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

Submission for technical assessment to UNFCCC

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April, 2019

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Acronyms

AGB	Above ground Biomass
AD	Activity Data
AFOLU	Agriculture, Forestry and Other Land Use
BGB	Below ground Biomass
CF	Community Forest
COP	Conference of Parties
DoFPS	Department of Forests & Park Services
FMU	Forest Management Unit
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GFC	Global Forest Change
GFOI	Global Forest Observation Initiative
GLC	Global Land Cover
GNH	Gross National Happiness
SEPAL	System for Earth Observation Data Access, Processing and Analysis for Land Monitoring
MoAF	Ministry of Agriculture & Forests
MRV	Monitoring, Reporting and Verification
NEC	National Executive Council
SOC	Soil Organic Matter
DW	Dead Wood
CDW	Coarse Woody Debris
PA	Protected Areas
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Degradation in developing countries
REDD+	Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks

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, 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 (additional) 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 includes Above Ground Biomass, Below Ground Biomass, dead wood, litter and Soil Carbon. Besides CO_2 emissions, non-CO_2 emissions, namely CH_4, CO and N_2O from forest fire have also been included as CO_2 equivalent.

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 IPCC and UNFCCC Decisions 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 0.01% applicable for countries with high forest and low deforestation. 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 emissions from the deforestation is 0.17 million tonnes of CO_2e and adjustment of 0.38 million tonnes of CO_2e per year. The proposed FREL for Bhutan is 0.55 million tonnes of CO_2e per year.

The total annual net sequestration from SMF, Conservation and Enhancement is 8.76 million tonnes of CO_2e and therefore the proposed FRL for Bhutan is 8.76 million tonnes of CO_2e per year.

The historical data used to construct the national FREL and FRL are a reflection of this high performance. The data therefore allow the country to objectively demonstrate the positive contribution to global climate change mitigation objectives that are results of the large and successful efforts in implementing conservation and sustainable forest management practices in the past. The benchmark set by the FREL and FRL demonstrates that the continuation of these 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, sustainable management of forests 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 Conference of the Parties (COP) to the UNFCCC in the nineteenth COP 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 and a national forest monitoring 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. 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 (additional) 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 13/CP.19 and its Annex.

3. National Context

Bhutan has a geographical area of 38,394 square km and is characterized by fragile mountainous ecosystems with elevations 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 and diverse climatic conditions with its altitude, 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 immense biodiversity, making Bhutan part of the Himalayan global biodiversity hotspot (Mittermeier et al., 2004). Forests provides 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 Bhutan (2008) under Article 5, section 2(d) mandates Bhutan to maintain 60% forests cover 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, having long-term policies and approaches which is in line with the vision of REDD+ mechanism, positions the country as a strong candidate to be recognized for its past and present actions and financially supported to continue to conserve 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, 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 1995 (FNCA) provides a legal framework for appropriate forest uses and enabling community and social forestry (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 it defines detailed management requirements for Forest Management Units (FMU), Community Forests (CF), Protected Areas (PA), watersheds and local forest management areas. About 51.44 % of the country's total area is managed under the protected area network system, around 5% under Forest Management Unit (FMU), 781 operational community forests and the remaining forest is managed under local forest management. The protected areas are focused 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. Further, watershed management plans are developed for degraded and critical watersheds. All areas outside these existing formal management regimes are being brought under local forest management plans. 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 initially 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 Conference of Parties 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 national forest monitoring system. REDD+ can contribute to the forest component of the NDC and to the overall development philosophy of Gross National Happiness (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. Definitions of Forests

The forests, defined under the National Forest Policy (NFP) of Bhutan 2011 (RGoB, 2011) and FNCRR, 2017 (RGoB, 2017b), 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", has been considered for the purpose of establishing the FREL and FRL for Bhutan.

This definition of forest is consistent with the criteria thresholds of 2006 International Panel of 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 of Bhutan (FRMD, 2016), land use and land cover 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 datasets of national forest inventory and land use and land cover used in this report are 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 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/exclusion of these activities are as follows:

7.1.1 Deforestation

The definition of deforestation has been 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 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 5meter 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 but which are expected to revert to forest.

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

7.1.2 Forest Degradation

Forest degradation is considered as 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 to below, all emissions resulting from 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 sustainable management of forest (SMF) has been 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 protected areas. Protected area shall mean the area under national parks, wildlife sanctuaries and strict nature reserve.

7.1.3 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 protected areas 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 protected areas.

7.1.4 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 49 % 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 121 t ha^{-1} and constitute 21 % of the carbon stock.	National Forest Inventory Report (FRMD, 2018)
3	Dead Wood	Coarse woody debris	Biomass density of DW is 6.44 t ha^{-1} and constitute 1 % of carbon stock.	National Forest Inventory

				Report (FRMD, 2018)
4	Litter	Litter	Biomass density of litter is 13.25 t ha^{-1} and constitute 3 % 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 26 % 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 emissions, 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. Deforestation area calculation within the reference period is spatially explicit. Historical emissions from Conservation of Forest Carbon Stocks and SMF are estimated using timber harvested records within 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. Non-CO_2 emissions from forest fire are estimated using the forest burnt area record.

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 data sets; 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 data sets 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 data sets (Table 2) were explored to generate activity data. Stepwise flow chart for generation of activity data for is described in Figure 1.

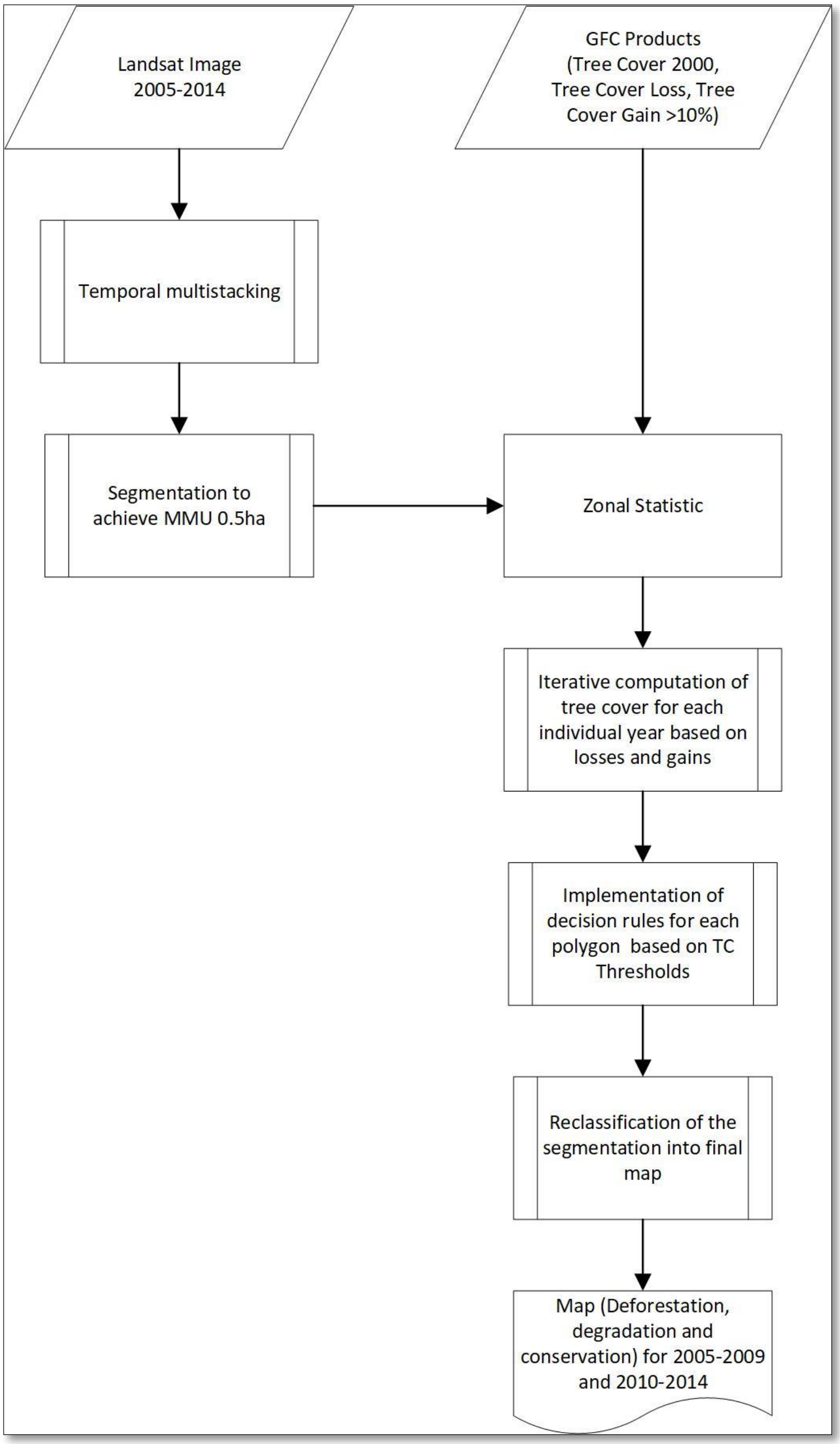

Figure 1: Deforestation activity data generation flow chart

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

Product	Producer	Resolution	Classes	Forest Types	Tree Canopy Cover	Year
LUPP1995	MoAF, Bhutan	10m, 20m, VHR	13	5	0-100	1995

LCMP2010	MoAF, Bhutan	10m	16	5	-	2010
LULC2016	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 was found to be the 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).

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 0.5ha. 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 users 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 and vegetation indices and very high-resolution imagery available in the Google Earth and Bing Maps, all assessed using the Open Foris Collect Earth interface (CE). 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 FAO under the Open Foris Initiative where software tools are open source and freely available online. Open source software allows any party to verify the assessment conducted 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 map for the period 2005-2009 and 2010-2014 (Figure 3 and 4 respectively) was developed and area of change were estimated for the reference period.

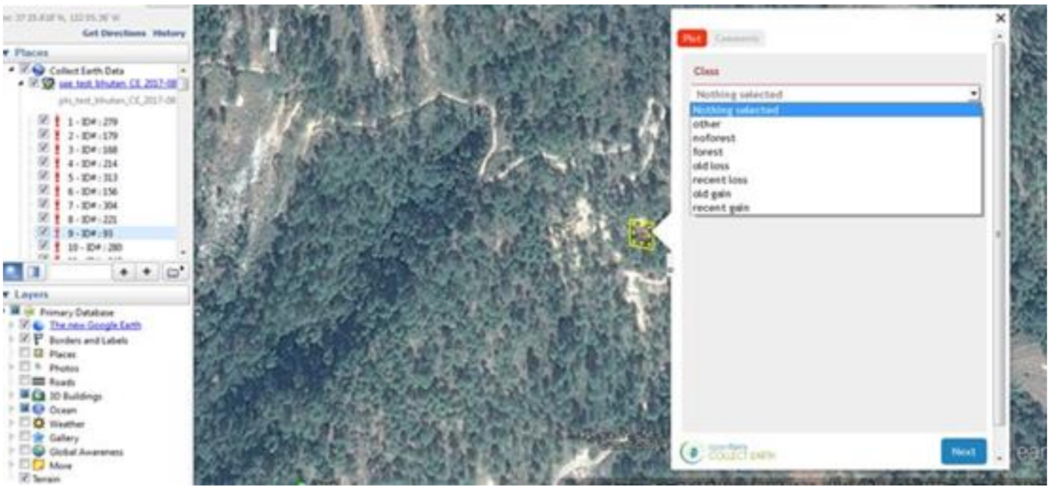

Figure 2: Validation of data products in Collect Earth

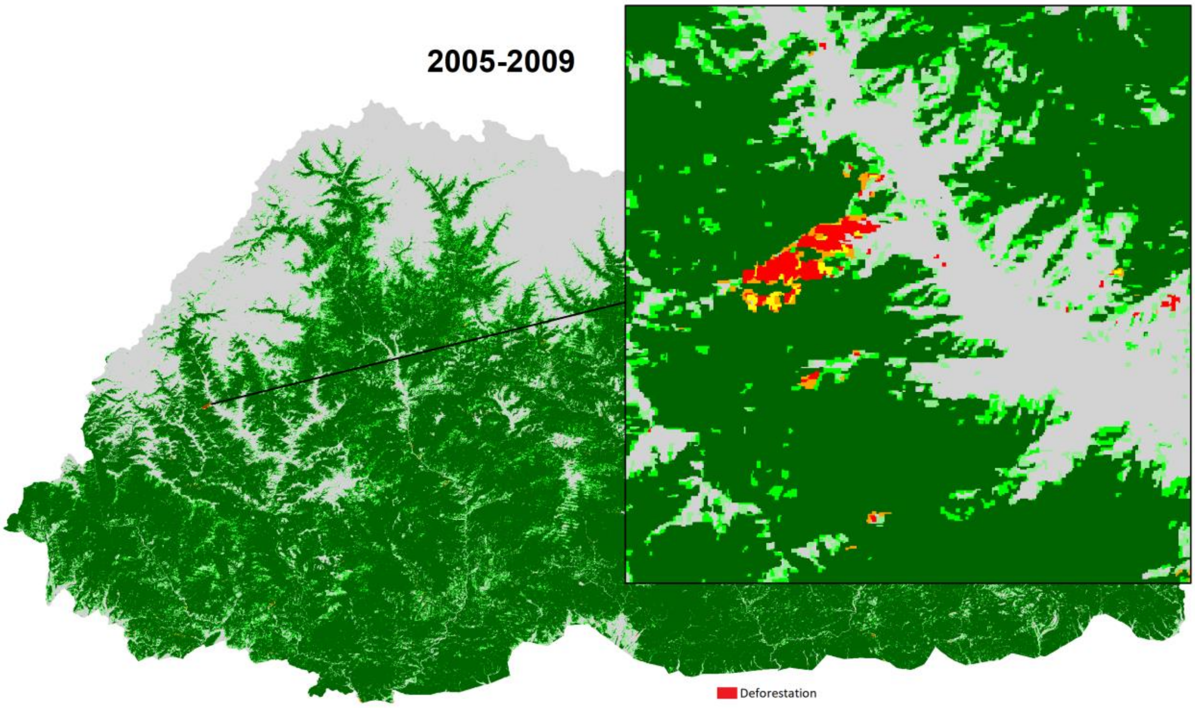

Figure 3: Deforestation Map (2005-2009)

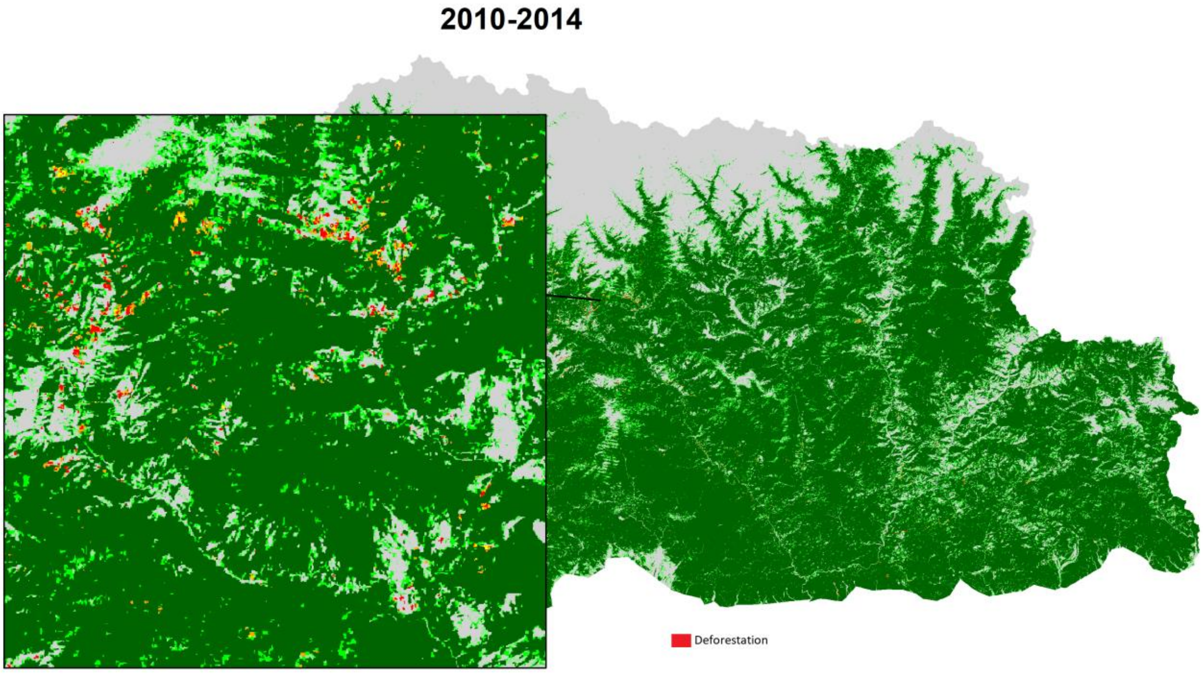

Figure 4: Deforestation Map (2010-2014)

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 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 grass land were misclassified as forests in the GFC (Figure 5 and 6).

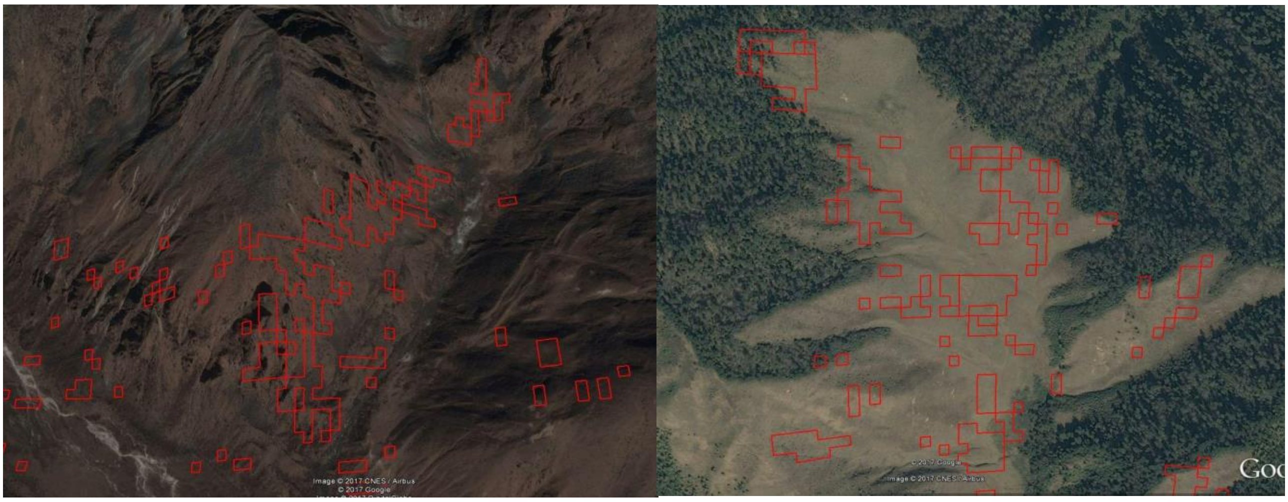

Figure 5: GFC misclassification of alpine grass land as forests in Bhutan

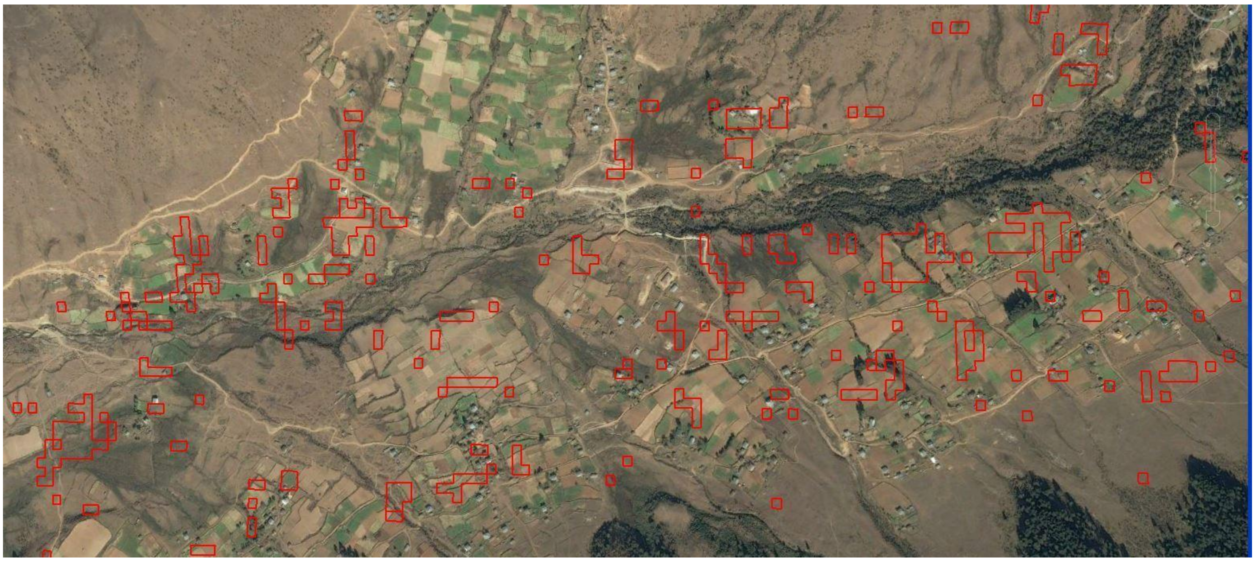

Figure 6: GFC misclassification of permanent agriculture land as forests in Bhutan

8.1.2 Emission factors

Emission factors 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 Otherland, the SOC density for non-forest land estimated using NFI data is considered as relevant and appropriate for these land categories distributed over 20 years transition period as prescribed by IPCC 2006. 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. Emission factor 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	**IPCC Category after conversion**	**EF (Tonnes of CO_2 equivalent)**
Forest	Cropland	707.70
Forest	Grassland	484.09
Forest	Settlement	707.70
Forest	Other land	707.70

Emissions from all carbon pools have been considered for Bhutan FREL and FRL study and the estimates of biomass /carbon density are generated from plot level measurements of the NFI of Bhutan. The emission factor 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 above ground biomass carbon density of trees. For the other carbon pools (herbs, shrubs, litters and SOC), about 20% of the 2424 NFI plots were systematically sub-sampled for actual collection of samples and 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 national forest inventory of Bhutan has systematic sampling design with sample plots laid 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 4500 plots of 0.05 ha) from 13 Forest Management Units (FMUs) 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 be 26935 cluster plots at 1.2 km systematic spacing. However, considering the human resource and financial limitations, it was decided on 4km by 4km 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 hectares and comes to 2424 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 at 50 meters 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 12.62m radius with an area 0.05 hectare for collecting tree data. The Elbow Plot will have an additional circular plot of 3.57m radius within it, for collecting regeneration data, whereas circular plot of 0.57m (1 meter square) radius will be laid in North and East Plot for collecting herb data.

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

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

Only 20 percent of the total 2424 plots were systematically sub-sampled for forest understory carbon assessment.

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

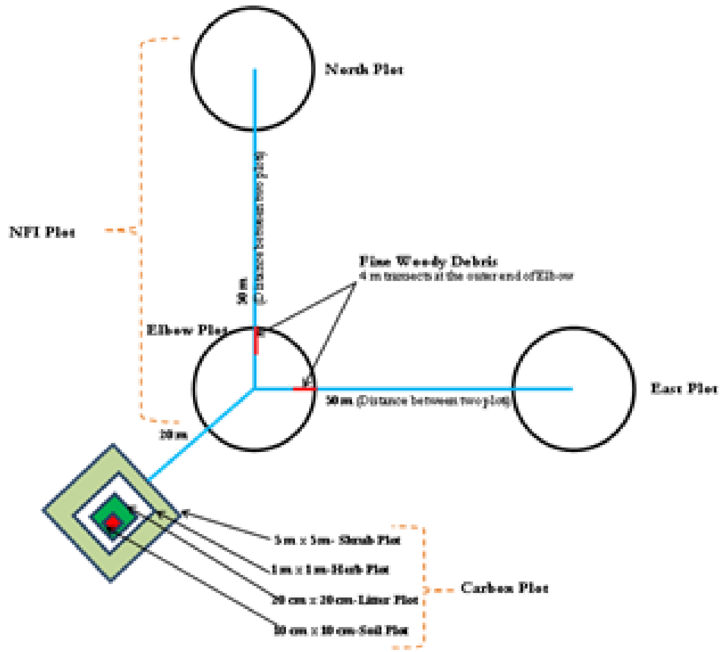

Figure 7: NFI Sampling Design

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 total of 32 trees was selected for each of the 14 tree species.

On 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 one for broadleaf were also developed to be applied to species lacking independent 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 form shown below.

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

Where, X1 =basal area (Ba), X2=g(X1), where and t1, t2 and t3 corresponds to the knots at 10th, 50th and 90th quantiles of the X1(Ba) values.

8.1.2.6 Estimating carbon density

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

Below ground biomass was estimated for the trees and saplings following the formula described in (Mokany et al., 2006):

BGB= 0.489 * AGB^0.89 (Equation 5)

Coarse woody debris biomass was estimated from the NFI coarse woody debris 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.

Soil organic carbon (SOC) density is estimated from the NFI soil samples that were analyzed for the organic carbon content.

Biomass density were then converted to carbon using carbon fraction of 0.47 (IPCC 2006 given in Table 4.3 of 2006 IPCC Guidelines for Forest Land) and details are provided in Table 7.

Table 7: Biomass and carbon density of carbon pools

Biomass/carbon pool	Tonnes of dry matter per hectare	Tonnes of C per hectare	Margin of Error (%)
Aboveground Biomass	269.32	127.10	6.4
Belowground Biomass	121.00	54.58	5
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 area converted into non-forest by emission factor. The table 8 and 9 shows emission during two reference period of 2005-2009 and 2010-2014 respectively.

Emission = Activity Data x Emission Factor (Equation 6)

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

IPCC Category	Activity data (ha)	Emission factor (CO_2 e ha^{-1})	Total emission (CO_2 e)
Cropland	125.00	707.70	88454.27
Grassland	312.47	484.09	151264.05
Settlement	312.47	707.70	221135.67
Other land	187.48	707.70	132681.40
	937.42		**593535.39**

Table 9: Total emission from deforestation during 2010-2014

IPCC Category	Activity data (ha)	Emission factor (CO_2 e ha^{-1})	Total emission (CO_2 e)
Cropland	272.34	707.70	192736.89
Grassland	363.12	484.09	175784.47
Settlement	607.11	707.70	429651.71
Other land	453.90	707.70	321228.15
	1696.47		**1119401.22**

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 protected area network in forest remaining forests. These areas are managed scientifically as Forest Management Units, Community Forests and Local Forest Management areas. The timber harvesting in areas not yet managed under these forest management regimes are still regulated by Forest Nature and Conservation Act, 1995 (RGoB, 1995) and Forest Nature and Conservation Rules and Regulations, 2017 (RGoB, 2017b) under the principles of sustainability.

The timber harvested from the aforementioned management regimes were considered as degradation in DD study (WMD, 2017). However, since all the harvesting are based on the principles of sustainability which does not result in net reduction in long term biomass/carbon density, these are now being accounted under SMF. 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 areas outside PAs

Timber Type	Timber Harvest Volume (m^3)	
	2005-2009	**2010-2014**
Broadleaf	401320.17	364583.76
Conifer	601980.25	546875.64

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, 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 below ground biomass.

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

Where, $SMF_{Timber\ emission}$ is emission from SMF in tonnes of CO_2, H is the volume of harvested timber (m^3), WD is wood density (tonnes/m^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 ABG. Two BEF, one for conifer and another for broad-leaved timber were developed using the following equation:

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

Where, BEF is biomass expansion factor (dimensionless), $W_{aboveground}$ is total AGB of tree (kg). 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 tonnes/m^3 and 0.483 tonnes/m^3 for broadleaf and conifer species respectively (UNIDO, 1994) and applied to equation 8. The biomass and emissions from timber harvested are presented in Table 11 and 12 respectively.

Table 11: Biomass from the timber harvest (SFM)

Timber type	Biomass (tonnes)	
	2005-2009	2010-2014
Broadleaf	457,541.11	415658.30
Conifer	375,075.83	340741.80
Total	832,616.94	756400.10

Table 12: Emission from timber harvest (SFM)

Timber type	Biomass (tonnes)	
	2005-2009	2010-2014
Broadleaf	789,212.66	716,969.00
Conifer	646,968.31	587,745.54
Total	1,436,180.96	1,304,714.54

8.2.1.2 Annual decrease in carbon stock through forest fire

Non-CO_2 emission from forest fire is included under SMF as forest fire doesn't lead to permanent land use change. Non-CO2 is estimated using adapted Equation 2.27, IPCC 2006, Vol.4, and Chapter 2 as follows:

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

Where,

L_{fire} is amount of GHG emission from fire, tonnes of each GHG (eg. CH_4, N_2O)

A = Area burnt, ha

M_B is mass of fuel available for combustion, t/ha

C_f is Combustion factor, dimensionless

G_{ef} is emission factor, (g/kg) dry matter burnt

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

Non-CO_2 to CO_2 equivalence were estimated using GWP Table 8.7, Chapter 8, Anthropogenic and Natural Radiative Forcing, IPCC AR 5 (IPCC, 2014). The table 13 shows area affected by forest fire while Table 14 and 15 shows combustion factor, emission factor, global warming potential and GHG emissions for two reference period.

Table 13: Forest area burnt during reference period

Activity data	**Area burnt (ha)**	
Forest area burnt	2005-2009	2010-2014
	39512.49	36415.77

Table 14: Non-CO2 emission during 2005-2009 from fire

Particulars	**CO**	**CH_4**	**N_2O**
Biomass	267	267	267
Combustion factor	0.45	0.45	0.45
Emission factor	107	4.7	0.26
Global Warming Potential	1.8	28	265
Emission	**914354.25**	**624761.26**	**327097.65**

Table 15: Non-CO2 emission during 2010-2014 forest from fire

Particulars	**CO**	**CH_4**	**N_2O**
Biomass	267	267	267
Combustion factor	0.45	0.45	0.45
Emission factor	107	4.7	0.26
Global Warming Potential	1.8	28	265
Emission	**842693.34**	**575796.69**	**301461.95**

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

Table 16: Total emission (tonnes CO2e) from SMF (2005-2014)

Emission from SMF	2005-2009	2010-2014
Emission from Timber Extraction	1436180.96	1304714.54
Emission from fire	1866213.17	1719951.98
Total Emission	3302394.13	3024666.52

8.2.1.2 Removal from SMF

The removal (carbon sequestration) within SMF is estimated based on the forest cover area outside the protected area network using the latest national land use and land cover map LULC 2016 (FRMD, 2017). The removal from SMF is calculated using equation 2.9, Chapter 2, Volume 4 of IPCC 2006:

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

Where, $SMF_{Removal}$ is removal by SMF (t CO_2 yr^{-1}), A_{smf} area under SMF, G_{mean} is mean annual biomass increment and CF is carbon fraction, 44/12 is CO_2e fraction.

The A_{smf} is derived from LULC 2016 and annul biomass growth of 2.01 tonnes /yr from NFI and carbon fraction of 0.47 is applied to Equation 11. The total removals from SMF is described in Table 17.

Table 17: Removal from SFM

REDD+ Activity	Area (ha)	Increment (t ha^{-1} yr^{-1})	CF	CO_2 Conversion	Sequestration (tCO_2 e yr^{-1})
SMF	1,859,235.63	2.01	0.47	44/12	6,440206.28

8.3 Conservation

Conservation of carbon stocks concerns forest remaining forest inside the protected areas. Protected area includes area under national parks, wildlife sanctuaries and strict nature reserve.

As per the existing rules and regulations of FNCRR (RGoB, 2017b), any form of commercial harvesting of timbers are prohibited inside the protected areas. The protected areas are not expected to reduce over time, and since 51.44 % of the country is declared as protected areas, it provides opportunity for long term conservation of forest carbon stocks.

Although, protected area network is primarily managed for biodiversity conservation; however, in Bhutan's context, there are local communities residing within the area. The people residing within the protected area are granted user right over timber and other resources with approved permit system for their bonafide domestic use. The timber is harvested on selection or thinning basis in accordance with Forest and Nature Conservation Act 1995 and FNCRR 2017 (RGoB, 1995, 2017b).

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

The method for estimating carbon stock changes in biomass for Conservation is estimated using equation 6.

8.3.1 Annual decrease in carbon stock from timber harvesting in the conservation

The emission from conservation is calculated using adapted equation 2.12, Chapter 2, Volume 4 of IPCC 2006 on the assumption that there is no changes 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.

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

Where, $Conservation_{Emission}$ is emission from conservation in tonnes of CO_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 SMF. The Table 18 and 19 shows the emission from timber harvested in conservation.

Table 18: Emission from timber harvest in protected areas (2005-2009)

	H (m^3)	**WD (t/m^3)**	**BEF**	**CF**	**CO_2 Fraction**	**Emission**
Broadleaf	57,970.66	0.62	1.83	0.47	3.67	113226.39
Conifer	86,443.13	0.48	1.29	0.47	3.67	92903.32
Total Emission						**206129.71**

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

	H (m^3)	**WD (t/m^3)**	**BEF**	**CF**	**CO_2 Fraction**	**Emission**
Broadleaf	**50,790.66**	0.62	1.83	0.47	3.67	99881.92
Conifer	**76,185.99**	0.48	1.29	0.47	3.67	81879.63
Total Emission						**181761.55**

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:

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

Where, $Conservation_{Removal}$ is removal from Conservation ($t\ CO_2\ yr^{-1}$), A_{con} is the forest area under Conservation, G_{mean} is mean annual biomass increment and CF is carbon fraction (IPCC).

The A_{con} is forest area derived from LULC 2016, and average annual biomass growth of 2.01 tonnes/yr from NFI

The details of forest cover area and increment for conservation activity is given in Table 20 below.

Table 20: Removal from conservation

REDD+ Activity	Area (ha)	Increment t $ha^{-1}yr^{-1}$	t CO_2 e yr^{-1}
Forest Remaining Forest	**857,926.02**	**2.01**	**2,971,769.93**

8.4 Enhancement of Forest 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 and some of the oldest official record of forest plantation dates back to 1950's. The total area of afforestation carried out within the 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

The forest plantations require certain time to establish as forests. The default transition period prescribed by IPCC (2006) is 20 years. Therefore, the annual biomass growth rate (12.05 t ha^{-1}) of plantations is obtained by dividing average annual above ground tree (241 t ha^{-1}) by 20. The equation 13 applied to Table 20 and 21 to estimate biomass and carbon sequestration from plantations during 2005-2009 and 2010-2014 period respectively.

$$Plantation_{tCO2e} = (\text{Age of plantation (yr)} \times \text{Biomass growth} ((t\ ha^{-1}yr^{-1}) \times \text{Successful Plantation (ha)} \times .047 \times 44/12) \quad \text{(Equation 14)}$$

Over the reference period, total of 3675.54 ha was planted, of which 1826.84 ha were successful, indicating the overall survival rate of afforestation and reforestation is 49.7 %. The details of yearly survived plantation are given in Table 21. Table 22 shows removals by plantations.

Table 21: Successful plantation area (2005-2014)

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Successful plantation area (ha)	141	103	110	161	299	238	428	167	161	19

Table 22: CO2 Removals by plantations during 2005-2009

		Removals Over the reference Period									
		2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Year in which plantation is established	**2005**	2934	2934	2934	2934	2934	2934	2934	2934	2934	2934
	2006		2142	2142	2142	2142	2142	2142	2142	2142	2142
	2007			2283	2283	2283	2283	2283	2283	2283	2283
	2008				3335	3335	3335	3335	3335	3335	3335
	2009					6209	6209	6209	6209	6209	6209
	2010						4942	4942	4942	4942	4942
	2011							8892	8892	8892	8892
	2012								3464	3464	3464
	2013									3347	3347
	2014										388
		2934	**5076**	**7359**	**10694**	**16903**	**21845**	**30737**	**34201**	**37548**	**37936**

9. FREL and FRL Construction Approach

For transparency, consistency and future reporting, separate reference levels for FREL (emission) and FRL (removal) is developed. The FREL for deforestation is constructed by calculating the historical average emissions from deforestation and adding an upward adjustment (Figure 5). The FRL for sustainable management of forest, conservation of forest carbon stock and enhancement of forest carbon stock is constructed based on historical removals (Figure 6).

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 Protected Area networks (51.44 %), as well as the highest proportion of forest cover (71%) of any Asian nation (FRMD, 2016, 2017; MoAF, 2009).

However, with growing population and economic development, there is growing pressure on forests and natural resources. The development of the rural population is a national priority and the attempts to further reduce timber extraction and deforestation risk to 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 12^{th} FYP (2018-2023) whose main objective is "Just, Harmonious and Sustainable Society through enhanced Decentralization" also recognizes the importance of improving productive capacity of the economy and prioritizes economic diversification as one of the 16 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 11^{th} FYP, indicating more developmental activities in the 12^{th} five-year plan period (2018-2023). Further, the 12^{th} FYP will also see the implementation of the Bhutan's Economic Development Policy 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 2007 also allows for both leasing and allotment of SRFL for different purposes.

Historic baselines are not adequate to capture future risk of forest loss. This section presents evidence 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:

$$tCO_2\ emission = Area * EF \qquad \text{(Equation 15)}$$

Where **Area**: Expected area to be lost to various developmental activities (WMD, 2017).

EF: Emission factor of the subsequent land use change from section 8.1.3

9.1.1 Population Growth

As per the statistics provided by the National Statistical Bureau (NSB) of Bhutan, population has been increasing over the years. The increase in life expectancy due to availability of free health care services, increasing literacy rates and improvement of health facilities have led to an increase in population over the years. The latest figures from the Bhutan Living Standard report of 2017 show the population of the country as 779,666 in 2016 (NSB, 2017) compared with 634,982 in 2005 (NSB, 2005). The population growth rate of the country is recorded at 1.8 %. The increase in population is rapid in urban areas due to rural to urban migration, which have led to construction booms and expansion of urban area. This exerts immense pressure on forests resulting in depletion of forest resources. As observed in other parts of the world, increasing population is correlated with higher deforestation. Hence, in Bhutan, deforestation rates in the future are 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 figures from 2008 – 2014, the study predicts that around 28,845 ha of SRFL (annually around 1923 hectares) will be allotted for various purposes (excluding hydropower, transmission lines and roads) between now (2015) and 2030 (WMD, 2017). **The annual loss of 1923 hectares of forests, would result in emission of 1.32 million tCO_2 annually (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 2800 hectares (DoFPS, 2015, 2016, 2017b) which is much higher than the predicted allotment of SRFL (1923 hectares).

9.1.3 Hydropower

The Bhutanese economy is mainly driven by hydropower. Bhutan has an estimated hydropower potential of 30,000 MW of which 23,760 MW is techno-economically feasible. Development of hydropower is estimated to remain a top priority into the future, given development plans underway. Based on reviews of proposed hydropower projects and on the assumption that future hydropower development would follow the same pattern as previous hydro impacts on forests in Bhutan, the DD study calculated that an average of 1 to 4 hectares of forest is lost for every megawatt (MW) generation capacity developed (WMD, 2017). Thus, the development of all the feasible hydropower plants with potential of 18,380 MW could result in the loss of about 39,760 hectares of forest (WMD, 2017). This can be considered a conservative estimate as the forest loss due to the construction of transmission lines and power grids is not included. **As per the draft 12th FYP, RGoB plans to start the implementation of 2585 MW hydropower project, which would be resulting in loss of 5120 hectares of forests and emission of 0.7 million tCO_2 annually (Table 23)**. This estimate can be considered as conservative as additional hydropower projects might be started based on feasibility and availability of budget.

9.1.4 Roads

The emphasis on 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 five year plan there are plans to upgrade existing national highways and build new roads to hydropower projects, Dzongkhags (districts) and villages. The DD study projects that about 4,100 hectares of forests will be lost between now and 2020 and up to 12,300 ha by 2030 (WMD, 2017). Approximately 1,200 km of farm roads are planned to be constructed during the 12th FYP. **Taking 5 meter standard width of farm road** (RGoB, 2009)**,**

total area of about 600 hectares of forest is expected to be cleared resulting in emission of 0.08 million tCO_2 annually (Table 23).

This estimate could be conservative as other roads such as construction of national highways and widening of existing roads would be carried out as required in the 12FYP but not included in the estimated emission. During the period from 2015 – 2017, on an average about 3895 hectares of SRFL was allotted annually for construction of roads (DoFPS, 2015, 2016, 2017a).

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 12^{th} 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 will exert pressure on forest if land is not available elsewhere. Increasing pressure for commercial cultivation is also a noted trend, as evidenced in the large number of land leases applied for agriculture purposes. Indications are also that as urban development places pressures to expand on flat paddy areas, it will displace agricultural production to other areas.

The DD study reports that the average forest area lost due to conversion of forest land to agriculture is predicted at about 3,890 ha between now (2015) and 2020, and up to 11,670 ha by 2030 (WMD, 2017).

9.1.6 Mining

Mining has historically been among the top four recipients of SRFL allotments. It is one of the fastest growing industries in the country. The growth rate recorded for the sector was 17% in 2014 and the share of mining and quarrying to GDP is about 3.4 % (NSB, 2016). Dolomite and gypsum mining in particular are increasing – with production more than doubling between 2002 and 2012 (ACC, 2016). It is reasonable to expect that mining will continue to exert pressure on forest resources and deforestation due to mining 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 now (2015) and 2020, and up to 9,495 ha by 2030. **The annual loss of 633 hectares of forest will result in emission of 0.4 million tCO_2 annually.** National Land Commission data from 2009-2014 indicates that the highest demand for land lease was for mining at 1,550 ha (RGoB, 2016a).

9.1.7 Allotment of forest resources

Extraction of forest resources in the form of timber, firewood or non-timber forest products are mainly for national use. As per the FNCRR 2017, every household in the rural areas is entitled to 4000 cft of timber for house construction once in 25 years and 700 cft of timber for repair/renovation/extension once in 12 years (RGoB, 2017b). The timber harvesting and firewood are the major drivers of forest degradation, which under this FREL and FRL report is accounted under sustainable management of forests (SMF) and conservation. Based on the national statistics (DoFPS, 2015, 2016, 2017b) most of the timber extracted have been supplied as subsidized timber, followed by commercial timber and royalty free timber. Increasing rural households as indicated by the national statistics (NSB, 2003, 2007, 2012, 2017) will exert further pressure on the resources as every new household will have to be supplied with entitled rural timber of 4000 cft. 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 contributes the biggest share of energy for Bhutan - 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 now (2015) and 2020, and up to 127,041 m^3 by 2030 will be harvested for firewood (WMD, 2017).

9.1.8 Forest fires

Bhutan's future climate projection indicates a warmer climate (NCHM, 2017). There is a consistent finding across climate projection models of a warming pattern, with greater temperature changes predicted during the winter months. Hence, a future warmer climate for Bhutan will most likely translate into increased forest fires. This is coupled with the country's rugged terrain making fire control very difficult. In addition, the capacity to manage fires is currently weak. Assuming a continuation of the annual average area of forest areas burned, one could predict that between now (2015) and 2030, about 93,800 ha of forest would be subjected to fire across the country (WMD, 2017).

The records shows that from the year 2015 to 2017 about 136 fire incidences were recorded, which burnt approximately 19,992 hectares of forests (DoFPS, 2015, 2016, 2017b).

9.2 Proposed adjustment

In summary, based on the assessment of national circumstances and development projections in future (section 9.1.1-9.1.8), future emissions from deforestation are predicted to increase to around **2.62 million tCO2** 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 0.15% as a result of the increased pressure from development activities (Table 23). This is below the regional rate of natural forest conversion 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, thus can be considered as conservative estimate. The projected emission from planned activities in 12 FYP is described in table 23.

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

Activity	Annual Area lost	tCO_2 (in millions)
Hydropower	1024	0.72
Roads	600	0.08
Mining	633	0.44
SRFL allotment for various purposes	1923	1.34
Total	4180	2.62

However, Bhutan respects the limit proposed by the Forest Carbon Partnership Facility (FCPF) Methodological Framework (FCPF, 2016) and Green Climate Fund (GCF) results-based payment pilot programme and associated scorecard (GCF, 2017). The FCPF Methodological Framework allows a 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 (Green Climate Fund) guidelines also allows upward adjustment of 0.1 % of the total forest carbon stock spread over the results reporting period (GCF, 2017).

The calculation is presented in Table 24 which shows the total maximum adjustment determined at 0.38 million tCO_2 per annum. The maximum adjustment is conservative estimate as carbon from the SOC (which accounts for 26 % of the total carbon stock) is not included for the adjustment.

Table 24: Calculation of the 0.1 % adjustment for Bhutan

Carbon Pool	Total carbon (million tonnes)
ABG	346.04
BGB	148.51
Litter	18.34
Deadwood	8.53
Soil	187.85
TOTAL	709.27
Only AGB, BGB, DW and litter is considered for adjustment	521.42
Conversion of carbon stock to tCO_2 emission	1.912
0.1 % of tCO_2 emission divided over 5 years validation	**0.38 million tCO_2**

Applying the 0.1 % adjustment applicable for HFLD countries under FCPF CF and GCF Methodological Framework, the adjusted emissions (0.38 million tCO_2) is significantly lower than the projected emission (2.62 million tCO2). Therefore, an annual upward adjustment of 0.1% divided over the validation period is applied for construction of Bhutan's FREL (Figure 8).

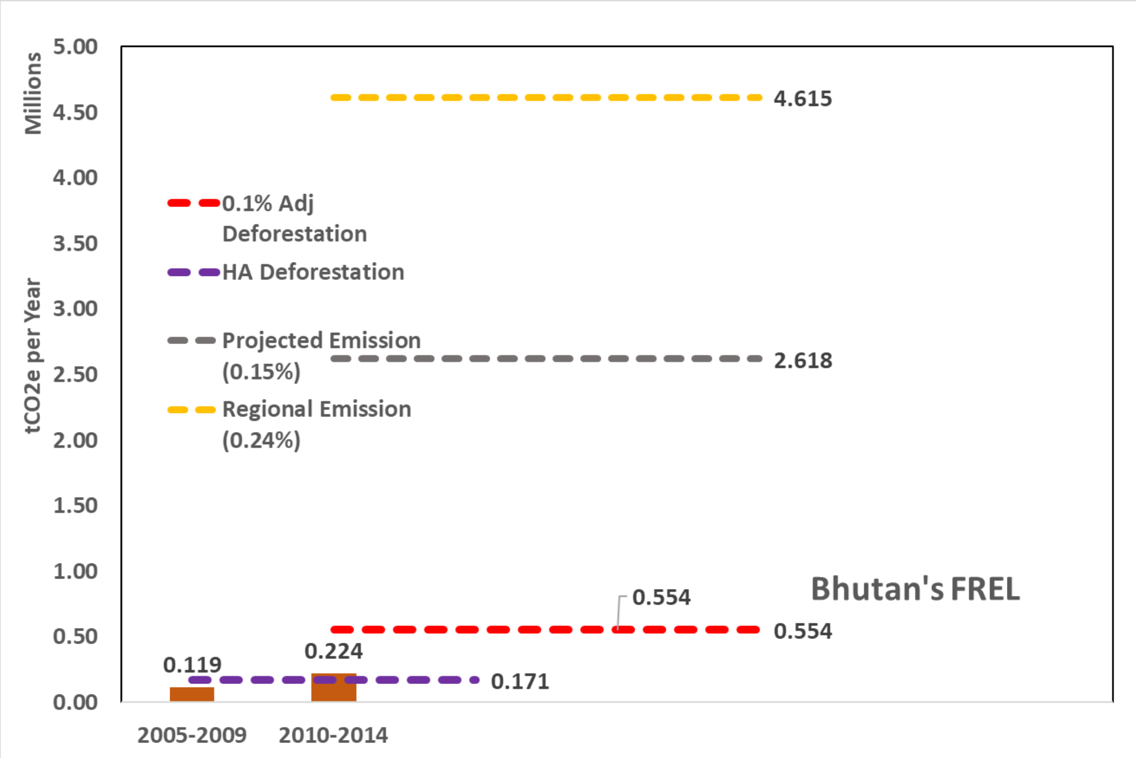

Figure 8: Historical Average emission from Deforestation and adjustment

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% applicable for countries with high forest and low deforestation (Figure 9) and Table 25.

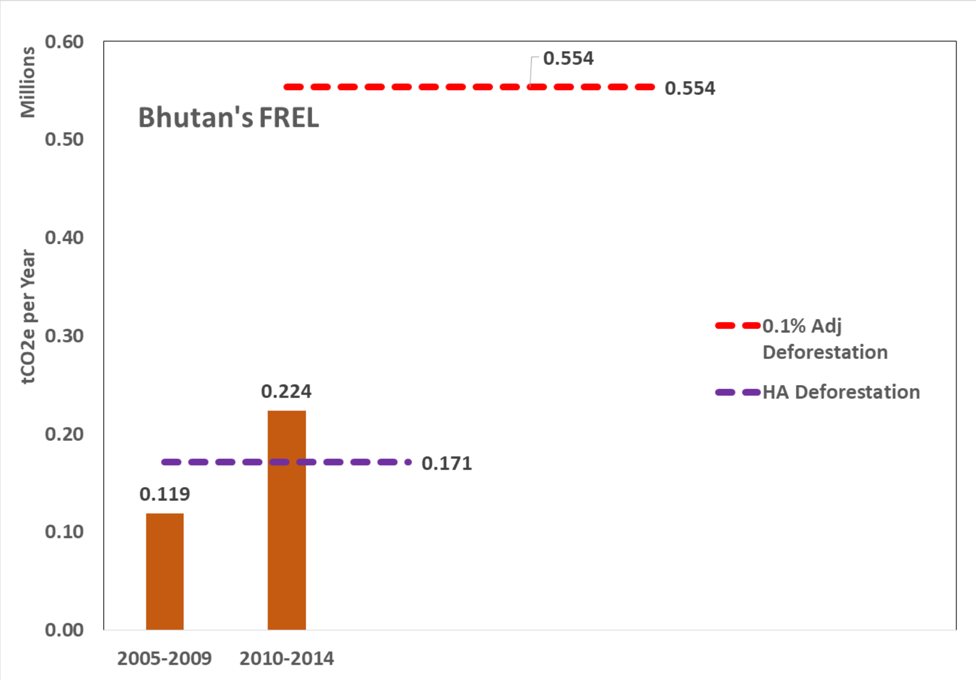

Figure 9: National FREL

Table 25: Total emission from deforestation per annum

REDD+ Activity:	2005-2009	2010-2014	Adjustment (0.1% of Carbon Stock spread over 5 years)	Emission tCO2e yr^{-1}
Deforestation	118,707	223,880	382,375	553,668

9.4 National Forest Reference Level

The national FRL is the sum of net removal from sustainable management of forests, conservation of forest carbon stock and enhancement of forest carbon stock.

The summary of estimation of FRL is provided in Table 26 and Figure 9.

Table 26: Summary of National FRL

Activity	Emission (m t CO_2e yr^{-1})		Removal(m t CO_2e yr^{-1})		Net Removal(m t CO_2e yr^{-1})		FRL (m t CO_2e yr^{-1}))
	2005-2009	**2010-2014**	**2005-2009**	**2010-2014**	**2005-2009**	**2010-2014**	
SMF	0.660	0.605	-6.440	-6.440	-5.780	-5.835	-5.808
Conservation	0.041	0.036	-2.972	-2.972	-2.931	-2.935	-2.933
Enhancement	0.000	0.000	-0.009	-0.032	-0.009	-0.032	-0.021
Total	**0.702**	**0.641**	**-9.421**	**-9.444**	**-8.719**	**-8.803**	**-8.761**

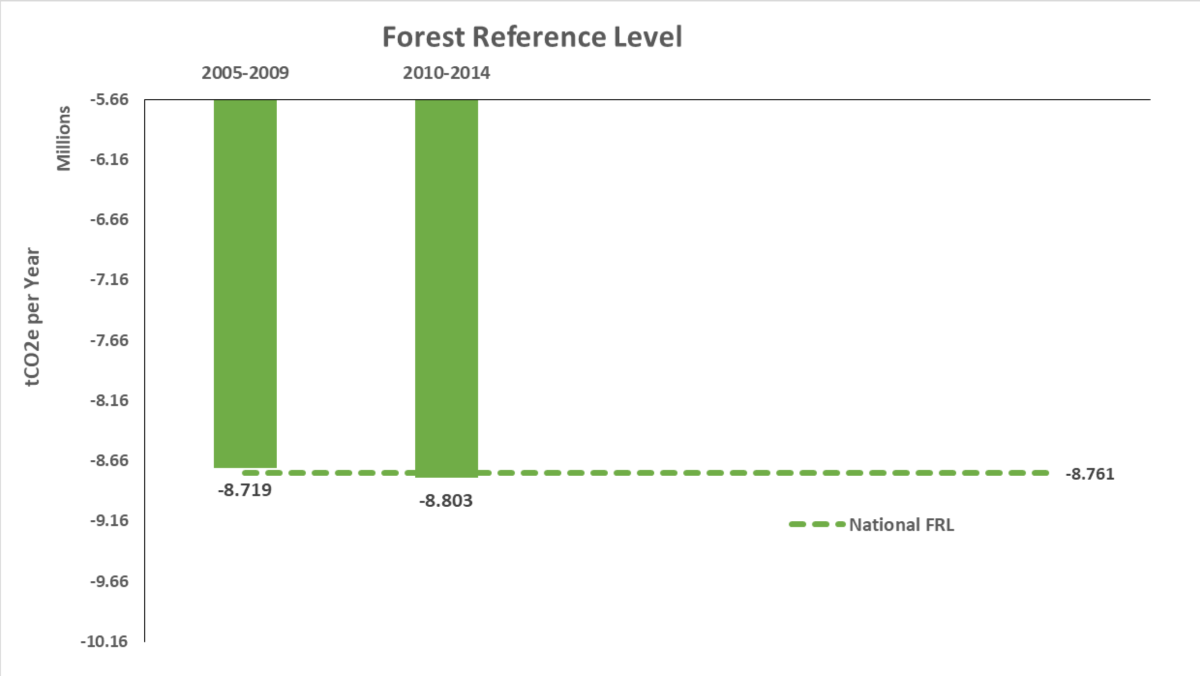

Figure 10: National FRL

10. Uncertainty

The uncertainty associated with activity data and emission factors are reported as margin of errors at 90 % confidence interval.

10.1 Uncertainty in Activity data

Among the activities, Deforestation quantification is based on the remote sensing activity data while Sustainable management of forests, Conservation of forest carbon stock, and Enhancement of forest carbon stock has been estimated based on the official record maintained by DoFPS.

Historical annual average deforestation area is estimated at 263.39 ha with MoE of 12.88 % based on the remote sensing activity data from 2005 to 2014. Remote Sensing methodology adopted was stratified area estimator in SEPAL platform and considered target standard error for overall accuracy at α = 0.05 (FAO, 2015b). The tables 27, 28 and 29 shows the detailed breakdown of the estimates with error or confidence interval of deforestation against each land conversion category.

Table 27: Uncertainty associated with deforestation from 2005-2009

Forest land converted to	Area estimates (ha)	Confidence Interval (ha)	MoE (%)
Cropland	124.99	28.14	22.51
Grassland	312.47	50.73	16.24

Settlement	312.47	70.35	22.51
Other land	187.48	42.21	22.51
TOTAL	**937.41**	**100.48**	**10.72**

Table 28: Uncertainty associated with deforestation from 2010-2014

Forest land converted to	Area estimates (ha)	CI (ha)	MoE (%)
Cropland	272.34	99.88	36.68
Grassland	363.12	133.18	36.68
Settlement	607.11	222.66	36.68
Other land	453.90	166.47	36.68
TOTAL	**1696.48**	**324.04**	**19.10**

Table 29: Uncertainty associated with annual deforestation

Forest land converted to	Annual Average (ha)	MoE (%)
Cropland	39.73	26.12
Grassland	67.56	21.09
Settlement	91.96	25.39
Other land	64.14	26.78
Total	**263.39**	**12.88**

However, uncertainties associated with activity data for SMF, Conservation of forest carbon stock and Enhancement of forest carbon stock is not quantified.

10.2 Uncertainty for Emission factor

Table 30 shows uncertainties associated with different carbon density of different carbon pools used for generating emission factors. The model errors are not reported.

Table 30: Uncertainty associated with Emission factor

Carbon pool	Carbon density (t ha^{-1})	MoE %
ABG	127.05	6.37
BGB	54.52	5.03
Litter	6.23	15.09
Dead Wood	3.03	46.58
SOC	64.07	6.51

11. Future improvement opportunities

Bhutan FREL and FRL construction was based on currently available national data and relevant global data. In some cases, analysis was limited to Tier 1 level. Bhutan would be improving the FREL & FRL submission in future with availability of new data and updated methodology. Potential improvement may include following:

- Explore use of high-resolution remote sensing data for generating national LULC dataset through advanced technologies and methodologies.
- Strengthening FIRMS database to maintain proper record of timber harvest and plantation
- Strengthening National Forest Inventory data management system
- Reducing the non-response plots during the next NFI to reduce uncertainties of Emission factors
- Developing additional species-specific biomass allometric model
- Carbon density modeling and mapping using remote sensing
- Exploring the possibility of assessing carbon locked up in harvested wood products.
- Developing a spatially explicit fire burnt area maps for Bhutan
- Spatial mapping of plantations with survival percent
- Generating the combined estimates of uncertainties for activity data and emission factor and for construction

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