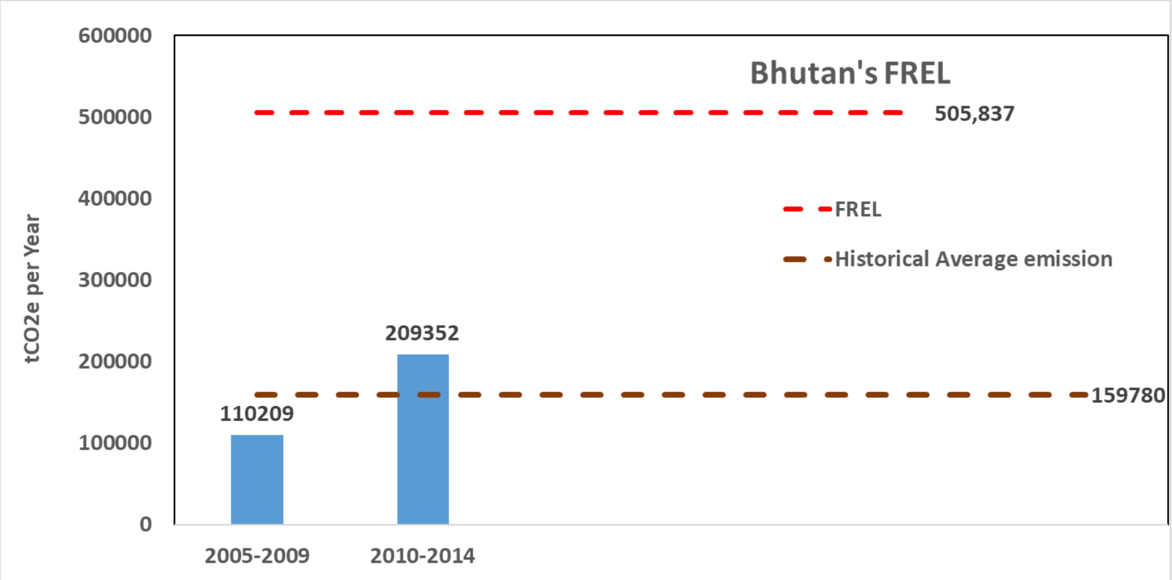

Figure 9: National FREL

Table 25: Total emission from deforestation per annum

REDD+ Activity	Reference period		Historical annual average emission	0.1% adjustment of carbon stock	Delayed soil emission	FREL (tCO_2-e)
	2005-2009	2010-2014				
Deforestation emission ($t\ CO_2$-e yr^{-1})	110209	209352	159781	335,331	10,725	**505,837**

9.4 National Forest Reference Level

The national FRL is the sum of net removal from SMF, Conservation of forest carbon stock and Enhancement of forest carbon stock. The summary of estimation of FRL is provided in Table 26 and Figure 10.

Table 26: Summary of National FRL

REDD+ Activity:	Emission (tCO_2-e yr^{-1})		Removal tCO_2-e yr^{-1})		Net Removal (tCO_2-e yr^{-1})		Historical average (tCO_2-e yr^{-1})
	2005-2009	**2010-2014**	**2005-2009**	**2010-2014**	**2005-2009**	**2010-2014**	
SMF	287,273.53	260,976.83	-6,703,186.87	-6,444,120.23	-6,415,913.34	-6,183,143.40	287,273.53
SMF-Fire	373,242.65	343,990.38			373,242.65	343,990.38	373,242.65
Conservation	41,251.89	36,357.03	-2,423,226.08	-2,832,277.27	-2,381,974.19	-2,795,920.24	41,251.89
Enhancement			-8,929.87	-9,521.57	-8,929.87	-9,521.57	
FRL (tCO_2-e yr^{-1})	-8,539,085.79						

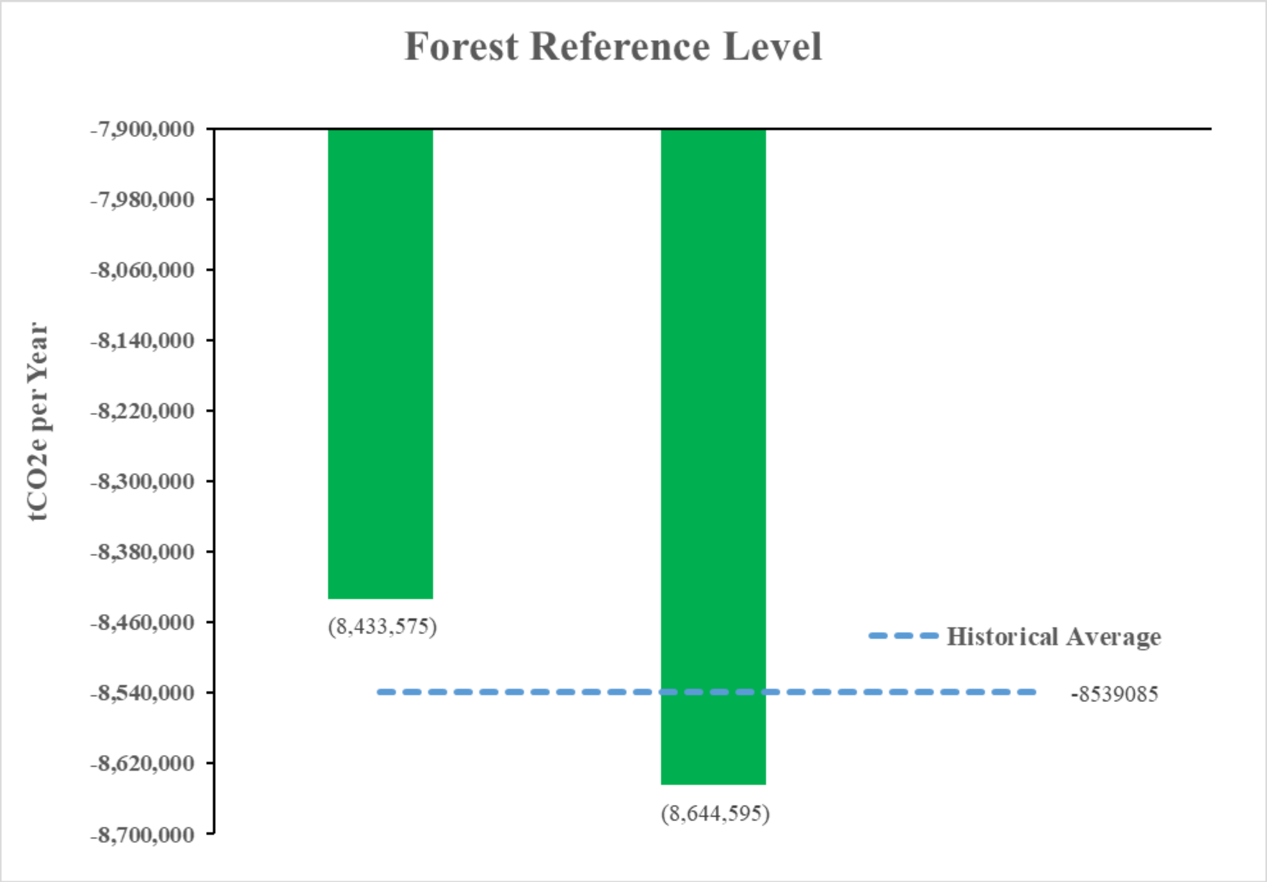

Figure 10: National FRL

10. Uncertainty Analysis

The uncertainty of the FREL and FRL is computed by error propagation method by combining uncertainty of activity data and emission factors using Equation 16.

$$U_{total} = \sqrt{U_{AD}^2 + U_{EF}^2} \qquad \text{(Equation 16)}$$

Where,

U_{total} is total combined uncertainty (%);
U_{AD} is uncertainty of the activity data (%); and
U_{EF} is uncertainty of the emission factor (%).

Equation 16 was adapted from 2019 refinement of IPCC 2006 guideline, Volume 1, Chapter 3. Further Equation 17 and 18 is applied for combining the uncertainties by addition and multiplication respectively.

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2} \qquad \text{(Equation 17)}$$

Where,

U_{total} is the percentage uncertainty in the product of the quantities (expressed as a percentage); and
U_n is the percentage uncertainties associated with each of the quantities

$$U_{total} = \frac{\sqrt{(U_1 \, x \, X_1)^2 + (U_2 \, x \, X_2)^2 + \cdots + (U_n \, x \, X_n)^2}}{(|X_1 + X_2 + \cdots + X_n|)} \quad \text{(Equation 18)}$$

Where,

U_{total} is the percentage uncertainty in the sum of the quantities and expressed as a percentage; and
X_n is quantities to be combined; X_i may be a positive or a negative number; and
U_n is the percentage uncertainties associated with each of the quantities

10.1 Combined Uncertainty of FREL

The combined uncertainty of the FREL is described in Table 27. The total emission during 2005-2009 is 551,044.87 tCO_2-e with uncertainty of 11.68%. Similarly, the total emission during 2010-2014 is 1,046,757.69 t CO_2-e with uncertainty of 36.212% for 2010-2014. The overall uncertainty of FRL is 23.95%.

Table 27: Uncertainty analysis of FREL

Emission source or sink	**Emission in each reference period**	
	2005-2009	**2010-2014**
Deforestation Biomass (t CO_2 e)	541,157.09	1,007,990.21
Deforestation SOC (t CO_2 e)	9,887.78	38,767.48
Total	551,044.87	1,046,757.69
Uncertainty (%)	11.68	36.21
Average uncertainty		**23.95**

10.2 Combined Uncertainty of FRL

The combined uncertainty of the FRL is described in Table 28. The total net removal during 2005-2009 is 42,123,271.02 t CO_2-e with uncertainty of 11.78%. Similarly, the total net removal during 2010-2014 is 43,190,722.68 t CO_2 -e with uncertainty of 11.31%. The overall uncertainty of FRL is 11.53%.

Table 28: Uncertainty analysis of FRL

Emission source or sink	**Emission/Removal in each reference period (CO_2-e)**	
	2005-2009	**2010-2014**
Sustainable management of forest - Emission	3302580.87	3024836.07
Conservation of carbon stock- Emission	206259.46	181785.17
Sustainable management of forest - Removal	-33515934.37	-32220601.16
Conservation of carbon stock- Removal	-12116130.40	-14161386.35
Enhancement	-44649.34	-47607.84
Total	-42167873.777	-43222974.117
Uncertainty (%)	11.766	11.299
Average uncertainty		**11.53**

The uncertainty for the volume of timber removed, forest area damaged by fire and plantation area are obtained by expert judgement following the procedure described by Hemming et al., 2018a; 2006 IPCC Guidelines; Hemming *et al*., 2018b; and, Protocol, G.H.G, 2003. The detail calculation of uncertainty for activity data and emission factors and their combination are provided in Annexure V.

11. Future Improvement Opportunities

The FREL and FRL of Bhutan have been developed with support from FCPF Readiness Fund of the World Bank. FREL and FRL are based on currently available national data and relevant global data. Bhutan would be improving the FREL and FRL submission in future subject to the availability of new data, methodology, technical and financial support. Following activities are identified as future improvement opportunities.

- Exploring use of high-resolution remote sensing data for generating national LULC dataset through advanced technologies and methodologies.
- Strengthening Forest Information Reporting and Monitoring System (FIRMS) database to maintain proper record of timber harvest and plantation.
- Strengthening NFI data management system.
- Reducing the inaccessible plots during the next NFI to reduce uncertainties of EF.
- Developing additional species-specific biomass allometric model.
- Modeling and mapping carbon density using remote sensing.
- Developing a spatially explicit fire burnt area maps.
- Spatial mapping of plantations with survival percent.
- Improving uncertainty estimates for activity data and EF.

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ANNEXURES

Annexure I: Land Use Change and Carbon Pool Disturbance Matrix

The carbon transfer matrix is developed to estimate the emission factor when the forest land is converted into new land use category. The table below shows the changes in the carbon pools when forest land is converted to Cropland, Settlement, Other land and Grassland. As result of this changes, the emission factors are different when forest land is converted to new land use category.

			Final Land Use			
		Carbon pool	Cropland	Settlement	Other land	Grassland
Initial Land Use	**Forest Land**	AGB_Trees	Loss	Loss	Loss	Loss
		AGB_Sapling	Loss	Loss	Loss	Loss
		AGB_Shrub	Loss	Loss	Loss	No loss
		AGB_Herb	Loss	Loss	Loss	No loss
		DOM_Litter	Loss	Loss	Loss	Loss
		Soil	Loss over 20 years (difference between SOC in FL and CL)	Loss over 20 years (difference (20% loss on paved surface) between SOC in FL and CL)	Loss over 20 years (difference between SOC in FL and CL)	Loss over 20 years (difference between SOC in FL and CL)
		DOM_CWD	Loss	Loss	Loss	No Loss
		BGB-Root	Loss	Loss	Loss	No loss

Annexure II: List of Biomass Model

The table below shows 14 species specific allometric biomass models and two general biomass models (one each for broadleaf and conifer trees) used for estimating AGB carbon.

Sl. No	Species	Equations	t1	t2	t3
1	*Abies densa*	(-5.76+3436.38*ba+36408.9*X2)	0.004562064	0.110446617	0.303648
2	*Alnus nepalensis*	(-12.3+5474*ba+1581*X2)	0.008812246	0.131185153	0.415138
3	*Castanopsis tribuloides*	1.39+5303*ba+2722*X2+4129*X3	0.007382271	0.134038	0.40222
4	*Cupressus corneyana*	(-3.96+4300*ba+50295*X2)	0.003904686	0.098999438	0.37853
5	*Juniperus recurva*	(-4.85+3234*ba+26753*X2)	0.006816078	0.075555303	0.263935
6	*Larix griffithii*	(-3.84+3455*ba+29738*X2)	0.008395906	0.131147749	0.330317
7	*Picea spinulosa*	(-6.164+3934*ba+43569*X2)	0.00664761	0.11341149	0.321234
8	*Pinus roxburghii*	(-3.44+5098*ba+56376*X2)	0.0023	0.1029	0.368529
9	*Pinus wallichiana*	(-1.57+3444*ba+55392*X2)	0.00309	0.09840699	0.394911
10	*Quercus glauca*	(-3.97+6437*ba+36970*X2)	0.006535691	0.099043421	0.374257
11	*Quercus griffithii*	(-9.38+5438*ba+15835*X2)	0.007310172	0.1321385	0.364998
12	*Quercus lanata*	(-0.77+4500*ba+25308*X2)	0.01333473	0.1418822	0.393956
13	*Rhododendron arboreum*	(-0.19+1637*ba+43190*X2)	0.006834221	0.09186331	0.207339
14	*Tsuga dumosa*	(-4.8+3854*ba+15174*X2)	0.006180612	0.138544236	0.440845
15	*General broadleaf*	(-1.06+4341*ba+30173*X2+4013*X3)	0.00664761	0.1194591	0.368977
16	*General conifer*	(-12.3+3299*ba+52756*X2)	0.004927274	0.107521009	0.369822

Where X_2 corresponds to value in X_1 as follow;

$$X_2 = g(X_1) = (X_1 - t_1)^3 - (X_1 - t_2)^3 \times \left(\frac{t_3 - t_1}{t_3 - t_2}\right) + (X_1 - t_3)^3 \times \left(\frac{t_2 - t_1}{t_3 - t_2}\right)$$

and the value of the positive part functions depend on the values of the knots as follows;

$(X_1\text{-}t_1)^3 = (X_1\text{-}t_1)^3$, if $X_1 > t1$ and $(X_1\text{-}t_1)^3 = 0$, if $X_1 < t_1$

$(X_1\text{-}t_2)^3 = (X_1\text{-}t_2)^3$, if $X_1 > t2$, and $(X_1\text{-}t_2)^3 = 0$, if $X_1 < t_2$

$(X_1\text{-}t_2)^3 = (X_1\text{-}t_2)^3$, if $X_1 > t3$, and $(X_1\text{-}t_3)^3 = 0$, if $X_1 < t_3$

Where t_1, t_2 and t_3 for the above models are 10^{th}, 50^{th} and 90^{th} percentiles and are called knots. The values of knots differ from species and models.

Annexure III: Plantation Area from 1985 to 2014 used for Estimating Enhancement of Carbon.

The area of plantation is obtained from the record maintained by DoFPS from 1985 to 2014 for estimation of carbon enhancement. The enhancement is calculated as land converted to forest land over 20 years transition period as per IPCC 2006.

Year	Plantation area survived (ha)	Cumulative Plantation Area (ha)
1985	15.2	15.2
1986	473.6	488.8
1987	28.6	517.4
1988	170.9	688.3
1989	721.8	1,410.1
1990	98.0	1,508.1
1991	44.4	1,552.4
1992	66.1	1,618.6
1993	18.4	1,636.9
1994	57.7	1,694.6
1995	152.9	1,847.5
1996	248.9	2,096.4
1997	159.9	2,256.3
1998	45.6	2,301.8
1999	77.2	2,379.0
2000	47.0	2,426.0
2001	92.9	2,518.9
2002	94.9	2,613.8
2003	62.2	2,676.0
2004	112.1	2,788.1
2005	141.3	2,914.2
2006	103.1	2,543.8
2007	109.9	2,625.1
2008	160.6	2,614.8
2009	299.0	2,192.0
2010	238.0	2,332.0
2011	428.2	2,715.8
2012	166.8	2,816.5
2013	161.2	2,959.3
2014	18.7	2,920.3

Annexure IV: Calculation of Enhancement of Forest Carbon Stock

The table below shows the calculation of enhancement of carbon sequestration from the plantation. The figures reported are in tCO_2. It is calculated as product of plantation area (Annexure III), biomass growth rate of 2.01 t d.m. ha^{-1} yr^{-1}, carbon fraction (0.47) and CO_2 fraction (44/12).

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1985	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53	-53										
1986		-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641	-1641									
1987			-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99	-99								
1988				-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592	-592							
1989					-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500	-2500						
1990						-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339	-339					
1991							-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154	-154				
1992								-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229	-229			
1993									-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64	-64		
1994										-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200	
1995											-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530	-530
1996												-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862	-862
1997													-554	-554	-554	-554	-554	-554	-554	-554	-554	-554	-554	-554	-554	-554	-554	-554	-554	-554
1998														-158	-158	-158	-158	-158	-158	-158	-158	-158	-158	-158	-158	-158	-158	-158	-158	-158
1999															-267	-267	-267	-267	-267	-267	-267	-267	-267	-267	-267	-267	-267	-267	-267	-267
2000																-163	-163	-163	-163	-163	-163	-163	-163	-163	-163	-163	-163	-163	-163	-163
2001																	-322	-322	-322	-322	-322	-322	-322	-322	-322	-322	-322	-322	-322	-322
2002																		-329	-329	-329	-329	-329	-329	-329	-329	-329	-329	-329	-329	-329
2003																			-215	-215	-215	-215	-215	-215	-215	-215	-215	-215	-215	-215
2004																				-388	-388	-388	-388	-388	-388	-388	-388	-388	-388	-388
2005																					-489	-489	-489	-489	-489	-489	-489	-489	-489	-489
2006																						-357	-357	-357	-357	-357	-357	-357	-357	-357
2007																							-381	-381	-381	-381	-381	-381	-381	-381
2008																								-556	-556	-556	-556	-556	-556	-556
2009																									-1036	-1036	-1036	-1036	-1036	-1036
2010																										-824	-824	-824	-824	-824
2011																											-1483	-1483	-1483	-1483
2012																												-578	-578	-578
2013																													-558	-558
2014																														-65
	-53	-1693	-1792	-2384	-4884	-5224	-5377	-5607	-5670	-5870	-6400	-7262	-7816	-7973	-8241	-8404	-8725	-9054	-9269	-9658	-10095	-8811	-9093	-9057	-7593	-8078	-9407	-9756	-10251	-10116

Annexure V: Uncertainty Calculation

1. Calculation of Uncertainties

The combined uncertainty of the FREL and FRL is estimated using error propagation method described in 2019 refinement of IPCC 2006 Guidelines, Volume 1, and Chapter 3. The combined uncertainty is estimated using Equation 1.

$$U_{total} = \sqrt{U_{AD}^2 + U_{EF}^2} \qquad Equation\ 1$$

Where,

U_{total} is the total combined uncertainty (%);
U_{AD} is the uncertainty of the activity data (%); and
U_{EF} is the uncertainty of the emission factor (%).

Further Equation 2 and 3 is applied for combining the uncertainties by addition and multiplication respectively.

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2} \qquad \text{(Equation 2)}$$

Where,

U_{total} is the percentage uncertainty in the product of the quantities (expressed as a percentage); and
U_n is the percentage uncertainties associated with each of the quantities.

$$U_{total} = \frac{\sqrt{(U_1\ x\ X_1)^2 + (U_2\ x\ X_2)^2 + \cdots + (U_n\ x\ X_n)^2}}{(|X_1 + X_2 + \cdots + X_n|)} \qquad \text{(Equation 3)}$$

Where:

U_{total} is the percentage uncertainty in the sum of the quantities and expressed as a percentage;
X_n is quantities to be combined; xi may be a positive or a negative number; and
U_n is the percentage uncertainties associated with each of the quantities.

2. Uncertainty of Forest Reference Emission Level

The combined uncertainty of the deforestation activity data and emission factors is estimated using Equation 3. The combined uncertainty of emission factor for mineral soil (SOC) and non-CO_2 emission factor is calculated using Equation 2 and 3. Table 1 and 2 shows the combined uncertainty of activity data during the reference period 2005-2009 and 2010-2014 respectively.

Table 1: Combined uncertainty of activity data between 2005-2009

Initial Land Use	Final Land Use	2005-2009	MoE %	Annual Average (ha)	MoE% (annual)
Forest Land	Cropland	124.99	22.51	25	22.51
Forest Land	Settlement	312.47	22.51	62.49	22.51
Forest Land	Other Land	187.48	22.51	37.5	22.51
Forest Land	Grassland	312.47	22.51	62.49	22.51
Total		937.41	11.911	187.48	11.91

Table 2: Combined uncertainty of activity data between 2010-2014

Initial Land Use	Final Land Use	2010-2014	MoE %	Annual Average (ha)	MoE% (annual)
Forest Land	Cropland	272.34	36.68	54.47	36.68
Forest Land	Settlement	607.11	36.68	121.42	36.68
Forest Land	Other Land	453.90	36.68	90.78	36.68
Forest Land	Grassland	363.12	36.68	72.62	36.68
Total		1,696.48	19.10	339.30	19.10

Table 3 and 4 shows the combined uncertainty of emission factor associated with biomass carbon and delayed emission from SOC respectively.

Table 3: Combined uncertainty of emission factor (biomass carbon)

Carbon Pool component	Carbon density (t C ha^{-1})	MOE%
Tree_AGB	113.74	5.785
Shrub_AGB	0.76	16.77
Herb_AGB	0.33	21.127
Sapling_AGB	12.22	38.462
Tree root_BGB	30.30	7.943
Sapling root_BGB	4.17	42.793
Litter	6.23	15.094
Coarse woody Debris	3.03	46.584
Total	**170.77**	**5.15**

Table 4: Combined uncertainty of SOC emission factor

Land conversion	SOC_{REF}		F_{LU}		F_{MG}		F_I		SOC_{Change}	Uncertainty combined (%)
	Mean (t C ha^{-1})	SE %	Mean	SE %	Mean	SE %	Mean	SE%		
FL-CL[5]	64.07	4.2	0.83	11	1	0	1	0	53.18	11.77
FL-GL	64.07	4.2	0.97	11	1	0	1	0	62.15	11.77
FL-SL[6]	64.07	4.2	0.8	3.36	1	0	1	0	51.26	5.38
FL-OL	64.07	4.2	0	0	0	0	0	0	0.00	4.20
Total									**166.58**	**6.01**

The combined uncertainty of the FREL is described in Table 7. The total emission during 2005-2009 is 551,044.87 tCO_2-e with uncertainty of 11.68% (Table 5). Similarly, the total emission during 2010-2014 is 1,046,757.69 t CO_2-e with uncertainty of 36.21% (Table 6). The overall uncertainty of FREL is 23.95% (Table 7).

Table 5: Uncertainty of emission from deforestation during 2005-2009

A	B	C	E	F	G	H
IPCC Category	**Gases**	**Emissions or removals**	**AD uncertainty**	**EF/ parameter uncertainty**	**Combined uncertainty**	**Contribution to variance by category**
		t CO_2 e	**%**	**%**	**%**	
					$SQRT(E^2+F^2)$	*$(GxC)^2/(TotalC)^2$*
Deforestation						
Biomass	**CO_2**	541,157.09	11.911	5.15	12.98	162.380
Soil Organic Carbon	**CO_2**	9,887.78	11.911	6.01	13.34	0.057
TOTAL		**551,044.871**			**12.745**	**162.437**
Inventory uncertainty	**%**					**12.745**

Table 6: Uncertainty of emission from deforestation during 2010-2014

A	B	C	E	F	G	H
IPCC Category	**Gases**	**Emissions or removals**	**AD uncertainty**	**EF/ parameter uncertainty**	**Combined uncertainty**	**Contribution to variance by category**
		t CO_2 e	**%**	**%**	**%**	
					$SQRT(E^2+F^2)$	*$(GxC)^2/(TotalC)^2$*
Deforestation						
Biomass	**CO_2**	1,007,990.21	19.1	5.15	19.78	1,309.334
Soil Organic Carbon	**CO_2**	38,767.48	19.1	6.01	20.02	1.985
TOTAL		**1,046,757.692**			**19.063**	**1,311.318**
Inventory Uncertainty	**%**					**36.212**

[5] Activity or factor for which uncertainty information are not available, a value of 0 in imputed.
[6] For Forest land converted to Settlement, only 20% of SOC is lost for paved surfaces. Therefore, a factor of 0.8 is applied to land use.

Table 7: Uncertainty analysis of FREL

Emission source or sink	**Emission in each reference period**	
	2005-2009	2010-2014
Deforestation Biomass **(t CO_2 e)**	541,157.09	1,007,990.21
Deforestation SOC **(t CO_2 e)**	9,887.78	38,767.48
Total	551,044.87	1,046,757.69
Uncertainty (%)	11.68	36.21
Average uncertainty		**23.95**

3. Uncertainty of Forest Reference Level

The FRL is constructed taking into consideration the area under SMF, Conservation of Forest Carbon Stock and Enhancement of Carbon Stock and associated emissions from each of these REDD+ activities.

Data for timber harvesting, forest fires and plantation were obtained from the record maintained by DoFPS and uncertainty information for these data are not available. Therefore, a semi-structured expert judgement for assessment of the uncertainty was conducted for each of these activities. According to the expert judgement analysis, the uncertainty was 15%, 15% and 25% for wood removal, forest area damaged by fire and successful plantation area respectively.

The area under Conservation of Carbon Stock and SMF is obtained by interpolation of LULC data of 1990, 2000, 2010 (Gilani *et al*., 2015) and LULC map of Bhutan 2016 (FRMD, 2017). The overall accuracy of the 2010 land cover map is 83% and same level of accuracy is applied to land use map of 1990 and 2000. The overall accuracy of 2016 LULC map is 98%. Therefore, due to lack of disaggregated information on uncertainty for LULC, an error of 17% was applied to 1990, 2000 and 2010 and 2% to 2016. The combined uncertainty of forest area was computed by taking average of the uncertainty of four LULC maps as neither Equation 2 nor 3 can be applied (Table 8). This average uncertainty is considered as activity data uncertainty for computing the sequestration from SMF and Conservation of Carbon Stock.

Table 8: Uncertainty of forest area

Year	Forest Area (ha)	Accuracy %	Error%
2010	2,673,200	83%	17
1990	2,556,358.00	83%	17
2000	**2,644,500.00**	83%	17
2016	1,717,161.64	98%	2
Combined error			**8.067**

The annual biomass increment of forest remaining forest is 2.01 ±0.22 t ha^{-1}, which is 10.94% margin of error and is applied as uncertainty for the removal factor. The uncertainty of emission factor for Non-CO_2 emission from forest fire is described in Table 9. The uncertainty for wood density and biomass expansion factor is computed and applied as emission factor uncertainty for wood removals from SMF and conservation of carbon stock. Table 10 shows uncertainty of biomass conversion and expansion factor (BCEF).

Table 9: Emission factor uncertainty of forest fire

Gases	M_B		C_f		G_{ef}		
	Mean	SE%	Mean	SE%	Mean	SE%	Combined Uncertainty (%)
CO	267	12.73	0.45	53	107	34.57	64.546
CH_4	267	12.73	0.45	53	4.7	40.43	67.865
N_2O	267	12.73	0.45	53	0.26	26.92	60.793

Table 10: Uncertainty of BCEF

Sl. No.	Timber type	BEF	MoE%	**WD (t m^{-3})**	MoE%	BCEF	MoE%
1	Conifer	1.292	60.759	0.48	4.969	0.624	60.983
2	Broadleaf	1.83	66.667	0.69	5.225	1.261	66.769
3	Forest	1.561	46.468	0.59	3.692	0.942	49.015

The combined uncertainty of the FRL is described in Table 11 and 12 respectively for reference period 2005-2009 and 2010-2014. The total net removal during 2005-2009 is 42,167,873.78 t CO_2-e with uncertainty of 11.77%. Similarly, the total net removal during 2010-2014 is 43,222,974.127 t CO_2 -e with uncertainty of 11.30%. The overall uncertainty of FRL is 11.53%.

Table 11: Uncertainty of FRL during 2005-2009

A	B	C	E	F	G	H
IPCC Category	**Gases**	**Emissions or removals (t CO_2 e)**	**AD uncertainty (%)**	**EF/parameter uncertainty (%)**	**Combined uncertainty (%)**	**Contribution to variance by category**
					SQRT(E^2+F^2)	*$(GxC)^2/(TotalC)^2$*
Sustainable management of Forest						
Wood Removal	**CO_2**	1,436,367.65	15	48.258	50.54	2.963
Forest Fire	**CO**	914,354.25	15	64.546	66.27	2.065
Forest Fire	**CH_4**	624,761.26	15	67.865	69.50	1.060
Forest Fire	**N_2O**	327,097.72	15	60.793	62.62	0.236
Conservation of Forest Carbon Stock						
Wood Removal	CO_2	206,259.46	15	48.258	50.54	0.061
Sustainable Management of Forest						
Forest growth	CO_2	-33,515,934.37	8.067	10.945	13.60	116.790
Conservation of Forest Carbon Stock						
Forest growth	CO_2	-12116130.40	8.067	10.945	13.60	15.263
Enhancement of carbon stock						
Plantation growth	CO_2	-44,649.34	25	10.945	27.29	0.001
TOTAL		**-42,167,873.777**			**11.766**	**138.438**
Total uncertainty	**%**					**11.766**

Table 12: Uncertainty assessment of FRL during 2010-2014

A	B	C	E	F	G	H
IPCC Category	**Gases**	**Emissions or removals (t CO_2 e)**	**AD uncertainty (%)**	**EF/parameter uncertainty (%)**	**Combined uncertainty (%)**	**Contribution to variance by category**
					SQRT(E^2+F^2)	*$(GxC)^2/(TotalC)^2$*
Sustainable management of forest						
Wood Removal	**CO_2**	1,304,884.15	15	48.258	50.54	2.328
Forest Fire	**CO**	842,693.34	15	64.55	66.27	1.669
Forest Fire	**CH_4**	575,796.70	15	67.87	69.50	0.857
Forest Fire	**N_2O**	301,461.88	15	60.79	62.62	0.191
Conservation of Forest Carbon Stock						
Wood Removal	CO_2	181,785.17	15	48.258	50.54	0.045
Sustainable Management of Forest						
Forest growth	CO_2	-32,220,601.16	8.067	10.945	13.60	102.731
Conservation of Forest Carbon Stock						
Forest growth	CO_2	-14,161,386.35	8.067	10.945	13.60	19.845
Enhancement of carbon stock						
Plantation growth	CO_2	-47,607.84	25	10.945	27.29	0.001
TOTAL		**-43,222,974.117**			**11.299**	**127.667**
Total uncertainty	**%**					**11.299**

4. Summary of uncertainty Assessment

Table 13 and 14 shows the summary of the uncertainty assessment of FREL and FRL respectively. Average uncertainty of FREL is 23.95% while FRL is 11.53%.

Table 12: Uncertainty Analysis of FREL

Emission source or sink	**Emission in each reference period (CO_2 e)**	
	2005-2009	2010-2014
Deforestation Biomass	541,157.09	1,007,990.21
Deforestation SOC	9,887.78	38,767.48
Total	551,044.87	1,046,757.69
Uncertainty (%)	11.680	36.212
Average uncertainty		**23.95**

Table 13: Uncertainty analysis of FRL

Emission source or sink	**Emission/Removal in each reference period (CO_2-e)**	
	2005-2009	**2010-2014**
Sustainable management of forest - Emission	3,302,580.87	3,024,836.07
Conservation of carbon stock- Emission	206,259.46	181,785.17
Sustainable management of forest - Removal	-33,515,934.37	-3,222,0601.16
Conservation of carbon stock- Removal	-12,116,130.40	-14,161,386.35
Enhancement	-44,649.34	-47,607.84
Total	-42,167,873.777	-43,222,974.117
Uncertainty (%)	11.766	11.299
Average uncertainty		**11.53**

Annexure VI: Expert Judgement for Assessment of Uncertainty

1. Description of the Problem

The volume of wood removed is used as activity data to estimate the emission from SMF and Conservation of Carbon Stock. The statistical record of wood removed from SMF and conservation area are available, while the uncertainty of the volume of wood removed is not available. The best assumption of error with these statistics is to consider that the data is 100% correct. However, the likelihood of either double counting or under reporting of the actual volume of wood removed cannot be ignored.

Similarly, huge forest area is damaged by forest fire annually. The assessment of the forest burnt or damaged by the forest fires is done using GPS mapping where possible and are reported by field offices. DoFPS produces the annual statistics of the forest area damaged by forest fire. However, no accuracy assessment of fire burnt forest area are carried out and uncertainty of this information are not available.

In addition, DoFPS has been carrying out forest plantation annually for since 1950s. However, no spatial mapping of the plantations was carried out in the past and spatially explicit records are not available. Therefore, it is difficult to ascertain where and how much of plantations are successfully converted into forest. Plantation monitoring carried out by Social Forestry and Extension Division (SFED) of DoFPS shows an average survival percent of 50%. Therefore, 50% of total planted area is used as an activity data for estimation of enhancement from plantation.

2. Parameters for which the uncertainty values are needed

1. Uncertainty of volume of wood removed
2. Forest area damaged by fire
3. Forest area brought under plantation

3. List of Experts

30 experts were identified for uncertainty assessment for volume of wood removed from forest, area of forest damaged by forest fires and plantation area survival percent reported by DoFPS in annual forestry facts and figure.

1. Chief Forestry Officers (21 Functional and Field Offices)
2. Data Manager (Ms. Jamyang Choden, Ms. Choney Wangmo and Mr. Rixzin Wangchuk)
3. Timber utilization specialist (Mr. Saran Pradhan)
4. Plantation specialist (Mr. Sither Wangdi)
5. Forest fire specialist (Mr. Kinley Tshering)

4. Expert Elicitation Questions

4.1 Wood Removal

All field offices under Department of Forest and Park Services report volume of timber allotted for various purpose through FIRMS and FRMD publish this data annually in forestry facts and figures.

Please rate your confidence on the data provided by field offices and published by the Department.

Data Accuracy	Your Rating (Please tick)
Extremely confident (>95% accurate)	
Very confident (> 85% accuracy)	
Somewhat confident (>75% accuracy)	
Not so confident (>65% accuracy)	
Not at all confident <65	

4.2 Forest Damaged by Fire

All field offices under Department of Forest and Park Services report forest area damaged due to forest fire through FIRMS and FRMD publish this data annually in forestry facts and figures.

1. Please specify the methodology adopted for estimating the forest area damaged due to forest fire.

Methodology	Your Rating (Please tick)
GPS mapping in the field	
Mapping through google earth	
Satellite image analysis	
Ocular estimate	
Others (specify)	

2. Please rate your confidence on the forest fire damage area reported by field offices and published by the Department.

Data Accuracy	Your Rating (Please tick)
Extremely confident (>95% accurate)	
Very confident (> 85% accuracy)	
Somewhat confident (>75% accuracy)	
Not so confident (>65% accuracy)	
Not at all confident <65 %	

4.3 Plantation

All field offices under Department of Forest and Park Services report area of land brought under plantation through FIRMS and FRMD publish this data annually in forestry facts and figures. Based on historical archived plantation data, the average survival percentage of plantation is 50% of the total area planted.

1. Please rate your confidence on the plantation area reported by field offices and published by the Department.

Data Accuracy	Your Rating (Please tick)
Extremely confident (>95% accurate)	
Very confident (> 85% accuracy)	
Somewhat confident (>75% accuracy)	
Not so confident (>65% accuracy)	
Not at all confident <65 %	

2. Please rate your confidence on the estimated average survival percent of plantations (50%) based on the historical archived plantation data.

Data Accuracy	Your Rating (Please tick)
Extremely confident (>95% accurate)	
Very confident (> 85% accuracy)	
Somewhat confident (>75% accuracy)	
Not so confident (>65% accuracy)	
Not at all confident <65%	

5. Aggregation of Uncertainties

5.1 Weighing of Expert Judgement

The data used for wood removal, area damaged by forest fire and plantation area were based on actual record with the Department. However, the potential omission and duplication at the time of data entry and reporting cannot be ignored. Therefore, estimation of uncertainty associated with these parameters was done using expert judgement as part of the post hoc analysis. Each expert was given equal weights and a percentage uncertainty for each of the parameters are assigned in 5 scales of:

1. Extremely confident :5% error
2. Very confident :15% error
3. Somewhat confident :25% error
4. Not so confident :35% error
5. Not at all confident :50% error

The uncertainty of each of the parameters identified above are assigned based on the confidence of the experts on the statistics. It was assumed that no data is 100% correct and there is some form of errors associated with it. The uncertainty for each parameter is selected from five categories of error percent (5%, 15%, 25%, 35% and 50%) by considering the number of experts as sampling size and the maximum agreed percentage by the experts as the associated uncertainty for that parameter.

5.2 Result of Expert Judgement

Based on the weights assigned to each expert in the previous section and the uncertainty of the volume of wood remove, forest area burnt by fire and area of successful plantation is as follow:

Parameter	Uncertainty (%)
Volume of wood removed	15
Forest area damaged by fire	15
Successful forest plantation	25