Forest Reference Emission Level (FREL) of Myanmar

Ministry of Natural Resources and Environmental Conservation

Myanmar

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Table of Contents

List of Tables

List of Figures

List of Annex

Acronyms

AD	Activity Data
AGB	Above Ground Biomass
BGB	Below Ground Biomass
BUR	Biennial Update Report
CH_4	Methane
CI	Confidence Interval
CO	Carbon Monoxide
CO_2 eq	Carbon Dioxide Equivalent
CSO	Central Statistical Organization
DBH	Diameter at Breast Height
ECD	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation (MONREC)
EF	Emission Factor
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
FD	Forest Department, Ministry of Natural Resources and Environmental Conservation (MONREC)
FRA	Forest Resource Assessment
FREL/ FRL	Forest Reference Emission Level/ Forest Reference Level
GDP	Gross Domestic Product
GFC	Global Forest Change
GFOI	Global Forest Observations Initiative
Gg	Gigagram
GHGs	Green House Gases
GIS	Geographic Information System
GOFC-GOLD	Global Observation of Forest and Land cover Dynamics
GPG	Good Practice Guidance
Ha	hectare
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRS	Indian Remote Sensing Satellites
LUKE	Natural Resources Institute Finland
LULUCF	Land Use, Land Use Change and Forestry
MCCSAP	National Climate Change Strategy and Action Plan

MGD	Methods Guidance Document
mm/year	millimeter per year
MOALI	Ministry of Agriculture, Livestock and Irrigation
MRV	Measuring, Reporting and Verification
N_2O	Nitrous Oxide
NAPA	National Adaptation Programme of Actions
NDC	Nationally Determined Contribution
NFI/ NFMIS	National Forest Inventory/ National Forest Monitoring Information System
NFMS	National Forest Monitoring System
NO_2	Nitrogen Dioxide
NRRPM	National Reforestation and Rehabilitation Programme in Myanmar
PaMs	Policy and Measures
PAS	Protected Area System
PFE	Permanent Forest Estate (RF + PPF)
PPF	Protected Public Forest
REDD+	Reducing Emissions from Deforestation and Forest Degradation, and Conservation, Sustainable Management of Forest and Enhancement of Forest Carbon Stocks
RF	Reserved Forest
RS	Remote Sensing
SBSTA	Subsidiary Body for Scientific and Technological Advice
SE	Standard Error of Sample Mean
SEPAL	System for Earth Observation Data Access, Processing and Analysis for Land Monitoring
SIS	Safeguard Information System
SNC	Second National Communication
STRS	Stratified Random Sample
TA	Technical Assessment
TWGs	Technical Working Groups (Drivers and Strategy TWG, Stakeholder Engagement and Safeguard TWG and MRV TWG)
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation, and Conservation, Sustainable Management of Forest and Enhancement of Forest Carbon Stock

Summary

The Government of Myanmar is fully aware of the causes and potential impacts of climate change. Myanmar actively participated in global climate change mitigation efforts as a non-Annex 1 party. Nationally Determined Contribution (NDC) was submitted in 2016. Under the NDC, forestry is a key sector and quantitative targets are likely to be included. Myanmar's Initial National Communication (INC) was submitted to UNFCCC in 2012 and the Second National Communication (SNC) is now under preparation. Currently, Myanmar views REDD+ initiatives as a contribution to the green development of Myanmar as well as supporting the mitigation of, and adaptation to, climate change. In addition, the Government of Myanmar stressed that the national REDD+ Programme is critical to their mitigation and adaptation pledges according to its country statement to COP 23.

Following the suggestion of Decision 12/CP.17, Myanmar prepared its FREL using a stepwise approach. This initial FREL submission will be a benchmark for assessing its performance in implementing REDD+ activities in contribution to climate change mitigation. The main objective of the FREL submission is to support the climate change mitigation efforts under the national context of Myanmar. Further objectives of the submission are;

- To assess and evaluate the performance of REDD+ policies and measures and sustainable forest management practices
- To provide information on emission projections to stakeholders including policy makers, government line departments, technicians and members of the public on a clear, transparent and consistent basis.
- To facilitate access to potential funding sources for results-based payments and to support efforts to reduce emissions from the forest and land use sector.

The development of the FREL was initiated by a group of experts; TWG on Measuring Reporting and Verification (MRV), representing a cross-section of ministerial agencies

and organizations. This submission is largely due to the effort and commitment of the members of this TWG.

Myanmar FREL is national level as all the existing land and forest monitoring and measurement capacities are at the national level. Initially, Myanmar prioritized two of the five REDD+ activities as the focus of the country's first FREL/FRL submission; deforestation and enhancement of forest carbon stock through afforestation/reforestation. In particular, the Government of Myanmar aims to include data on enhancement of forest carbon stocks, in recognition of the potential importance of plantation and forest restoration measures to climate change mitigation efforts. Work on improvement of data on historical forest enhancement is currently ongoing, and once incorporated into the calculations within this document, either during the Technical Assessment (TA) process, or as part of a revised submission, will convert the FREL to a FRL. At the time of this submission, therefore, the scope of the FREL is limited to **deforestation only.**

Three carbon pools of Above Ground Biomass (AGB), Below Ground Biomass (BGB) and Litter are included in this FREL, using allometric equations derived from district forest management and according to IPCC Good Practice Guidance. This submission omitted soil and deadwood carbon pools due to limited information/data at national level. Strategies are currently being developed to facilitate the inclusion of these two pools in forthcoming submissions. Myanmar submitted only CO_2 gas in this initial FREL although there are also non- CO_2 emissions from LULUCF.

Through a series of consultation meetings, the proposed reference period was identified as the period from 2005 to 2015, due to the availability of the most reliable national existing Activity Data (AD) and Emission Factors (EF) for this period. Consistency with GHGs Inventory reporting was also considered for this submission. Data generated in this FREL development process will benefit the SNC and the Biennial Update Report (BUR) to the UNFCCC.

AD have been developed by estimating the extent of forest change measured as gross area estimates of forest, non-forest and deforestation during 2005-2015, excluding forest degradation, forest improvement and forest area gain. The amount of deforestation (forest loss) has been estimated using a sample based approach. Following the IPCC (2003, 2006) guidelines and the GFOI (2016) methods guidance documents, the bias-corrected area estimates with confidence intervals were calculated. The bias-corrected forest loss is about 387,527 ha per year over the period 2005-2015.

This submission applied data generated from 11,284 inventory plots of district level forest inventory that were collected during 2005 to 2017. A combination of Tier 1 and 2 approaches were used in estimating these carbon pools using the management inventory of 40 districts. *Weighted mean values of tCO_2 eq per ha* through the calculation based on 40 districts forest inventory result in a national EF of ***125.43 tCO_2 eq*** *per ha*. *Annual CO_2 emission from deforestation* during the historical reference period 2005-2015 is estimated as ***48,607,511 tons per year***.

This submission follows the IPCC Good Practice Guidance and Uncertainty Management of National Greenhouse Gas Inventories. The uncertainty only includes sampling error through the propagation of errors and not allometric equation errors. The *% uncertainty of AD, i.e.* Forest loss area is *9.89 %* for this submission whereas the *% uncertainty of 40 district forest inventory* and resulting *overall % is 12.10* for this submission.

In conclusion, Specific activities which are either planned or ongoing for improvement of AD and EF, especially strengthening of the national forest monitoring and information system and in order to provide more qualified data and information for future FREL/FRL submissions, are also mentioned in this submission.

Forest Reference Emission Level (FREL) of Myanmar

1. Introduction

The Government of Myanmar is fully aware of the causes and potential impacts of climate change. Myanmar actively participated in global climate change mitigation efforts by ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and the Kyoto Protocol in 2003 as a non-Annex 1 party. Currently, Myanmar views REDD+ initiatives as a contribution to the green development of Myanmar as well as supporting the mitigation of, and adaptation to, climate change. Myanmar became a partner country of the UN-REDD Programme in December 2011 and has quickly taken steps to start implementing REDD+ Readiness activities. Regarding Decision 1/CP.16, paragraph 71(b) of the 16th Conference of Parties to the UNFCCC (COP 16) in Cancun, 2010, a Forest Reference Emission Level and/or Forest Reference Level (FREL/FRL) is one of the four key elements to be developed to participate in REDD+ and its submission is on a voluntary basis.

Myanmar submitted its Intended Nationally Determined Contribution (INDC) in 2015 as a contribution to global climate change mitigation and adaptation efforts. It was confirmed as the country’s first Nationally Determined Contribution (NDC) after ratification of the Paris agreement in 2016. Under the NDC, forestry is a key sector and quantitative targets are likely to be included. Furthermore, in their statement to COP 23 in 2017, the Government of Myanmar stressed that the national REDD+ Programme is critical to their mitigation and adaptation pledges. Myanmar’s Initial National Communication (INC) was submitted to UNFCCC in 2012 and the Second National Communication (SNC) is now under preparation.

Following the suggestion of Decision 12/CP.17, Myanmar prepared its FREL using a stepwise approach. Myanmar prepared this initial FREL submission as a benchmark for assessing its performance in implementing REDD+ activities in contribution to climate change mitigation. The proposed FREL in this submission is entirely based on historical data which Myanmar considers to be transparent. Nonetheless, the choice of using average historical emissions as its benchmark was made after consideration of the national circumstances and expected future development plans. This submission will also be consistent with anthropogenic forest-related greenhouse gas emissions as contained in the country's GHGs inventories of the SNC. This submission covers all natural forests, covering approximately 52% of the total country land area in 2005. The scope of this FREL submission covers one REDD+ activity (reduced deforestation), three carbon pools (AGB, BGB and litter), and CO_2 only, with the final FREL calculation expressed in tons of carbon dioxide equivalent per year (tCO_2 eq). Since the submission covers only emissions of Greenhouse Gases (GHGs), not removals, it is considered a Forest Reference Emission Level (FREL), rather than a Forest Reference Level (FRL), and is referred to as such throughout this document. Myanmar intends to expand the scope of the FREL as more extensive and better quality data become available.

In particular, the Government of Myanmar aims to include data on enhancement of forest carbon stocks, in recognition of the potential importance of plantation and forest restoration measures to climate change mitigation efforts. Work on improvement of data on historical forest enhancement is currently ongoing, and once incorporated into the calculations within this document, either during the Technical Assessment (TA) process, or as part of a revised submission, will convert the FREL to a FRL.

1.1. Objectives of FREL

The main objective of the FREL submission is to support the climate change mitigation efforts under the national context of Myanmar. The national REDD+ Programme is critical to the mitigation and adaptation pledges according to the Myanmar Country Statement submitted to COP 23. Further objectives of the submission are;

- To assess and evaluate the performance of REDD+ policies and measures and sustainable forest management practices

- To provide information on emission projections to stakeholders including policy makers, government line departments, technicians and members of the public on a clear, transparent and consistent basis.
- To facilitate access to potential funding sources for results-based payments and to support efforts to reduce emissions from the forest and land use sector.

This is also one of the key technical reports to support the efforts of multiple stakeholders to achieve the goal of reducing deforestation. With the submission of this initial FREL, the country team wishes to interact with the UNFCCC through a technical assessment to improve the current document and technical approaches. This submission will also provide information to facilitate effective implementation of forest management plans in order to contribute to climate change mitigation targets.

1.2. Summary of guidance *considered for FREL development*

The following four major decisions at the level of the UNFCCC are related to the development of FREL/FRLs and were considered during the process of developing Myanmar´s FREL:

- Decision 4/CP.15 in Copenhagen recognizes that developing countries in establishing FREL/FRLs should do so transparently considering historic data, and adjust for national circumstances;
- Decision 1/CP.16, paragraph 71(b) of Cancun includes FREL/FRLs as one of the four key elements to be developed for REDD+;
- Decision 12/CP.17 Durban provides guidance for modalities of development of FREL/FRLs, as follows;
    - Express FREL/FRLs in tons of carbon dioxide equivalent (tCO_2 eq) per year, in order to serve as benchmarks for assessing the country's performance in implementing REDD+ policies and measures
    - Maintain consistency with anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks as contained in the country's GHG inventories

- Follow a step-wise approach to national FREL/FRL development, enabling Parties to improve FREL/FRLs by incorporating better data, improved methodologies and, where appropriate, additional pools,
- Sub-national FREL/FRLs may be elaborated as an interim measure, while transitioning to a national FREL/FRL, and
- Update FREL/FRLs periodically as appropriate, considering new knowledge, new trends and any modification of scope and methodologies

- Decision 13/CP.19 Warsaw provides guidelines on procedures for the Technical Assessment (TA) of submissions of FREL/FRLs, including:
  - Each FREL/FRL submission shall be subject to a technical assessment
  - Submission is on a voluntary basis
  - Technical assessment is possible also in the context of results-based payments
  - A synthesis report on the TA process is prepared by the Secretariat, for consideration by SBSTA after the first year of technical assessments
  - Countries are invited to nominate experts to the roster for TA as well as to support capacity-building efforts in relation to the development and assessment of FREL/FRLs

The UNFCCC decisions considered at the country level in Myanmar can then be summarized as follow:

- A transparent process in developing the FREL was applied
- The FREL is based on historical data
- The FREL is consistent with the upcoming GHG inventory under development for the Second National Communication (coordinated by ECD),
- The FREL has been developed with a stepwise approach in mind as well as the present measuring capacities in country (which are expected to improve over the coming years). In particular, within the short term, it is expected that the scope of the FREL will be extended to include enhancement of forest carbon stocks.

2. National Context

2.1. National circumstances

The Republic of the Union of Myanmar is a largely rural country, with 70% of its total population of 51.5 million people living in rural areas. In Myanmar, there are around 135 different ethnic groups with 100 different languages. The rural population still relies primarily on biomass for energy purposes, as only 30% of the total population has access to electricity (Population Census, 2014). The rate of population growth is 0.8% per year with an increase of 2.5% in urban areas and a decrease of 0.1% in rural areas. The agricultural sector is still a major contributor to the country's economy, accounting for roughly 30%[1] of Gross Domestic Product (GDP).

Myanmar is in a process of economic and political reform with the overall goal of becoming a modern, developed and democratic nation by 2030. The political reform process is accompanied by a structural reform process of the economic sector with strong and increasing foreign direct investment. However, significant challenges still exist with wide socio-economic gaps and sub-national inequalities in poverty and other human development indicators. In particular, geographically remote areas (e.g. Chin and Rakhine states) are suffering from low levels of infrastructure and lack of basic social services (especially health and education) and job opportunities.

Additionally, inequalities between women and men are particularly significant in the country. Women, especially from forest-dependent communities, participate unequally in socio-political and decision-making processes, due in significant part to an inferior status in a religious context and the institutionalization of the view within society that gender inequality is not a problem. Policies and strategies are in the process of being reviewed and updated for all sectors of the country in order to support gender inclusiveness in the overall comprehensive national development plan and the fulfilment of sector specific gender-related targets and goals.

[1] http://www.csostat.gov.mm/

Current economic development is concentrated on the regions of the country which are particularly exposed to climate hazards such as cyclones, heavy rain, flooding, drought or erratic rainfall (e.g. the regions of Ayeyarwady, Bago, Mon, Rakhine and the Central Dry Zone in general). Negative impacts on agriculture, fisheries, livestock or forestry will be especially felt by the poor and smallholder farmers which constitute the great majority of all farmers in the country. Those regions are also the ones with the highest rates of deforestation over the last 10 – 15 years. The economic and social circumstances in Myanmar as well as the cultural and ethnic diversity make climate change mitigation (including REDD+) challenging and all the proposed policies and measures need to be thoroughly screened for potential negative impacts on people's livelihoods.

2.2. Myanmar's Nationally Determined Contributions-(NDC) submission and relation to the FREL

The 2016 NDC document of Myanmar formulates several actions relevant for climate change mitigation. The main mitigation actions concerning forest and land use are as follows:

- Fulfilment of the national Permanent Forest Estate (PFE) target by 2030 with an increase of Reserve Forests (RF) and Protected Public Forests (PPF) to 30% of the national land area and the Protected Area System (PAS) to 10% of the national land area.
- Energy efficient cook stoves in order to reduce fuel wood for energy purposes, especially for the Dry Zone of Myanmar. The target is to distribute 260,000 new cook stoves between 2016 and 2030.

Based on the 2012 National Adaptation Programme of Actions (NAPA), adaptation actions are described in the NDC for different levels of priority and sectors. Forest preservation measures, together with resilience in the agricultural sector and early warning systems, are among the first priorities. In addition, several strategies and policies are in process of development, or already being implemented, in order to support the achievement of targets such as those in the National Climate Change Strategy and Action Plan (MCCSAP); Green Economy Strategic Framework; National Environmental Policy, Framework and Master Plan; Environmental Conservation law; Environmental Impact Assessments (EIAs), and state of Environment reports etc. According to the MCCSAP, the action area of "environment and natural resources" includes REDD+ and LULUCF. For REDD+ specifically (and linked to the overall MCCSAP goal) the following REDD+ goal is envisioned:

"The Land Use and Forestry Sector contributes to an overall low-carbon development pathway of the Nation through reducing deforestation and forest degradation and the related GHG emissions while enhancing the livelihood of forest dependent people and communities as well as ensuring inclusive sustainable growth and development of the country as a whole".

For the policy area of Forest Management, the implementation of the National Forestry Master Plan (2001-2030) is mentioned as well as the national Biodiversity Strategy and Action Plan of 2015-2020.

The NDC does not lay out quantitative targets for emission reductions. Its mitigation section focuses on forestry by maintaining Myanmar's carbon-sink status. An update of the NDC, using more concrete, quantifiable data, is currently in process.

2.3. Forests in Myanmar

Myanmar forests are diverse and varied in composition and structure, and constitute a valuable ecosystem due to their wide extent (between latitudes 958' - 28 29' N and longitudes 92 10' - 101 10' E), varied topography and different climatic conditions. The forests are distributed over three main climatically distinct regions (Tropical, Subtropical and Temperate). The Forest Department of Myanmar recognized and adopted eight dominant forest types, (Burmese Forester, June 1956, Departmental Instructions for Forest Officers in Burma, Annex VIII, pages 214 – 217) as described in Table 2.1.

Table 2. 1: Area coverage of the major forest types and rainfall range

Forest types	Typical rainfall (mm/year)*	% of total forest area
I. Tidal/ Mangrove Forests **II. Beach and dune forests** **III. Swamp forests**	>3,500	4
IV. Hill and temperate evergreen forest **a. Hill evergreen forests** **b. Dry hill forests** **c. Pine forests**	>3,000	26
V. Evergreen forest **a. Riverine evergreen forests** **b. Giant evergreen forests** **c. Typical evergreen forests**	2,500-4,000	16
VI. Mixed deciduous forest **a. Moist upper mixed deciduous forests** **b. Dry upper mixed deciduous forests** **c. Lower mixed deciduous forests**	1,250-2,500	39
VII. Deciduous *Dipterocarp* forest **a. High *indaing* forests** **b. Semi-*indaing* forests** **c. Scrub *indaing* forest**	900-1,250	5
VIII. Dry forest **a. Than-dahat forests** **b. Thorn forests**	< 900	10
Total		100

Source: Davis, 1960, Kermode, 1964, Kress et.al. 2003, Departmental Instruction of FD

There is no recent study that provides an update of national-level distribution and extent of these different forest types in Myanmar. According to available information, the most abundant forest types are the tropical Mixed Evergreen and Deciduous forest, both containing upland and lowland subtypes. These forest types are well known for the occurrence of teak and other valuable timber species that are subject to commercial timber logging. The subtropical forests, which are scattered over slopes and peaks of hill and mountain ranges, e.g., in Chin and Shan states, are traditionally under the influence of shifting cultivation carried out by local communities for their livelihood. In recent years, logging has been extended to lowland Evergreen Hardwood forests (e.g. Tanintharyi region, Southern Myanmar) sometimes followed by conversion to oil palm and rubber plantation on accessible or degraded stands (Rao *et al*., 2013). The tropical dry forest types in Myanmar, concentrated in the Central Dry Zone of the country, are also affected by human activity (e.g. conversion to agriculture, firewood collection) as well as forest fires. Although the latter can cause serious soil degradation, they are part of the natural dynamics in some open dry or savannah-like forests where species occur which can benefit from burning (Ratnam *et al.*, 2011). Forests on wetlands, especially mangroves along the coastlines and freshwater swamp forests in river deltas (e.g. Ayeyarwady) are threatened by agriculture and aquaculture (e.g., shrimp farming), unsustainable collection of firewood or coastal development activities (Stibig *et al*., 2007).

2.4. Forest Land Use and Land Cover by Forestry Legislation

Myanmar has a decentralized statistical system where the Central Statistical Organization (CSO) and line ministries have responsibilities for data collection in their respective domains. As a decentralized statistical system, statistical production activities are scattered across the ministries and agencies. According to the Forest Law, all forest areas and forest tree cover are subject to declaration as Permanent Forest Estate (PFE) and administered by the Forest Department (FD) under MONREC. The FD is responsible for protection and conservation of biodiversity and sustainable management of the country’s forest resources through establishment of PFE. PFEs include all forested areas on Land at the Disposal of the Government and constitutes Reserved Forest (RF), Protected Public Forest (PPF) and the Protected Areas System (PAS). RF and PPF are accorded similar legal status under the Forest Law. The status of land as PF indicates administrative responsibility for FD but does not directly imply any information regarding tree cover. Table 2.2 shows the major land categories reported to CSO by % of total country area;

Table 2. 2. : Major Land Categories Reported to CSO

No	Major Land Categories	2013-2014	2015-2016
1	Forest Land (RF, PPF, PAS)	27.64%	27.42%
2	Agriculture Land (6 sub categories)	18.08%	18.41%
3	Vacant Land/Virgin Land/ Cultivable Waste Land (2 sub categories)	29.75%	29.54%
4	Other Land (13 sub categories)	24.53%	24.62%

2.5. REDD+ development in Myanmar

Myanmar is a signatory to the UNFCCC, having ratified the convention in November 1994 and signed the Kyoto protocol in 2003. The government of Myanmar together with many key stakeholders is aware of the causes and potential impacts of climate change and is striving to reduce its GHG emissions and contribute to climate change mitigation. Myanmar became a partner of the UN-REDD Programme in December 2011. During 2012 and 2013, a REDD+ Readiness Roadmap was developed through a national multi-stakeholder consultation process[2]. The process of implementing the Roadmap is currently underway, in order to establish the national REDD+ design elements according to the Warsaw framework for REDD+ (COP 19). A stakeholder engagement process has been established and a safeguards roadmap has been developed with the objectives of clarifying safeguards in the national context and setting the ground for a future Safeguard Information System (SIS). REDD+ strategy development began in 2016 with a comprehensive driver analysis and a first draft of a REDD+ strategy document was developed by the end of the first quarter of 2017

[2] The proceedings of the workshops are available on the country page of Myanmar on the UN-REDD workspace (www.unredd.net)

through series of discussions with relevant Technical Working Groups[3] and wider stakeholder consultations. Sub-national consultations on the REDD+ strategy began in the last quarter of 2017 and are expected to be completed in 2018. Action plans for a National Forest Monitoring System (NFMS) and FREL/FRL were developed during 2015 and implementation is ongoing.

The development of the FREL was initiated by a group of experts representing a cross-section of ministerial agencies and organizations. The TWG on Measuring Reporting and Verification (MRV) provided technical guidance and direction on the implementation of both the NFMS and FREL/FRL action plans. The MRV TWG provides a forum to access national technical capacities and institutional arrangements within Myanmar, for both NFMS and FREL/FRLs development for REDD+. This submission is largely due to the effort and commitment of the members of this TWG.

3. Definitions

Definitions used for the FREL are also consistent with those used in relation to SNC and NDC preparation, including as follows;

3.1. Forest definition

The definition of 'forest' in Myanmar follows that used for the FAO Forest Resource Assessment (FRA): "**Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent or trees able to reach these thresholds in situ**". In addition to land cover, land use is also considered in identifying areas that fall under this forest definition. Therefore it does not include land that is predominantly under agricultural or urban land use. However, it also excludes temporarily de-stocked land for which the long-term use remains forest. This definition was also applied by FD, MONREC for satellite image classification in the national forest resource assessment. In the context of this submission, 'forest' refers

[3] There are three Technical Working Groups for REDD+ in Myanmar, which are (1) Stakeholder Engagement and Safeguard TWG, (2) Drivers and Strategy TWG and (3) Monitoring, Reporting and Verification TWG. Detail TORs are available through http://www.myanmar-redd.org/.

to all areas under forest cover which meet the above criteria, both under PFE and outside PFE as mentioned in section 2.4.

3.2. Deforestation definition

Deforestation is defined as **the conversion of forest land use into to non–forest land use** (i.e., 100% loss of AGB). This FREL submission takes into account the complete conversion of forest land use to other land use during the period 2005-2015, not including land that was temporarily de-stocked (and subsequently restocked) during this period.

3.3. Enhancement of forest carbon stocks through reforestation/afforestation activities

Enhancement of forest carbon stocks through reforestation/afforestation is defined as **the development of new carbon pools resulting from the change of non-forest land use to forest land use**. This submission does not include enhancement due to reforestation/afforestation activities due to insufficient data, but work is ongoing to include this as soon as possible. Enhancement of forest carbon stocks may also occur in forest land remaining as forest land. This submission excludes this latter aspect of enhancement due to data limitation, but will be included at a later date.

4. Scale

In accordance with the draft REDD+ strategy, Myanmar FREL is national level. A national scale FREL is appropriate as all the existing land and forest monitoring and measurement capacities are at the national level and there is currently limited capacity at the sub-national level.

5. Scope (activities, pools, gases)

5.1. REDD+ activities

Myanmar prioritized two of the five REDD+ activities as the focus of the country's first FREL/FRL submission; deforestation and enhancement of forest carbon stock through afforestation/reforestation, for FREL/FRL calculation due to the following reasons;

- Deforestation is estimated to be the main contribution to the total emissions from the land use, land use change and forestry (LULUCF) sector in Myanmar;
- To measure the impact and effectiveness of the existing National Reforestation and Rehabilitation Programme in Myanmar (NRRPM)

In common with many other developing countries, Myanmar experiences both deforestation and forest degradation due to various anthropogenic effects. The measurement of deforestation, however, is possible using data and methodologies currently available at the national level, whereas considerable further work is required before the change of carbon stocks in forest remaining as forest can be measured with confidence. Moreover, it is currently estimated that the impact of deforestation, in recent years, has had more of an impact on forest carbon stocks than forest degradation. The definition of forest degradation, and methodologies to assess and measure it, are currently under discussion and will be included in future submissions. The definition of conservation of forest carbon stocks and sustainable management of forests, in the context of REDD+, will also be further considered, but at present it is assumed that the impact of these two REDD+ activities will be captured by measurement of deforestation and forest degradation.

The NRRPM was initiated in 2017 and is intended to continue to 2026-2027. The NRRPM has been accorded priority in national forest sector policy in recognition of the fact that the provision of forest products and services from natural forests is insufficient to meet demand. Under the NRRPM, establishment of new plantations in degraded forest areas and restoration of natural forests by silvicultural practices are being conducted through systematic planning, implementation and monitoring.

Enhancement of forest carbon stocks was therefore prioritized as the second activity in the FREL/FRL submission for Myanmar, initially with a focus on afforestation/reforestation.

The data used and the methodology employed to develop this initial submission was sufficient to measure deforestation, due to the substantial areas affected during the reference period of 2005-2015. However, they were insufficient to measure enhancement from afforestation/reforestation during this period, due to the much smaller areas affected. At the time of this submission, therefore, the scope of the FREL is limited to **deforestation only**, but work is ongoing to improve data so that enhancement from afforestation/reforestation can be added.

5.2. Pools and gases

Three carbon pools of Above Ground Biomass (AGB), Below Ground Biomass (BGB) and Litter are included in this FREL, using allometric equations derived from district forest management and according to IPCC Good Practice Guidance. This submission omitted soil and deadwood carbon pools due to limited information/data at national level. Strategies are currently being developed to facilitate the inclusion of these two pools in forthcoming submissions. Several site-specific studies on soil carbon content have been carried out in the past, though these have not yet been correlated with land cover classes at national scale. Approaches to include soil carbon in future FREL/FRLs will initially focus on expert analysis of these past studies. Dead wood is also omitted due to a lack of country specific data. IPCC (2006) also does not provide default values for dead organic matter stocks, particularly dead wood, due to the fact that these are highly variable and site-specific, depending on forest type and age, disturbance history and management. In addition, data on coarse woody debris decomposition rates are scarce and thus, IPCC explains, it was deemed that globally applicable default factors and uncertainty estimates cannot be developed (IPCC 2006, Volume 4 Chapter 2.2.1).

Myanmar submitted only CO_2 gas in this initial FREL although there are also non- CO_2 emissions from LULUCF. Myanmar's INC report included non- CO_2 gases from biomass burned due to land clearing and forest fire. These non-CO_2 gases included CH_4, N_2O and NO_2 and the total combined emissions were 637 Gg[4] while that of CO_2 was 102,264 Gg. Based on the data in the INC, therefore, this submission considers the contribution of non-CO_2 gases to be insignificant.

6. Reference period of FREL

Through a series of consultation meetings, the proposed reference period was identified as the period from 2005 to 2015, due to the availability of the most reliable national existing Activity Data (AD) and Emission Factors (EF) for this period. Consistency with GHGs Inventory reporting was also considered for this submission. Currently the SNC is being prepared based on 2010 data sets by using IPCC GPG 2003 and 2006 in order to ensure consistency with the development of AD and EF for the FREL.

Although the reference period does not overlap with the INC, which used data from the year 2000, The INC used EF based on IPCC global default factors and AD based on the projected data from the FRA. This FREL used AD based on real time estimation and EF from district management inventory. The emission factors are therefore considered as national specific data and more detailed compared to the previous GHGs inventories. Data generated in this FREL development process will benefit the SNC and the Biennial Update Report (BUR) to the UNFCCC.

7. Data used in the FREL

7.1. Activity data

According to the revised IPCC Guidelines for National Greenhouse Gas Inventories, Activity Data (AD) are defined as data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time. The emissions include human activities resulting from deforestation and from forest degradation while the removals include forest gain or enhancement of canopy cover. In this report

[4] **1** Gg = **1000** ton

the AD have been developed by estimating the extent of forest change measured as area estimates of forest, non-forest and deforestation during 2005-2015, excluding forest degradation, forest improvement and forest area gain. The amount of deforestation (forest loss) has been estimated using a sample based approach. The data sets used to generate activity data are listed in Annex 1.

7.1.1. Rationale of sample-based approach:

Wall-to-wall maps for the years 2005, 2010 and 2015 have been prepared by the Remote Sensing and GIS (RSGIS) unit of Myanmar Forest Department (see Annex 1). These wall-to-wall maps were pixel-based and are produced through supervised maximum-likelihood classifiers using imagery from Landsat (30 m), for the years 2005 and 2015, and using imagery from IRS (23.5 m) for the year 2010. The eleven national land use/cover categories are compatible with IPCC land use/cover classes and FAO-FRA classes (Annex 2).

The post-classification change detection method could be a suitable option to estimate changes within and across different land cover types (IPCC, 2006). In this method, the AD for each mapping year could be derived using estimates from each map on various land-cover classes, as sum of areas of map units assigned to map classes are characterized as *pixel counting*.

The three wall-to-wall maps (Annex 3) were produced by different people in the RS & GIS unit without defining standard operating procedures which could be followed to maintain quality control or reproduced in the context of a long-term forest monitoring system. Moreover, the mapping datasets (satellite imagery) used to produce maps were not from the same reference year. For example, the year 2005 map had been produced from Landsat imagery collected during 2004-2006.

Following a detailed evaluation, errors in the wall-to-wall maps were assumed to be substantial because the maps have shown inconsistencies in geo-locations both within individual maps and across three temporal maps. The causes of these inconsistencies are uncertain and might be attributed to, for example, lack of consistent application of mapping between time periods, inconsistencies in classification procedures, and inconsistencies in map qualities (IPCC, 2006).

According to IPCC Good Practice Guidance (2003), AD should be neither over- nor under-estimates (without bias or quantification of bias) and uncertainty should be reduced as much as practically possible. The existing wall-to-wall maps, generally, make no provision for accommodating the effects of map classification errors (Foddy, 2010). Moreover, the map accuracy assessment indices (error matrix) can inform issues of systematic errors and precisions but they do not directly produce the information necessary to construct confidence intervals. Therefore, the pixel-counting-based wall-to-wall approach provides no assurance that estimates are unbiased or that uncertainties are reduced (GFOI, 2016).

We therefore used a sample-based approach as an independent method to derive estimates between 2005 and 2015 of forest, non-forest and areas of deforestation only. Among various types of probability-based sampling design, stratified random sample (STRS) design has been used. The STRS offers the option to increase the sample size in change class and forest loss in a portion of the total area, and reduce the standard errors of the class-specific accuracy estimates for rare classes such as deforestation. In addition, STRS is one of the easier designs to implement and have unbiased variance estimators (Olofsson et al., 2014).

It is necessary to identify a spatially-explicit forest change map for a given period by using a combination of the multiple maps within the same period. The forest change areas often occupy a small proportion of the landscape and assumptions of the STRS design largely depend on accurate delineation of the change strata. Given the limitations of the wall-to-wall maps, as described above, Global Forest Change (GFC) maps[5] (Hansen et al., 2013) were used to generate the strata map for the years 2005-2015. The GFC maps were adjusted to the forest definition adopted by Myanmar; a minimum of 5 m canopy height and a minimum tree canopy cover of 10% within a 0.5 ha area. The GFC maps are transparent and consistent and offer a complete application of the independent sample-based approach. Figure 7.1 illustrates the steps

[5] https://earthenginepartners.appspot.com/science-2013-global-forest

followed to generate stratified random sample-based estimates of forest change between 2005 and 2015.

A tree cover map of 2000 and gross forest cover loss data from 2001 to 2015 were used to produce forest change (loss) strata map from 2005 to 2015. A forest gain map was not used in stratification because the gain map did not indicate the years of change, which would be required to identify the amount of forest gain (enhancement) between 2005 and 2015. Through the *Stratified Area Estimator – Design* tool within FAO's **System for Earth Observation Data Access, Processing and Analysis for Land Monitoring** (SEPAL[6]), a total of 1,884 stratified random samples were generated using the GFC-based strata map of 2005-2015.

The validation process followed recognized design considerations in which three distinctive and integral phases are identified: **sampling design**, **response design**, and **analysis and estimation** (Stehman and Czaplewski, 1998).

Figure 7. 1: Steps followed to produce stratified random sample-based estimates of forest change during 2005-2015 in Myanmar.

Step 1: Forest Change Map 2005-2015

Forest/NonForest Map 2005

Forest/NonForest map 2000 (≥10% canopy cover threshold from the treecover2000 map) + Gross forest cover loss event (loss year) 2001-2005 (Hansen et al., 2013)

Forest/NonForest Map 2015

Forest/NonForest map 2005 + Gross forest cover loss event 2006-2015 (Hansen et al., 2013)

Stratification: Forest change map 2005-2015

Stratified Forest Change Map 2005-2015: Three strata (Forest, NonForest, Loss) were generated from Forest/NonForest 2005 Map and Forest/NonForest 2015 Map

Step 2: Generate Samples

Generate stratified samples

The stratified forest change map 2005-2015

Sample size formula of Cochran (1977)

Sample generation: Sepal platform (http://sepal.io)

Sample survey design

using survey designed in Open Foris Collect

[6] https://sepal.io/

Step 3: Sample Assessment

Sample assessment:

Using Collect Earth Tool in Open Foris Collect. Interpreters' check every sample for a Forest or NonForest cover, using available high-quality validation datasets in Google Earth, Bing Map and Google Earth Engine; accessible through Collect Earth.

Quality Control

Following a standard operating procedure, all interpreters were allocated 70 samples randomly selected which followed by consistance check.

All assessed samples were randomly rechecked for quality control through open discussuion for assurance of quality check.

Step 4: Straified Estimator Analysis

Prepare master sample assessment file

By combining all files from different interpreters following quality control

Stratified Estimator - Analysis: Using SEPAL platform (http://sepal.io)

Sample-based area estimates of three land cover classes: Forest, NonForest and Loss were generated from a stratified randon design sampling estimators and from a theoretical simple random design sampling estimators.

7.1.2. *Sample design*

The sampling design refers to the methods used to select the locations at which the reference data are obtained, in this case, the methods through which the 1,884 samples were derived from the GFC-based strata map of 2005-2015 using SEPAL's *Stratified Area Estimator – Design* tool. By default, this tool allocates a minimum of 50 samples in the smallest stratum, following the Cochran (1977) formula (see **Equation 1 below**) (Olofsson et al., 2014), which in this case is the forest loss stratum. However, a total of 300 samples, out of 1,884 samples, were generated for the forest loss stratum with an aim to reduce standard error for the change user's accuracy estimate. Figure 7.2 shows the distribution of the samples across Myanmar.

Equation 1

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

Where: $N = number\ of\ units\ in\ the\ region\ of\ interest$

$S(\hat{O})\ is\ the\ standard\ error\ of\ the\ estimates\ over\ all\ accuracy\ that\ we\ would\ like\ to\ achieve,$

$W_i = mapped\ proportion\ of\ area\ of\ class\ i,$

$S_i = standard\ deviation\ of\ stratum\ i, S_i = \sqrt{U_i(1 - U_i)}$

Figure 7. 2: Distribution of the 1,884 samples across Myanmar.

(a) Stratified forest change map 2005-15 (b) Stratified random sample

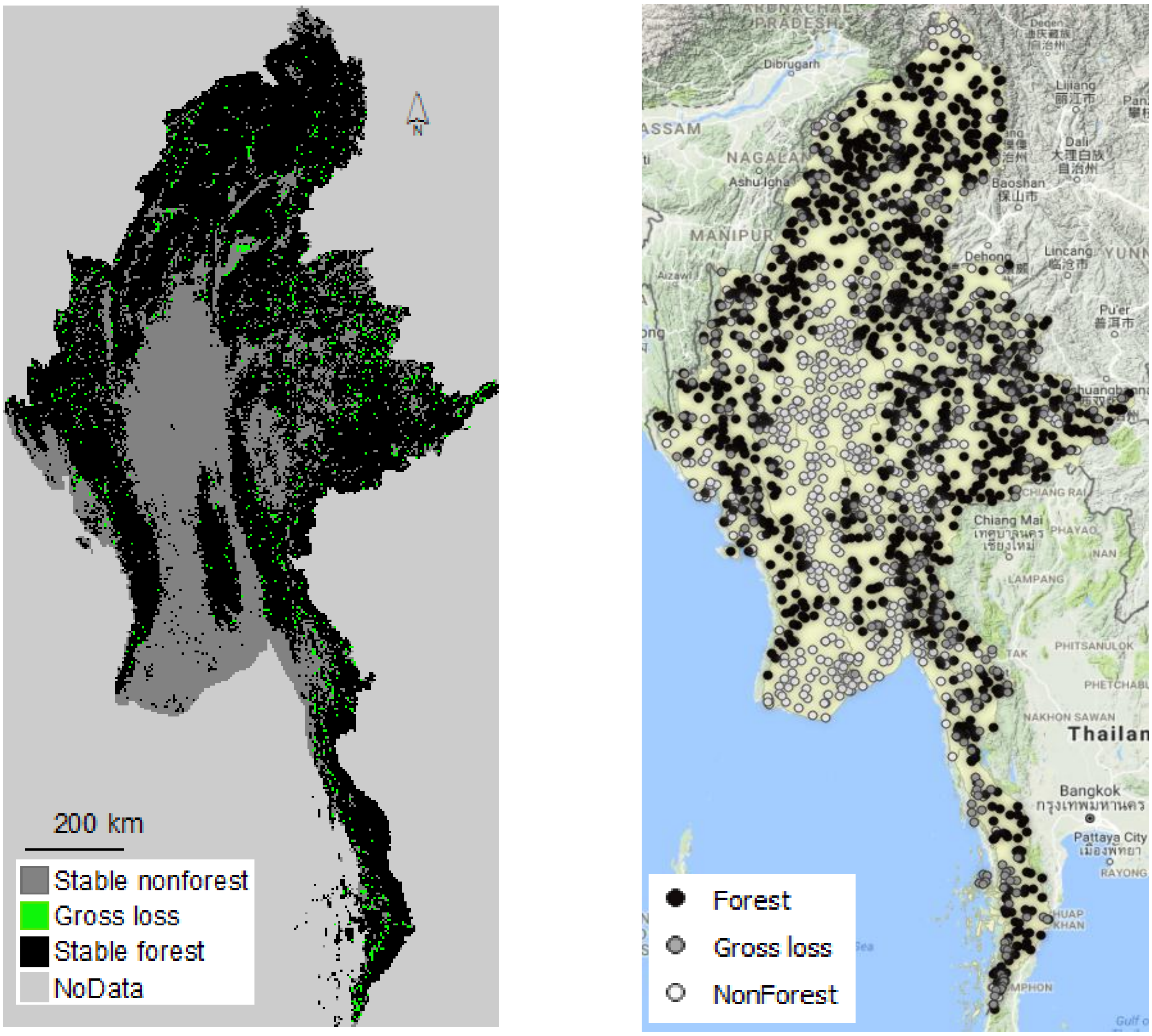
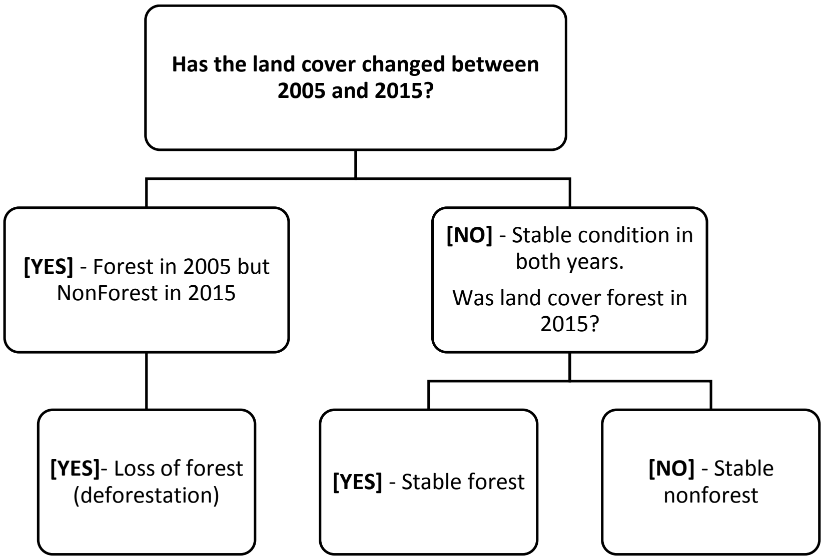


Figure 7.3 illustrates a change decision tree where the 2005 land cover is forest. There will be equivalent decision trees for other scenarios e.g. rich forest to degraded forest, and forest to non-forest land cover types. These statistics allow change in major land cover categories to be reported and areas estimated.

Figure 7. 3: Decision tree for sample change analysis



7.1.3. *Response design*

The desired goal of this validation was to derive a statistically robust and quantitative assessment of the uncertainties associated with the forest area change estimates. Several factors potentially impact on the quality of forest mapping (GOFC-GOLD, 2015), namely:

- The spatial, spectral and temporal resolution of the imagery
- The radiometric and geometric pre-processing of the imagery
- The automated and manual procedures used to interpret the forest map category
- Thematic standards (i.e. minimum mapping unit and land use definitions)
- The availability of field reference data for evaluation of the results.

Approaches were used to minimize these sources of error following IPCC and GOFC-GOLD good practice guidelines, as appropriate. However, the quality of reference data and the sample selection for accuracy assessment of the change area were slightly compromised by the restricted availability of high-spatial resolution archived imagery in Google Earth and Bing Map across Myanmar.

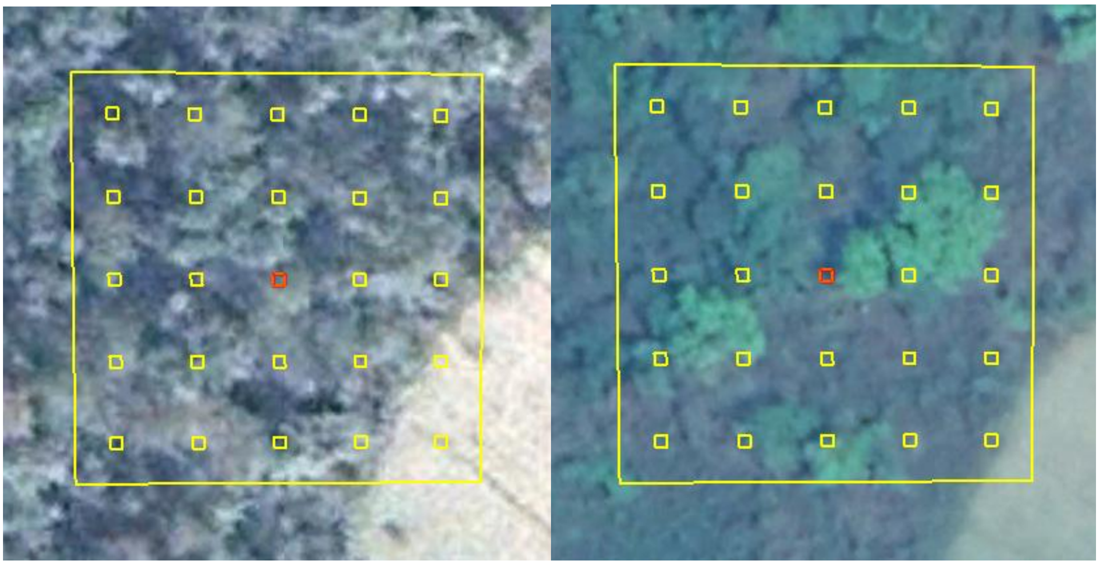
Through a collect survey design form using *Open Foris Collect*, the two Land cover types (forest and non-forest) were assessed within each sample through an expert image interpretation of medium (15m pan-sharpened Landsat) to very high (<1m) spatial resolution satellite data. The map and reference datasets used in the accuracy assessment are listed in Table 7.1. The reference datasets have sufficient temporal representation consistent with the change period: 2005-2015. The collect survey design form has been set for each reference label to allow an interpreter-specified confidence level of high, medium or low. Figure 7.4 shows an example of reference data available within Google Earth-based Collect Earth System[7] used to interpret land use/cover and monitor changes with time. The figure illustrates sample no. 1517 with temporal resolution of Google Earth imagery, used for sample assessment during 2005-2015.

Table 7. 1: Validation datasets used to assess 1,884 samples

Type	Data types	Spatial resolution	Source
Stratified	Landsat scenes captured in 2005 and 2015	30-m	USGS Earth Explorer
Validation	High-resolution RGB imagery from various satellite sensors, such as SPOT, GeoEye-1, WorldView-1/2/3, Digital Globe, IKONOS, etc.	10-m to 30-cm	Google Earth Pro/ Bing Maps
	Landsat time series archive: 2005-2015	30-m (15-m pan-sharpened)	Google Earth Engine Landsat/Sentinel MSI 2 Archive

[7] http://www.mdpi.com/2072-4292/8/10/807/html

Figure 7. 4: Example of reference data (Google Earth Archive)



2005 2015

7.1.4. *Analysis design*

Table 7.2 shows the generic structure of error matrix that has been used to derive sample-based area estimates. Grey coloured cells represent map areas that have been validated as correct. Orange coloured cells, however, are either false positives or false negatives. For example, cell p_{12} is false negative and cell p_{21} is false positive. Interpretation of these data assumes that the reference data are error free and that the sampling is unbiased and of sufficient size. Nevertheless, the confusion matrix provides a simple and convenient method to illustrate the nature of any disagreement between the stratified map and the reference data.

The accuracy of a class is expressed in two ways: user's and producer's accuracies. The producer's accuracy provides a measure of accuracy of the classification scheme. The producer’s accuracy is also known as the error of omission because areas that have been incorrectly classified are “omitted” from the correct class. This accuracy indicates how well the sample points falling on a given land cover type are classified, i.e., it is the probability of how well the reference data fitted the map.

Table 7. 2: Structure of accuracy assessment matrix

		Reference data using Collect Earth System			Total	User's accuracy (U_i)
		Forest	Loss	Non-Forest		
Stratified map	Forest	p_{11}	p_{12}	p_{13}	$p_{1.}$	$\frac{p_{11}}{p_{1.}}$
	Loss	p_{21}	p_{22}	p_{23}	$p_{2.}$	$\frac{p_{22}}{p_{2.}}$
	Non-Forest	p_{31}	p_{32}	p_{33}	$p_{3.}$	$\frac{p_{33}}{p_{3.}}$
Total		$p_{.1}$	$p_{.2}$	$p_{.3}$	1	
Producer's accuracy (P_i)		$\frac{p_{11}}{p_{.1}}$	$\frac{p_{22}}{p_{.2}}$	$\frac{p_{33}}{p_{.3}}$		$Overall\ accuracy = p_{11} + p_{22} + p_{33}$

7.1.5. *Estimation and uncertainty*

GFOI 2016 methods guidance document (MGD) version 2 was used to derive sample-based area estimates and uncertainty of the area estimates. Both simple random and stratified estimators were used to derive sample-based estimates. A brief description of the simple and stratified random sampling estimators have been described in Annex 4.

7.1.6. Results

The error matrix of the 1,884 assessed samples is summarized in table 7.3. The reference datasets were used to generate sample-based estimates along with the associated confidence intervals for these sample-based area estimates. The user's accuracy, or commission error, represents an over-estimation of forest cover compared with forest loss and non-forest cover classes. For example, 237 samples out of 831 were detected as forest cover when they were not. Specifically, 49 of these samples were actually forest loss in 2015 and 188 samples were non-forest. Three examples of sample assessment using different validation datasets have been illustrated in Annex 5, including forest 2005 to forest 2015; non-forest 2005 to non-forest 2015; and forest 2005 to non-forest 2015.

Table 7. 3: Confusion matrix for 2005-2015 forest change map based on 1,884 stratified random samples

		Reference data				
		Forest	Loss	Non-forest	Total	User's accuracy
GFC Map (Modified)	Forest	0.32	0.03	0.25	0.44	0.71
	Loss	0.09	0.03	0.04	0.16	0.21
	Non-forest	0.16	0.02	0.22	0.40	0.55
Total		0.56	0.08	0.36	1	
Producer's accuracy		0.56	0.42	0.62		0.57

Table 7.4 provides area estimates of bias-corrected forest and non-forest cover classes for the years 2005 and 2015. Forest cover estimates reported to FRA (FA0, 2015) were 33.32 million ha in the year 2005 and 29.04 million ha in the year 2015, much lower than sample-based forest cover estimates. Table 7.5 provides more detailed estimates on various parameters from the sample-based assessment, considering the weighted producer accuracy (proportional to the area per class) for forest, non-forest and loss. This corresponds to the interpretation of the results from the perspective of the reference data. In general, it indicates that the forest loss class has comparatively lower producer's accuracy in spatial detection of information. Therefore, the sample-based estimates showed a much wider (20%) confidence interval in the forest loss class compared to stable forest and stable non-forest classes. Apart from the usual subjective differences between estimators, it is assumed that the uncertainty might also be associated with misinterpretation of samples, lack of high spatial resolution imagery for some samples, misinterpretation of some forest types with non-tree vegetation cover, and seasonal variations.

Table 7. 4: Bias-corrected area estimates in hectare (ha) with confidence intervals (CI), weighted producer's accuracy and user's accuracy under forest and non-forest cover classes for the years 2005 and 2015.

Land cover classes	Accuracy			GFC Map (modified) area (ha)	Sample-based estimates			
	Producer's	Weighted Producer's	User's		Area (ha)	SE (ha)	CI (ha)	CI (%)
Year 2005								
Stable forest	0.62	0.56	0.55	44561156	44850934	694451	1361124	3.0
Non-forest	0.72	0.77	0.77	23096596	22806817	694451	1361124	6.0
Year 2015								
Stable forest	0.56	0.73	0.72	42736493	41916413	769766	1508741	3.6
Non-forest	0.71	0.53	0.55	24921258	25741339	769766	1508741	5.9

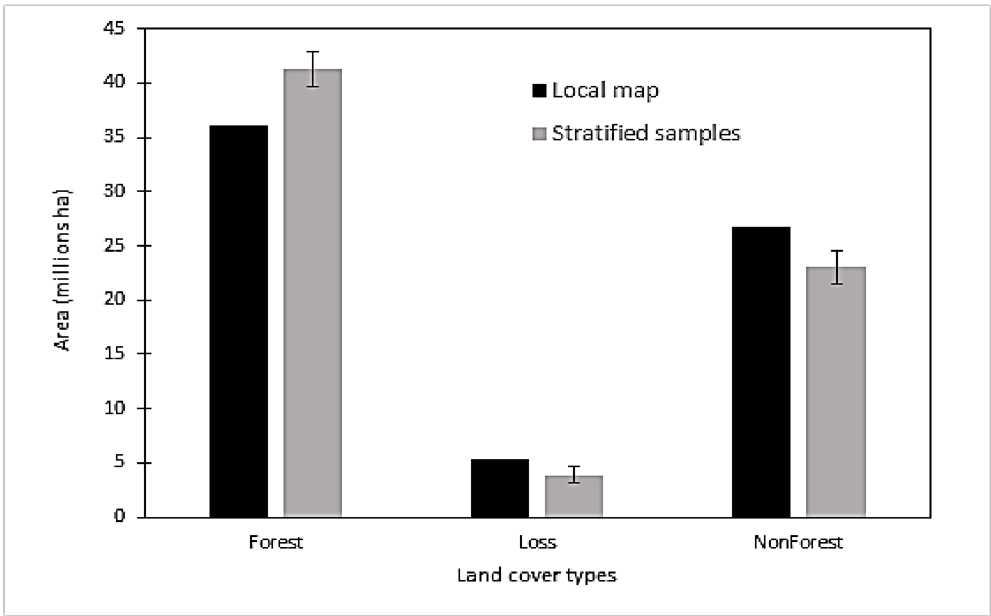
Table 7. 5: Bias-corrected area estimates in hectare (ha) with confidence intervals (CI), weighted producer's accuracy and user's accuracy for three land cover classes during 2005-2015.

Land cover classes	Accuracy			GFC Map (modified) area (ha)	Sample-based estimates			
	Producer's	Weighted Producer's	User's		Area (ha)	SE (ha)	CI (ha)	CI (%)
Stable forest	0.56	0.75	0.71	42736493.2	40928208.2	789266.8	1546962.9	3.78
Loss	0.44	0.10	0.21	1768548.9	3875270.2	390950.6	766263.1	19.77
Stable non-forest	0.62	0.56	0.55	23152709.4	22854273	750506.9	1470993.4	6.44

Along with the forest and non-forest classes, the sample-based area estimate and associated confidence interval of the forest loss class have been improved through four approaches: increasing sample number to 300; using local knowledge and information on areas of forest loss and cross-checking existing national maps that can be used as proxy for the investigation of forest loss, using high spatial-resolution imagery available in Google Earth for those samples, and following a quality control procedure. The bias-corrected area estimates with confidence intervals outlined in table 7.5 were calculated following the IPCC (2003, 2006) guidelines and the GFOI (2016) methods guidance documents. It is important to underline that the map estimates are bias-corrected ('adjusted') considering the national forest definition, which includes land classification as well as tree cover.

In conclusion, the bias-corrected forest loss is about 387,527 ha per year over the period 2005-2015. In comparison, the forest loss between 2005 and 2015 reported to FRA 2015 (based on locally-produced wall-to-wall maps) was 428,000 ha per year, or 37,244 ha per year higher than the sample-based estimates. Figure 7.5 shows a comparison of estimates from local maps and estimates after bias-correction for forest, non-forest and forest loss classes. Given the current limitations of local maps, as explained above, it was decided to use the *bias-corrected forest loss estimates as activity data*.

Figure 7. 5: Area estimates of forest cover change during 2005-2015, in million ha, from local land cover maps and from stratified random sampling design.



7.2. Emission factors

The FD conducted initial national forest inventory measurements in 1981-82 with the financial and technical support of UNDP and FAO under the National Forest Management and Inventory Project. However, resources were insufficient to extend the project across the whole country and to all forested areas, and after 1991-92, FD carried out the forest inventory exercises with its own resources. According to the available records and documents, inventory surveys were based on a variety of sampling methods. Estimates from such surveys were used in calculating annual allowable cuts and reliable estimates for efficient management planning mainly at the district level. There are 68 Forest Districts in Myanmar, defined by administrative boundaries. District forest inventory surveys covered 40 Districts during a 10-year rotation, using a variety of sampling intensities and sample plot designs (Table 7.6). Detailed descriptions of different sample plot designs is mentioned in Annex 6. This submission drew upon the data generated from 11,284 inventory plots of district level forest inventory that were collected during 2005 to 2017 (Figure 7.6).

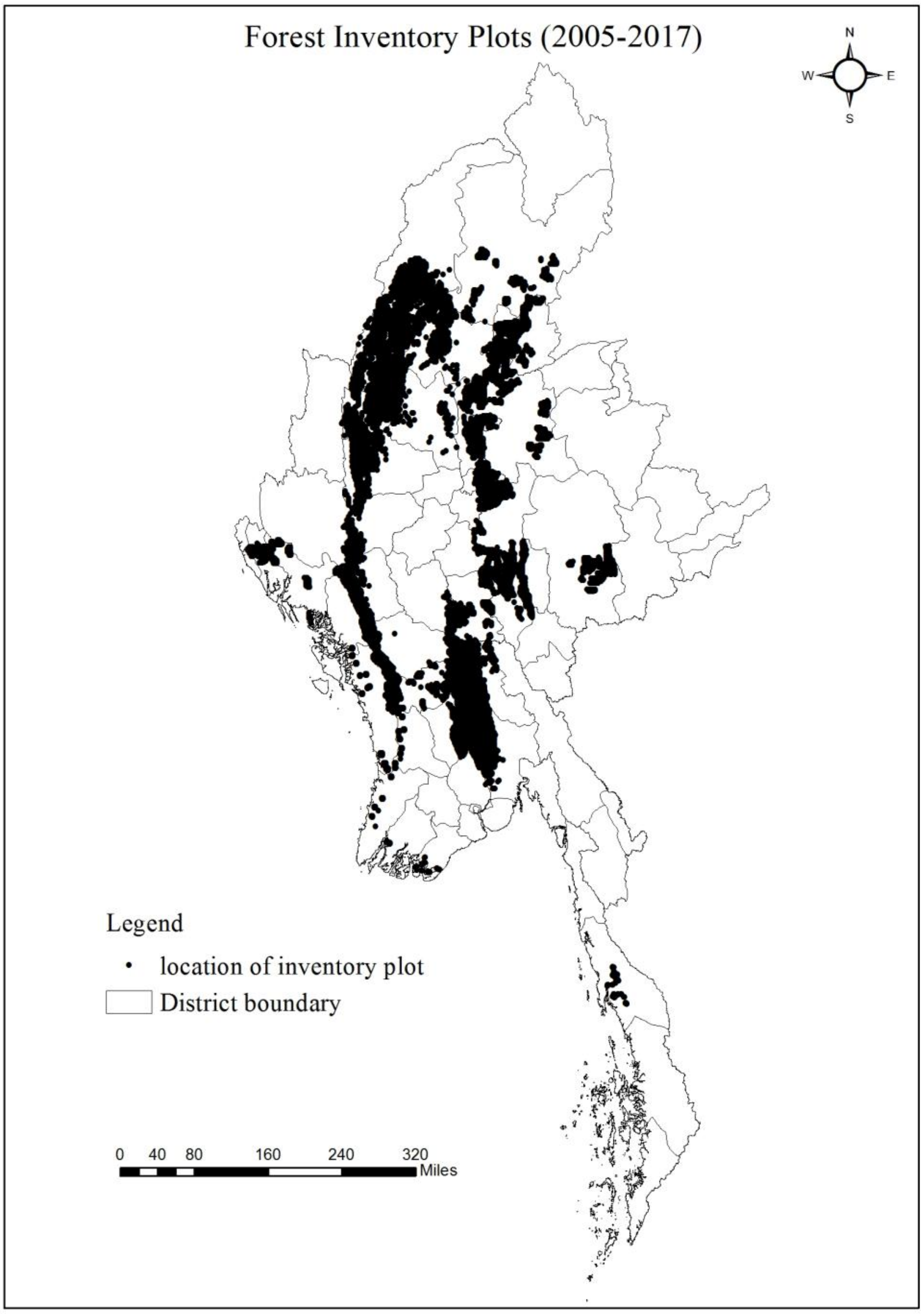
Table 7. 6: Sample Plot Design for 40 Districts used in Emission Factor Calculation

Sr. No.	State/ Region	District	Year	Sample Design	Interval	Sub-Plots	Shape	Size	Measurement
1	Kachin State	Myintkyina Bhamo	2004-2007	Systematic	3000 yard/ 2743.2 m	7	L-shape: IL 7 RU IL RU 1, 4, 7 IL RU 1, 4, 7	1.05 ha 15m radius 10m radius	DBH >= 20 cm DBH bt 10 cm to 19 cm DBH bt 5 cm to 9 cm
2	Sagaing Region								
	Upper Chindwin	Tamu, Mawleik and Kalay Khanti	2014 2015	Systematic	2000 m	3	Square Square	100m x 100m 50m x 50m	DBH >= 20 cm DBH bt 5 cm to 19 cm
	Lower Chindwin	Shwebo and Monywa Katha	2015 2015				Square	25m x 25m	< 5 cm, Regen & Bamboo
3	Bago Region	Tharrawaddy	2011	Systematic	2000 m	1	Circular	50m radius	all DBH classes (>=5cm)
		Bago	2012	Systematic	2000 m	3	Square Square Square	100m x 100m 50m x 50m 25m x 25m	DBH >= 20 cm DBH bt 5 cm to 19 cm < 5 cm, Regen & Bamboo
		Taungoo	2010	Systematic	2000 m	1	Circular	50m radius	all DBH classes (>=5cm)
		Pyay	2017	Systematic	2000 m	3	Square	100m x 100m 50m x 50m 25m x 25m	DBH >= 20 cm DBH bt 5 cm to 19 cm < 5 cm, Regen & Bamboo
4	Magwe Region	Minbu	2013	Systematic	2000 m	3	Square	100m x 100m	DBH >= 20 cm

		Thayet	2013				Square	50m x 50m	DBH bt 5 cm to 19 cm
		Kaunggaw Magwe Pakkoku	2013 2013 2013				Square	25m x 25m	< 5 cm, Regen & Bamboo
5	Nay Pyi Taw	Ottarathiri Dekinathiri Taungoo Taunggyi	2008 2008 2008	Systematic	3000 yard/ 2743.2 m	7	L-shape: IL 7 RU IL RU 1, 4, 7 IL RU 1, 4, 7	1.05 ha 15m radius 10m radius	DBH >= 20 cm DBH bt 10 cm to 19 cm DBH bt 5 cm to 9 cm
6	Shan State	Kyaukmae Linkhay Taunggyi North (Yasauk and Ywangan)	2007 2007 2007	Systematic Systematic	3000 yard/ 2743.2 m	7	L-shape: IL 7 RU IL RU 1, 4, 7 IL RU 1, 4, 7	1.05 ha 15m radius 10m radius	DBH >= 20 cm DBH bt 10 cm to 19 cm DBH bt 5 cm to 9 cm
		Taunggyi South (Kalaw, Naungshwe, Phekon, Pinlaung and Taunggyi)	2011	Systematic	2000 m	3	Square Square Square	100m x 100m 50m x 50m 25m x 25m	DBH >= 20 cm DBH bt 5 cm to 19 cm < 5 cm, Regen & Bamboo
7	Rakhine State	Sittwe	2005	Systematic	3000 yard/ 2743.2 m	7	L-shape: IL 7 RU IL RU 1, 4, 7 IL RU 1, 4, 7	1.05 ha 15m radius 10m radius	DBH >= 20 cm DBH bt 10 cm to 19 cm DBH bt 5 cm to 9 cm
		Maungdaw	2005	Systematic	3000 yard/ 2743.2 m	7	L-shape: IL 7 RU IL RU 1, 4, 7	1.05 ha 15m radius	DBH >= 20 cm DBH bt 10 cm to 19 cm

							IL RU 1, 4, 7	10m radius	DBH bt 5 cm to 9 cm
		Thandwe	2015	One Shot	2000 m	1	Circular	50m radius	all DBH classes (>=5cm)
		Kyaukphyu	2015	One Shot	2000 m	1	Square	1 ac plot	all DBH classes (>=5cm)
		MyaukOo	2005	Systematic	3000 yard/ 2743.2 m	7	L-shape: IL 7 RU IL RU 1, 4, 7 IL RU 1, 4, 7	 1.05 ha 15m radius 10m radius	 DBH >= 20 cm DBH bt 10 cm to 19 cm DBH bt 5 cm to 9 cm
8	Tanintharyi	Dawei	2015	One Shot	2000 m	1	Square	1 ac plot	all DBH classes (>=5cm)
9	Chin	Falam	2015	One Shot	2000 m	1	Square	1 ac plot	all DBH classes (>=5cm)
10	Ayeyarwaddy	Myaungmya	2015	One Shot	2000 m	1	Circular	50m radius	all DBH classes (>=5cm)
		Pyarpon	2015	One Shot	2000 m	1	Square	1 ac plot	all DBH classes (>=5cm)
		Bogalay	2015	One Shot	2001 m	1	Square	1 ac plot	all DBH classes (>=5cm)
		Pathein	2015	One Shot	2000 m	1	Circular	50m radius	all DBH classes (>=5cm)
		Hinthada	2015	One Shot	2000 m	1	Circular	50m radius	all DBH classes (>=5cm)
11	Mandalay	KyaukSe Mandalay Meiktila Pyin Oo Lwin Yamethin	2015-2016	Systematic	2000 m	3	Square	100m x 100m 50m x 50m 25m x 25m	DBH >= 20 cm DBH bt 5 cm to 19 cm < 5 cm, Regen & Bamboo

Figure 7. 6: Location of Inventory plots data collected during 2005 to 2017



7.2.1. Methodology for Emission Factor Calculation

As described above, Myanmar decided to include three carbon pools, i.e. AGB, BGB and Litter for initial FREL development. A combination of Tier 1 and 2 approaches were used in estimating these carbon pools using the following information from the management inventory of 40 districts:

- ID of Tree/Stand and its Location (District ID, Latitude and Longitude)
- Tree Type/Categories (by two categories, i.e. stand DBH of 20 cm and above, and that of 10 cm to 19 cm)
- Forest Types (by 19 Types that were mentioned in Section 2.3)
- Tree Species Code (based on Forest Inventory Manual of Forest Department)
- Diameter at Breast Height (DBH) in cm

For estimating stocks of three carbon pools, all individual trees in each plot were first examined together with general plot information, basal area and stand density. AGB was then derived based on allometric equations, then BGB and carbon content in litter were estimated by using default factors of IPCC GPG in accordance with the AGB value. Finally, carbon content in tCO_2eq of each sample plot was calculated and plots were grouped into districts and into different forest types. Step by step calculation of the EFs was as follows;

Step (1)

District management inventories in Myanmar did not include tree height information, but only DBH as the key parameter. Therefore, the AGB of individual trees in each plots was estimated using allometric equations developed for pan-tropical forest by the following equation from IPCC GPG for LULUCF[8]: (IPCC, 2006)

Equation 2

$$AGB = EXP\ ((-2.289 + 2.649 * LN(DBH) - 0.021 * \left(LN(DBH)\right)^2)$$

Where AGB= Above Ground Biomass in Kg Dry Matter/ Tree

The total AGB for each plot was quantified by the sum of AGB of all individual trees and then converted into a per hectare value based on the respective sample plot area/sampling design. There were four different plot designs applied by FD in the period 2005-2017 (Table 7.7).

[8] Table 4. A. 1; Allometric Equations for Estimating Above Ground Biomass of Tropical and Temperate Hardwood and Pine Species from IPCC Good Practice Guidance for LULUCF

Table 7. 7: Per Ha Prorated Value for four different plot designs

No	Plot Size	Prorated to Per Ha Value	Plot Design
1	100mx50mx25m	1 ha x 0.25 ha x 0.0625 ha	Systematic (Square)
2	50m x 50m x 50m	0.7854 ha x 0.7854 ha x 0.7854 ha	One Shot (Circular)
3	1 ac x 1 ac x 1 ac	0.4047 ha x 0.4047 ha x 0.4047 ha	One Shot (Square)
4	1.05 ha x 15m x 10m	1.05 ha x 0.0707 ha x 0.0314 ha	Systematic (L-shaped)

In this regard, the representative area is different for each design. The detailed plot designs for each district, together with AGB per ha prorated value, can be seen in table 7.8. The prorated AGB (Kg Dry Matter) per ha value was then converted into AGB tons per ha.

Table 7. 8: AGB Value in CO_2 eq ton per ha per plot design for each district

No.	Sample Plot Design	Number of Plots	Sample Size in ha	Mean CO_2 eq ton per ha	Standard Error	Districts
1	Systematic: L-shaped	1,942	2,039.10	1,937.05	334.87	Myitkyina, Bhamo, Dekhina, Ottathiri, Taungoo-NYT, Taungyi-NYT, Sittwe, Linkhay, Taungyi-North, Kyaukme, Maungdaw, MyaukOo (10 Districts)
2	Systematic: Square	7,099	7,099.00	1,449.2	102.77	Bago, Katha, Shwebo, Monywa, Gangaw, Magway, Minbu, Pakokku, Thayet, Pyay, Kalay, Khamti, Mawlaik, Tamu, Taungyi-South, Kyaukse, Mandalay, Meiktila, Pyin Oo Lwin, Yamethin (20 Districts)
3	One shot (Circular)	1,709	1,342.25	320.13	25.30	Hinthada, Myaungmya, Taungoo, Thandwe, Tharyarwaddy, Pathein (6 Districts)
4	One shot (Square)	534	216.11	647.16	48.03	Dawei, Falam, Pyarphon, Kyaukphyu (4 Districts)
	Total	**11,284**	Forest Inventory plots for 40 Districts			

Step (2)

In order to calculate the BGB, the mean AGB (ton per ha) based on forest types was multiplied with R (Ratio of BGB to AGB). The R values are mentioned according to different forest types as described in IPCC Guidelines.[9] Although the forest type categories according to forest inventory Field Instruction (1985) are different to the global forest type categories, they have similar characteristics. The forest types are then simplified according to global categories in order to select the appropriate ratio of BGB to AGB according to Table 7.9.

Table 7. 9: Description on the forest types and respective value of R (Ratio of BGB to AGB) and litter range

No.	Forest Type Code according to Field Instruction	Forest Type for BGB Calculation	R (Ratio of BGB to AGB) Value Range	Litter Range
1	Mangrove, Typical Mangrove, high (Kanazo Forest)	Tropical Rain Forest	0.37	2.1
2	Beach and Dune Forest	Tropical Dry Forest	AGB< 20 Ton/ Ha = 0.56 (0.28-0.68) AGB> 20 Ton/Ha = 0.28 (0.27-0.28)	5.2
3	Swamp Forest Evergreen Forest, Riverine	Tropical Rain Forest	0.37	2.1
4	Evergreen Forest, Typical Evergreen Forest, Giant Bamboo Forest	Tropical Rain Forest	0.37	2.1
5	Mixed Deciduous Forest, Lower Mixed Deciduous Forest, Upper Moist	Tropical Moist Deciduous Forest	AGB< 125 Ton/ Ha = 0.20 (0.09-0.25) AGB> 125 Ton/Ha = 0.24 (0.22-0.33)	2.1
6	Mixed Deciduous Forest, Upper Dry	Tropical Moist Deciduous Forest	AGB< 125 Ton/ Ha = 0.20 (0.09-0.25) AGB> 125 Ton/Ha = 0.24 (0.22-0.33)	2.1
7	*Dipterocarp* (Indaing) Forest, High *Dipterocarp* (Indaing) Forest, Low	Tropical Dry Forest	AGB< 20 Ton/ Ha = 0.56 (0.28-0.68) AGB> 20 Ton/Ha = 0.28 (0.27-0.28)	2.1
8	Dry Forest, than-dahat Dry Forest, Thorn	Tropical Dry Forest	AGB< 20 Ton/ Ha = 0.56 (0.28-0.68) AGB> 20 Ton/Ha = 0.28 (0.27-0.28)	2.1

[9] Table 4.4 of Chapter 4: Forest Land in 2006 IPCC Guidelines for National Greenhouse Gas Inventories

	Dry Forest, Aukchinsa-thinwin			
9	Hill Forest, Evergreen	Tropical Mountain Systems	0.27 (0.27-0.28)	2.8
10	Hill Forest, Dry	Tropical Dry Forest	AGB< 20 Ton/ Ha = 0.56 (0.28-0.68) AGB> 20 Ton/Ha = 0.28 (0.27-0.28)	2.1
11	Hill Forest, Pine	Temperate: Conifers	AGB< 50 Ton/ Ha = 0.40 (0.21-1.06) AGB 50-150 Ton/ Ha = 0.29 (0.24-0.50) AGB >150 Ton/ Ha = 0.20 (0.12-0.49)	4.1

Step (3)

The sum the AGB and BGB values (ton per ha) were converted into tons of carbon per ha by the multiplication with the default value of carbon fraction of dry matter 0.47 (IPCC Guideline 2006).

Step (4)

The default litter values[10] (tons of carbon per ha) according to respective forest types are described in table 7.9.

Step (5)

Total tons of carbon per ha was estimated by the sum of three values of AGB, BGB and litter.

Step (6)

The default factor of 3.664 was used to convert the total tons of carbon per ha to tCO_2eq per ha value for three carbon pools.

One National Emission Factor will be used as an uncertainty test is needed for forest type stratification and national data sources are currently insufficient for this purpose. In future FREL/FRL submissions, more stratification will be conducted to improve the accuracy of EFs and resulting emission and removal estimates.

[10] Table 2.2: Tier 1 Default values for Litter in 2006 IPCC Guidelines

7.2.2. Results

The following table gives the values of tCO_2 eq per ha, for three carbon pools combined, for the respective forest districts, including the number of sample plots used for the calculation. Myanmar will use *weighted mean values of* tCO_2 eq *per ha* for a national level EF based on 40 districts, i.e. ***125.43*** $\boldsymbol{tCO_2}$ ***eq per ha*****.** (Table 7.10)

Table 7. 10: Results of the CO_2 eq Mean Value ton per ha and weighted mean CO_2 eq ton per ha

No.	District Name	Total No of sample plots:	Weighted CO_2 eq Mean Value per ha	Overall weighting
1	Bago	567	57.06	32,353.79
2	Dawei	109	535.90	23,639.58
3	Falam	159	246.24	15,844.79
4	Hinthada	68	128.78	6,877.59
5	Bhamo	427	198.56	89,023.55
6	Myitkyina	200	249.67	52,430.70
7	Katha	661	98.45	65,077.32
8	Shwebo	174	92.66	16,122.59
9	Monywa	190	110.16	20,930.61
10	Magway	8	63.92	511.32
11	Gangaw	311	124.22	38,631.23
12	Minbu	467	109.87	51,309.52
13	Pakoku	33	80.64	2,661.06
14	Thanyet	274	106.05	29,057.04
15	Myaungmya	10	22.47	176.51
16	Dekkina:NPT	105	131.36	14,482.34
17	Ottarathiri:NPT	67	118.63	8,345.42
	Taungoo: NYT	10	100.17	1,051.82
	Taunggyi: NYT	20	147.99	3,107.87
18	Pyarphon	47	14.99	285.05
19	Pyay	430	82.06	35,286.86
20	Sittwe	6	843.94	5,316.81
21	Taungoo	962	80.67	60,952.09
22	Thandwe	147	87.43	10,093.97
23	Tharyarwaddy	446	70.89	24,833.13
24	Kalay	869	119.52	103,861.64
25	Khamti	951	85.07	80,905.13
26	Mawlaik	971	145.56	141,341.44
27	Tamu	45	73.23	3,295.45
28	Linkhay	234	97.73	24,011.47

29	Taunggyi_North	225	197.36	46,625.58
30	Taunggyi_South	334	151.49	50,596.34
31	Kyaukme	519	315.70	172,038.75
32	Pathein	76	63.88	3,813.04
33	Kyaukphyu	219	93.77	8,311.04
34	Maungdaw	52	99.23	5,417.97
35	MyaukOo	77	99.65	8,056.62
36	KyaukSe	163	125.09	20,389.03
37	Mandalay	19	71.73	1,362.88
38	Meiktila	90	65.36	5,882.73
39	Pyin Oo Lwin	465	112.77	52,438.86
40	Yamethin	77	64.36	4,955.61
Total inventory plots		11,284	5,884.26	1,341,706.12
			147.11 (Arithmetic Mean)	**125.43 (Weighted Mean)**

8. Myanmar FREL

Myanmar proposes an initial FREL by historical average of emissions during the reference period from 2005 to 2015. The *bias-corrected area of annual deforestation is estimated **387,527 ha per year** during 2005-2015*. *Weighted mean values of tCO_2 eq per ha* through the calculation based on 40 districts forest inventory result in a national EF of ***125.43 tCO_2 eq per ha***.

Annual CO_2 emission from deforestation during the historical reference period 2005-2015 is estimated as ***48,607,511 tons per year***.

From sample based estimation, it was not possible to develop a forest gain map for the period 2005 to 2015 and this therefore severely limited the information available to develop a reference level for forest gain (enhancement of forest carbon stocks). Efforts are ongoing to improve the data available and this will be added to the submission in due course.

In the meantime, it is recognized that an increase in biomass and carbon stocks on afforested/reforested areas should be expected as a result of the 10-year NRRPM. A summary of the afforestation/reforestation activities undertaken during the reference period is therefore included in Annex 7, as a means of creating a benchmark against which these gains can be measured.

9. Uncertainty test

The uncertainty test for activity data and emission factor was conducted according to the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The uncertainty only includes sampling error through the propagation of errors and not allometric equation errors.

In calculation of the % uncertainty of activity data, especially deforestation estimate, the following equation was applied,

Equation 3[11]

$$\% \, Uncertainty = \frac{\frac{1}{2}(95\% \, Confidence \, Interval \, Width)}{\mu} \, x \, 100$$

Where μ=mean of the distribution

As described in the equation, the 95% Confidence Interval for all 40 districts are calculated with the equations of:

Equation 4

$$95\% \, Upper \, Confidence \, Interval = Mean \, CO2 \, Ton \, Per \, Ha + 1.96 * (\frac{Standard \, Deviation}{\sqrt{Sample \, Size \, In \, Ha}})$$

$$95\% \, Lower \, Confidence \, Interval = Mean \, CO2 \, Ton \, Per \, Ha - 1.96 * (\frac{Standard \, Deviation}{\sqrt{Sample \, Size \, In \, Ha}})$$

$$95\% \, Confidence \, Interval \, Width = 95\% \, UCI - 95\% \, LCI$$

The uncertainty of the overall inventory was calculated by the error propagation equation,

Equation 5

$$U_{total}{}^{12} = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}}{x_1 + x_2 + \cdots + x_n}$$

U_{total}= the percentage uncertainty in the sum of the quantities

x_n and U_n are the uncertain quantities and the percentage uncertainties associated with them, respectively.

[11] Box 5.2.1: Chapter 5 of IPCC Good Practice Guidance for LULUCF

[12] Table 6.1: Tier 1 Uncertainty Calculation and Reporting under IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventory

Table 9.1 shows the *% uncertainty of AD*, forest loss area, i.e. *9.89%* for this submission whereas Table 9.2 shows the *% uncertainty of 40 district forest inventory* and resulting *overall % is 12.10* for this submission.

Table 9. 1: Uncertainty Result for Activity Data in %

	Area in ha (estimate)	Standard Error in ha	**Uncertainty %**
Forest	40,928,208	789,266	1.89
Forest loss (deforestation area)	3,875,270	390,950	**9.89**
Non forest	2,2854,273	750,506	3.22
Total area	67,657,751		

Combined uncertainty was finally estimated by using the uncertainty of AD, especially uncertainty % of forest loss (deforestation) and that of EF as follows:

Equation 6

$$Combine\ Uncertainty\ (\%) = \sqrt{Uncertainty\ \%\ of\ AD^2 + Uncertainty\ of\ \%\ EF^2}$$

Regarding the above calculation, *uncertainty % of AD, deforestation area estimation and EF* were *9.89 % and 12.10 %* respectively and therefore, *combined uncertainty % of 15.57%* is estimated for this submission.

Table 9. 2: Uncertainty Result for Emission Factor in %

No	Districts	Plots (n)	Plot Size	Sample Size in Ha	Mean CO_2 eq Ton Per Ha[13]	Standard Deviation	Confidence Level (95%)		Width/ Confidence Interval	% Uncertainty	U x Xn	(U x Xn)^2
							Upper	Lower				
1	Bago	567	1	567	41.02	38.30	44.18	37.87	6.31	7.69	315.29	99,408.64
2	Dawei	109	0.4047	44.1123	385.55	308.31	476.53	294.57	181.97	23.60	9,098.27	82,778,547.65
3	Falam	159	0.4047	64.3473	185.81	181.23	230.09	141.53	88.56	23.83	4,428.18	19,608,738.88
4	Hinthada	68	0.7854	53.4072	100.90	65.50	118.47	83.34	35.13	17.41	1,756.61	3,085,682.03
5	Myitkyina	200	1.05	210	96.99	82.50	108.15	85.83	22.32	11.50	1,115.79	1,244,993.41
6	Bhamo	427	1.05	448.35	152.36	96.34	161.28	143.44	17.84	5.85	891.79	795,294.70
7	Katha	661	1	661	73.49	44.24	76.86	70.11	6.75	4.59	337.25	113,738.51
8	Shwebo	174	1	174	68.36	58.30	77.02	59.69	17.32	12.67	866.24	750,368.64
9	Monywa	190	1	190	84.60	34.98	89.57	79.63	9.95	5.88	497.36	247,366.59
10	Gangaw	311	1	311	96.15	71.96	104.15	88.15	15.99	8.32	799.74	639,591.49
11	Magway	8	1	8	46.85	32.13	69.11	24.59	44.52	47.52	2,226.23	4,956,078.42
12	Minbu	467	1	467	81.07	68.20	87.26	74.89	12.37	7.63	618.57	382,629.12
13	Pakokku	33	1	33	57.99	36.75	70.52	45.45	25.08	21.62	1,253.81	1,572,030.22
14	Thayet	274	1	274	78.85	51.35	84.93	72.77	12.16	7.71	607.99	369,647.99
15	Myaung-mya	10	0.7854	7.854	2.04	15.14	12.62	(8.55)	21.17	519.29	1,058.51	1,120,448.33
16	Dekhina	105	1.05	110.25	102.84	73.17	116.50	89.18	27.32	13.28	1,365.85	1,865,549.50
17	Ottarathiri	67	1.05	70.35	92.11	69.50	108.35	75.87	32.48	17.63	1,624.17	2,637,941.38
	Taungoo: NYT	10	1.05	10.5	77.07	29.17	94.71	59.42	35.28	22.89	1,764.19	3,112,350.50
	Taungyi: NYT	20	1.05	21	116.92	37.29	132.86	100.97	31.90	13.64	1,594.75	2,543,236.62
18	Pyarphon	47	0.4047	19.0209	5.32	6.96	8.45	2.20	6.25	58.75	312.69	97,774.36
19	Pyay	430	1	430	61.51	64.47	67.60	55.42	12.19	9.91	609.33	371,281.91
20	Sittwe	6	1.05	6.3	674.39	655.33	1,186.13	162.65	1,023.47	75.88	51,173.74	2,618,751,828.74
21	Taungoo	962	0.7854	755.5548	60.76	52.35	64.49	57.03	7.47	6.14	373.31	139,360.36
22	Thandwe	147	0.7854	115.4538	62.85	49.81	71.93	53.76	18.17	14.46	908.65	825,637.30
23	Tharyarwa-ddy	446	0.7854	350.2884	52.55	71.39	60.03	45.07	14.95	14.23	747.60	558,911.31

[13] Mean CO_2 eq ton per ha is only for Above Ground Biomass Pool.

24	Kalay	869	1	869	91.46	78.06	96.65	86.27	10.38	5.68	519.04	269,399.13
25	Khamti	951	1	951	61.90	55.83	65.45	58.35	7.10	5.73	354.87	125,931.78
26	Mawlaik	971	1	971	110.77	68.99	115.11	106.43	8.68	3.92	433.95	188,316.28
27	Tamu	45	1	45	53.07	24.20	60.14	46.00	14.14	13.32	707.02	499,875.86
28	Linkhay	234	1.05	245.7	73.29	33.62	77.49	69.08	8.41	5.74	420.33	176,674.23
29	Taunggyi_North	225	1.05	236.25	152.97	70.08	161.91	144.03	17.87	5.84	893.68	798,655.52
30	Taunggyi South	334	1	334	115.70	280.59	145.79	85.61	60.18	26.01	3,009.21	9,055,334.17
31	Kyaukme	519	1.05	544.95	245.45	164.62	259.27	231.63	27.64	5.63	1,382.14	1,910,309.77
32	Pathein	76	0.7854	59.6904	41.03	29.89	48.53	33.53	15.00	18.28	749.87	562,305.64
33	Kyaukphyu	219	0.4047	88.6293	70.48	46.13	80.09	60.88	19.21	13.63	960.34	922,246.74
34	Maungdaw	52	1.05	54.6	76.25	34.34	85.36	67.14	18.22	11.95	910.94	829,804.39
35	MyaukOo	77	1.05	80.85	76.44	41.96	85.59	67.29	18.29	11.97	914.71	836,687.16
36	KyaukSe	163	1	163	96.80	88.94	110.46	83.15	27.31	14.10	1,365.36	1,864,220.60
37	Mandalay	19	1	19	52.06	62.24	80.05	24.08	55.97	53.75	2,798.63	7,832,350.74
38	Meiktila	90	1	90	47.41	51.40	58.03	36.79	21.24	22.40	1,061.91	1,127,662.07
39	Pyin Oo Lwin	465	1	465	85.98	97.45	94.83	77.12	17.72	10.30	885.76	784,565.34
40	Yamethin	77	1	77	44.26	39.22	53.02	35.50	17.52	19.80	876.06	767,480.94
		11,284			4,353.63							2,777,220,256.96

$\sqrt{(U_1 * x_1)^{2} + (U_2 * x_2)^{2} + \cdots + (U_n * x_n)^{2}}$ **52,699.34**

$$U_{total}{}^{14} = \frac{\sqrt{(U_1 * x_1)^{2} + (U_2 * x_2)^{2} + \cdots + (U_n * x_n)^{2}}}{x_1 + x_2 + \cdots + x_n}$$

Uncertainty value for overall emission factor is accepted as: **12.10**

[14] Table 6.1: Tier 1 Uncertainty Calculation and Reporting under IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventory

10. Future improvement opportunities

10.1. For Activity *Data*

Much uncertainty exists in identification of forest gain (enhancement) classes while using remote sensing technologies because of difficulties in distinguishing between afforestation and growing cycles of the forest plantations, and difficulties in identifying the ecological pattern of forest regrowth. Indeed, seasonality (leaf phenology) and soil moisture variations may have played a role in the other misclassifications such as dry forest types or teak plantation. Therefore, forest gain has not been considered for sample-based estimates and has been identified as one of the areas of future improvement for the FRL.

There is a need to develop a standard operating procedure to detect land cover change under the six IPCC land cover classes through remote sensing-based and ground-based information to provide a more robust estimate of carbon emissions and removals.

The existing land cover maps do not allow precise estimates of forest cover change, either loss or gain. Improvement of these maps is a priority. To reduce uncertainty and improve the estimates of confidence intervals, it may be possible to allocate samples through stratification using high-quality locally-produced maps.

Further developments may include analysis of degradation with particular attention to the definitions in the national context (e.g. the types of plantations which can be classified as forest).

Specific activities which are either planned or ongoing for improvement of AD include the following:

The local technical team is trying to standardize the image interpretation methodology in order to reduce the effect of interpreter and human bias in image interpretation.

- In order to set up the long term assessment, FAO Open Foris: Collect Earth System has been introduced and sample plots have been set up throughout the country.

- Since the available datasets are from satellite images, perennial crops and home gardens cannot be clearly distinguished from forest cover and the future plan is to collect the attributes of recorded land areas for perennial crops/home garden and create a spatial database through which they can be reliably identified against satellite imagery.
- Detailed land use maps are not currently available. Ongoing land use assessment using Rapid-eye images will assist in the development of these maps.
- Classification of rubber plantations is inconsistent. Previously, rubber plantations fell under the management of the Ministry of Agriculture, Livestock and Irrigation (MOALI). In the last few years, such plantations are also permitted within PFE. Rubber plantation within PFE at the moment is consider as forest land but those outside PFE are considered agricultural crops.
- AD calculations will be refined based on individual states and regions
- Stepwise approach should be applied to improve the current FREL over time by incorporating more REDD+ activities, better data, improved methodologies and additional pools.
- Although this submission is at national level, strengthening of land and forest monitoring and measurement capacities under various projects, like the National Forest Inventory/ National Forest Monitoring and Information System (NFI/ NFMIS) and OneMap Myanmar, future FREL/FRL submissions may be divided into sub-national levels based on the available improved datasets.

10.2. For Emission Factors

FD conducted district forest inventories every year in available districts and many forest parameters are available. On the other hand, there is no database management system or standardization of parameter coding system. The forthcoming NFI/NFMIS project will focus on the national forest monitoring and information system and will provide more qualified data and information to inform future FREL/FRL submissions.

The NFI/NFMIS project will also improve accuracy of geo-location of the sample plots and integrated application of remote sensing data/ satellite and forest inventory data for effective estimation of forest resources.

At the moment, soil data has been partially collected and analyzed by the Forest Research Institute. Monitoring of soil organic carbon will be possible in the future and planned to be conducted with the support of the Finland Forest Research Institute (LUKE) and the NFI/NFMIS project.

References:

Cochran, W.G. (1967). Sampling Techniques. John Wiley and Sons Ltd. 413 pp.

Cochran, W.G. (1977). Sampling Techniques, Third Edition, New York: John Wiley & Sons

COP 16-1. (GOFC-GOLD project office, Natural Resources Canada, Alberta)

FAO (2005, 2010, 2015). Global Forest Resource Assessment – Country reports Myanmar. FAO, Rome. www.fao.org/forest-resouces-assessment/en/

GFOI (2016). Methods and Guidance Documentation. https://www.reddcompass.org/ measurement-estimation

GOFC-GOLD (2010). A source book of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests and forestation. GOFC-GOLD report version

GOFC-GOLD, (2016). A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals associated with deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report version COP22-1, (GOFC-GOLD Land Cover Project Office, Wageningen University, The Netherlands).

Hansen, M.C., et al. (2013, 2014). High resolution global maps of 21st century forest cover change. Science 342, 850; DOI:10.1126/science. 1244693 and http://earthengine-partners.appspot. com/science-2013-global-forest

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehmann, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O. & Townshend, R.G. 2013. High resolution global maps of 21st century forest cover change. Science 342, 850; DOI:10.1126/science. 1244693

Hilden, M., Maekinen, K., Jantunen, J., Jokinen, M., Lilja, R., Than, M.M., Rantala, S. Aung, T. (2016). Needs assessment for the effective implementation of the Environmental Conservation Law in Myanmar. UNDP, Yangon. 124 pp. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html

IPCC (2000). Good practice guidance and uncertainty management in national greenhouse gas inventories. http://www.ipcc-nggip.iges.or.jp/public/ gp/english/index.html

IPCC (2003). Good practice guidance for land use, land use change and forestry. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html

IPCC (2003). Good practice guidance for land use, land use change and forestry.

IPCC (2006). Guidelines for national Greenhouse Gas Inventories. Volume 4 : Agriculture, Forestry and Other Land Use. http://www.ipcc-nggip.iges.or.jp/ public/2006gl/ vol4.html

IPCC (2006). Guidelines for national greenhouse gas inventories. Volume 4. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories

IPCC GL. (2006). Agriculture, Forestry and Other Land Use. IPCC Guidelines for national greenhouse gas inventories.

MOECAF (2012). Myanmar's Initial National Communication under the UNFCCC – chapter 3 GHG-Inventory. Nay Pyi Taw. 313 pp.

MOECAF (2012). Myanmar's first national communication under the United Nations Framework Convention on Climate. MMR/COM/1 B. Nay Pyi Taw, 268pp. (url: http://unfccc.int/resource/docs/natc/mmrnc1.pdf, date of access: 12 December 2017)

MOECAF (2015). Development of a National Forest Monitoring System for Myanmar. Forest Department – UN-REDD Programme, Nay Pyi Taw, 84 pp.

MOECAF (2015a). Forest Reference (Emissions) Level action plan for Myanmar. Forest Department – UN-REDD Programme, Nay Pyi Taw, 39 pp.

MOECAF-UN-REDD Programme (2013). Myanmar REDD+ Readiness Roadmap. Nay Pyi Taw. 148 pp.

MONREC (2017). Country Statement on Climate Change COP 23, http://unfccc.int/files/ meetings/bonn_nov_2017/statements/application/pdf/myanmar_cop23cmp13cma1-2_hls.pdf

MONREC-ECD. (2016). Myanmar Climate Change Strategy and Action Plan, MCCSAP, Final Draft 2016 – 2030. Nay Pyi Taw, 180 pp.

MONREC-FD (2016). National Reforestation and Rehabilitation Programme of Myanmar, NRRPM, MONREC, Nay Pyi Taw.

MONREC-FD. (2011, 2016). Myanmar's Biodiversity Strategy and Action Plan. MOECAF/ MONREC, Nay Pyi Taw. https://www.cbd.int/nbsap/ about/latest/ default. shtml #mm

Olofsson et al. (2013). Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation, Remote Sensing of Environment 129, 122-131

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

Annex

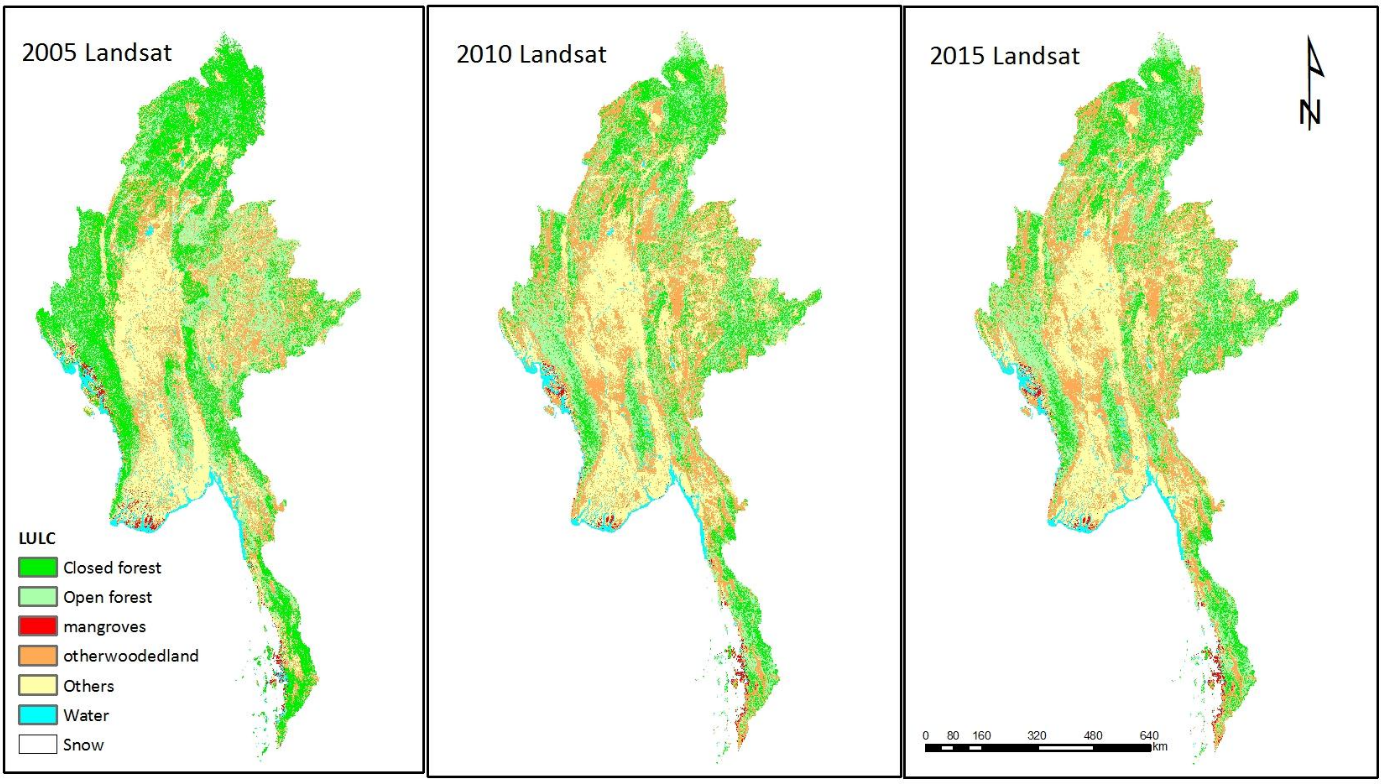
Annex 1: Datasets used to generate activity data for establishing a forest reference emission level in Myanmar during 2005-2015

no	Data type	Format	Note
1	Wall-to-wall maps: Land cover map from Forest Department		
	Land cover map 2005 (30 m-Landsat-based)	Raster	The maps were generated using supervised maximum likelihood classifier into seven land cover classes which include: Close forest, Open Forest, Other wooded land, Mangrove, water, snow, and others.
	Land cover map 2015 (23.5 m-IRS-based)	Raster	
	Land cover map 2015 (30-m-Landsat-based)	Raster	
2	Sample-based estimates		
2.1	Global Forest Change (Stratifier)		
	Tree canopy cover for year 2000 (treecover2000)	Raster	Tree cover in the year 2000, defined as canopy closer for all vegetation taller than 5m in height. Encoded as a percentage per output grid cell, in the range of 0-100.
	Year of forest cover loss event 2001-20015 (loss year)	Raster	Forest loss during the period 2000-2015 defined as a stand-replacement disturbance, or a change from a forest to non-forest state. Encoded as either 0 (no loss) or else a value in the range of 1-15, representing loss detected primarily in the year 2001-2015, respectively.
2.2	1,884 stratified random samples	Vector and csv	The samples were generated following stratified random sampling design using stratified forest change map of 2005-2015, derived from Global Forest Change Maps. The samples were checked against high-quality reference data.

Annex 2: Harmonizing national land use categories with FRA and IPCC land use categories

Land use code	National land use/cover categories	IPCC	Forest Resources Assessment
1	Closed forest	Forest land	Forest (includes primary forest, other naturally regenerated forest, and planted forest)
8	Mangrove		
2	Open forest		
3	Other wooded land		Other wooded land
11	Grassland	Grassland	
4	Cropland	Cropland	Other land with tree cover Other land
5	Other lands	Other lands	
9	Snow		
6	Settlements	Settlement	
7	Wetland	Wetland	
10	Water		Inland water bodies

Annex 3: Wall-to-wall thematic raster maps of Myanmar under seven national land use/cover categories at three years: 2005, 2010 and 2015.



Annex 4: A brief description of the simple and stratified random sampling estimators

Stratified estimators

Stratified estimators of the mean ($\hat{\mu}_{STR}$) and the variance of the estimate of the mean ($V_{\hat{a}r}(\hat{\mu}_{STR})$) are provided by Cochran (1977) as,

$$\hat{\mu}_{STR} = \sum_{h=1}^{H} w_h \hat{\mu}_h \text{-----------}(Eq. 3)$$

and

$$V_{\hat{a}r}(\hat{\mu}_{STR}) = \sum_{h=1}^{H} w_h^2 \frac{\hat{a}_h^2}{n_h} \text{-----------}(Eq. 2)$$

Where

$$\hat{\mu}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} y_{hi} \text{------------}(Eq. 4)$$

And

$$\hat{\sigma}_h^2 = \frac{1}{n_h - 1} \sum_{i=1}^{n_h} (y_{hi} - \hat{\mu}_h)^2 \text{-------------}(Eq. 5)$$

$h = 1, \dots \dots, H$denotes strata;

$y_{hi}$is the i^{th}sample observation in the h^{th} stratum;

$w_h$is the weight for the h^{th} stratum;

$n_h$is the number of plots assigned to the h^{th} stratum; and

$\hat{\mu}_h$and$\hat{\sigma}_h^2$ are the sample estimates of the within-strata means and variance, respectively.

Using the notation of *Eq. 1 (see section 7.1.2)*, and adding the subscript j to indicate reference class j,

$$\hat{\mu}_{hj} = \frac{1}{n_h}\sum_{i=1}^{n_h} y_{hji} \text{------------ } (Eq.6)$$

But because

$$y_{hji} = \begin{cases} 1 & if\ h = j \\ 0 & if\ h \neq j \end{cases} \text{------------- } (Eq.7)$$

Equation (1) can be expressed as,

$$\hat{\mu}_{hj} = \frac{n_{hj}}{n_h} \text{-------------- } (Eq.8)$$

So that from *Eq. 3*

$$\hat{\mu}_j = \sum_{h=1}^{H} w_h \, .\hat{\mu}_{hj} = \sum_{h=1}^{H} w_h \, .\frac{n_{hj}}{n_h} = \sum_{h=1}^{H} \hat{P}_{hj} \text{ ----------------}(Eq.9)$$

The area for reference class j is estimated as the product of $\hat{\mu}_j$and the total area(A_{tot}).For example the estimated deforestation $\hat{A}_1 =$ $Producer's\ accuracy\ of\ deforestation\ class * A_{tot}$

Confidence Interval

Using the notation of *Eq. 5* and again adding the subscript to denote reference class j,

$$\hat{\sigma}_{hj}^2 = \frac{1}{n_{hj} - 1}\sum_{i=1}^{n_h}\left(y_{hij} - \hat{\mu}_{hj}\right)^2 \text{ -------------}(Eq.10)$$

Noting from *Eq. 7*, the *Eq. 10* can be expressed as,

$$\hat{\sigma}_h^2 = \frac{1}{n_h - 1}\sum_{i=1}^{n_h} \hat{\mu}_{hj} \, .\left(1 - \hat{\mu}_{hj}\right) \text{ -------------}(Eq.11)$$

So that from *Eq. 2*

$$V_{\hat{a}r}\left(\hat{\mu}_j\right) = \sum_{h=1}^{H} w_h^2 \frac{\hat{a}_h^2}{n_h} = \sum_{h=1}^{H} w_h^2 . \frac{\hat{\mu}_{hj}.\left(1 - \hat{\mu}_{hj}\right)}{n_{hj} - 1} = \sum_{h=1}^{H} \frac{w_h . \hat{p}_{hj} - \hat{p}_{hj}^2}{n_{hj} - 1} \text{-----------}(Eq. 12)$$

And standard error,

$$SE\left(\hat{\mu}_j\right) = \sqrt{V_{\hat{a}r}\left(\hat{\mu}_j\right)} \text{------------}(Eq. 13)$$

From *Eq. 13* so that the standard error of the estimated area of forest loss is

$$SE\left(\hat{A}_1\right) = SE(\hat{\mu}_1) * A_{tot}$$

At 95% confidence interval of the estimates area of forest loss is $\pm 1.96 * SE\left(\hat{A}_1\right)$

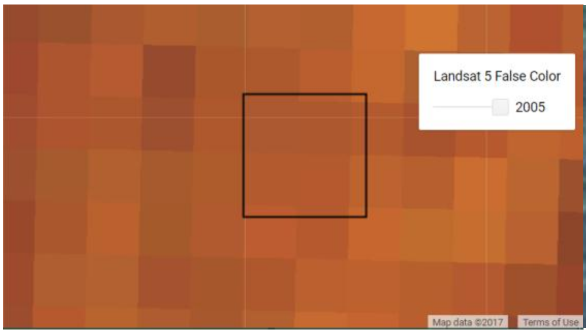
Strata (j)	$\hat{\mu}_j$ (proportion)	$SE(\hat{\mu}_j)$ (proportion)	$\hat{\mu}_j$ (ha)	95% Confidence interval	
				Lower (ha)	Upper (ha)
Stable Forest					
Stable Non-Forest					
Loss					

Annex 5: Examples of sample assessment using validation datasets:

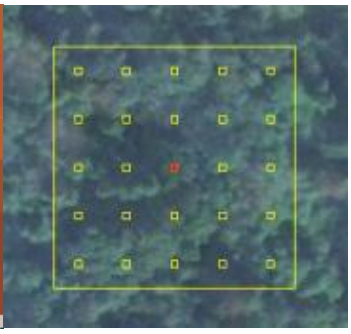
(i) Forest 2005 > Forest 2015; (ii) NonForest 2005 > NonForest 2015; (iii) Forest 2005 > NonForest 2015 (sample # 408). 30-m spatial resolution Landsat False Color Composite (NIR_SWIR1_R) and high spatial resolution Google Earth natural color (RGB) imagery were used as validation datasets.

(i) Forest 2005 > Forest 2015

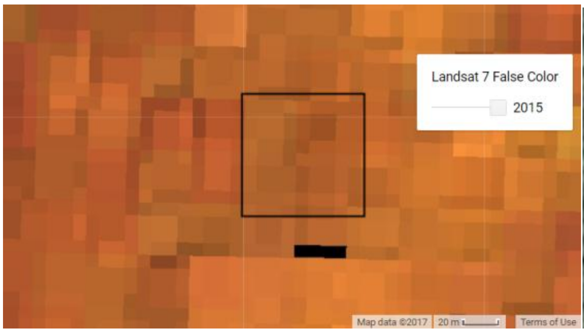
2005 Landsat 5 TM



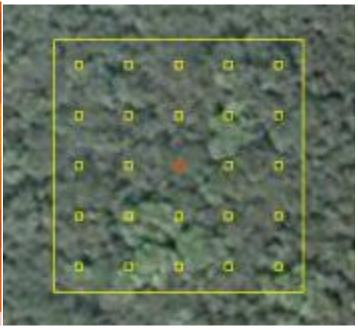
2005 Google Earth Imagery



2015 Landsat 7 ETM+

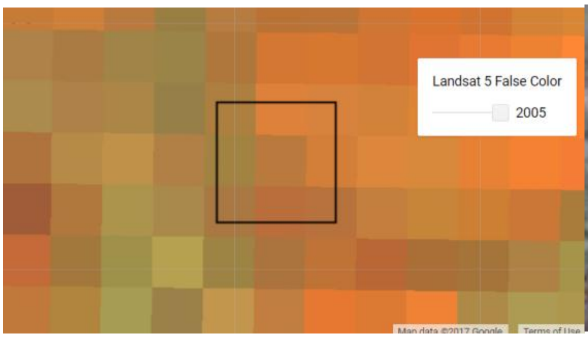


2015 Google Earth Imagery

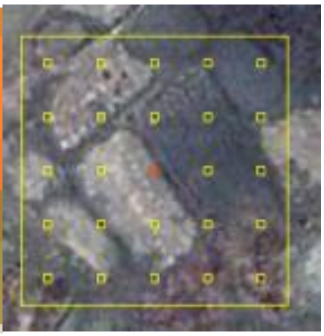


(ii) Non-Forest 2005 > Non-Forest 2015

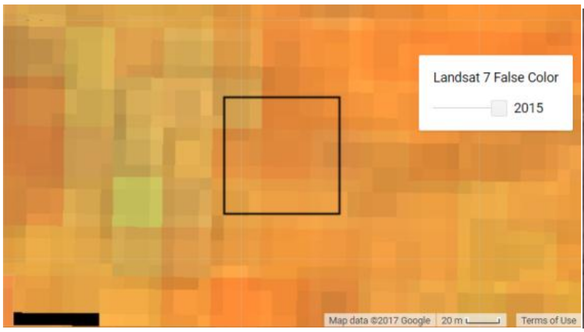
2005 Landsat 5 TM

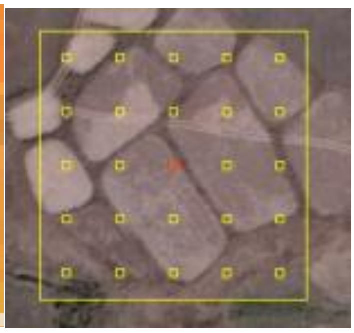


2005 Google Earth RGB Imagery

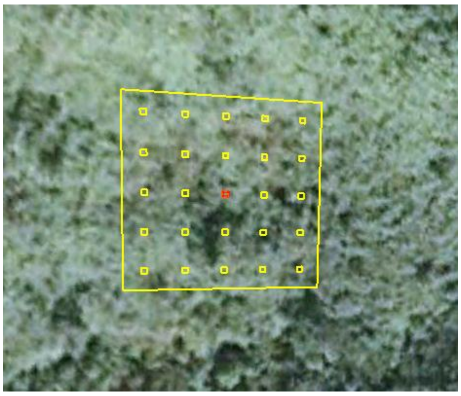


2015 Landsat 7 ETM+ 2015 Google Earth Imagery

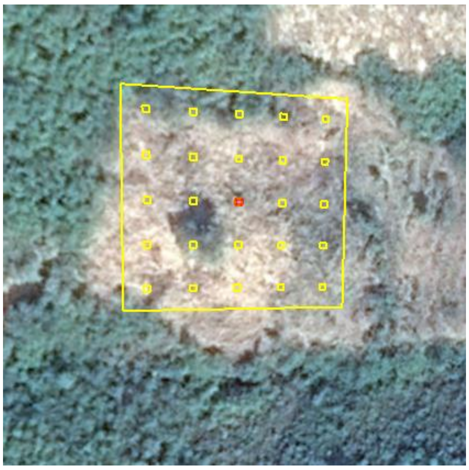


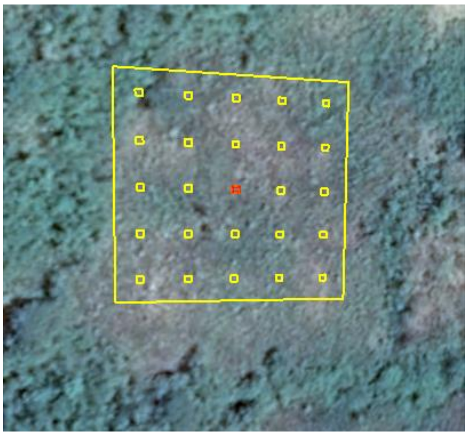


(ii) Forest 2005 > Non-Forest 2015 Time-series imagery from Google Earth


2005


2013


2014


2017

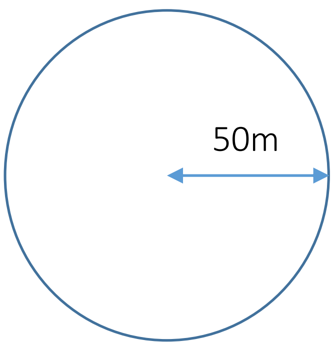
Annex 6: Plot Designs and Description

The sample plots are of circular, square or rectangular shape. The strip is a special shape of rectangular which is particularly used in forested areas that are not easily accessible.

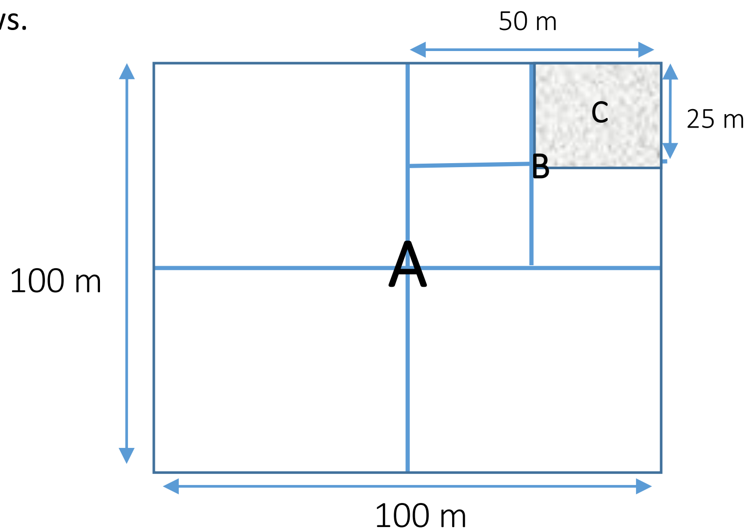
A sample tree is considered to fall inside a plot of given boundaries, if the center of the bole at the base of the tree falls inside the plot. Consequently, each sample plot contains edge trees with a growing space which is partly located outside the plot boundaries. One of the important non-sampling errors in forest inventories is the incorrectly omitting or including such edge trees.

Circular sample plots are often preferred to other plot shapes because they have the smallest perimeter for a given area. Circular plots, therefore, tends to produce less borderline trees than other plot shapes for the same plot size. A further advantage of circular plots is that they are less time consuming to establish than square or rectangular plots. In stands without undergrowth, the plot boundaries can be conveniently located with the aid of optical devices.

In many tropical forests, however, it is more convenient to lay out square or rectangular plots or strip-shaped sampling units. Due to the adverse environmental conditions and the need for a larger plot size, utilizing circular sample units creates difficulties in tropical forest. Square or rectangular shape can be used in inventories of forest plantations where the trees were planted in rows. In this case, boundaries of sample units should be established in the middle of two rows.

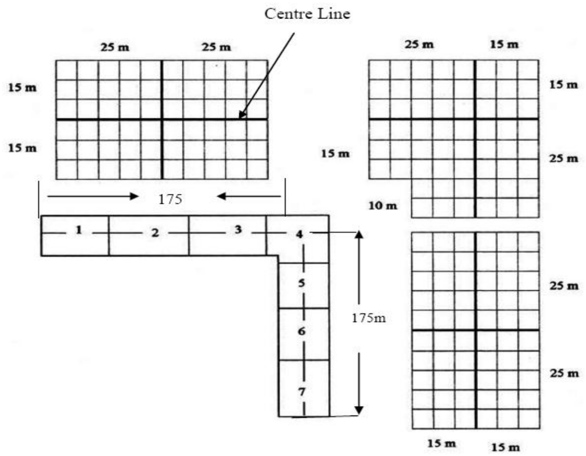


Circle shape Design



Square shape Design

All DBH classes are collected in 50 m radius Circular plots whereas, the trees with DBH 200 mm and above are collected within square A area (100m x 100m: 1 Ha), trees within 50 mm and 199 mm collected within square B area (50m x 50m: 0.25 Ha) and the regeneration and bamboo are collected in square C area (25m x 25m: 0.0625Ha).



L-shaped design

The Sampling unit is composed by a strip of 15m wide to the left and right of a center line which runs 175 meters in East-West and North-South Direction. It is distributed systematically in a grid of 3 km x 3 km in the forest area with a sampling intensity 0.11 percent. The strip has an Inverted L-shape and is divided into seven units of size 30m x 50m equal to 1.05 ha as shown in figure.

In the three special sample plots (15 meters radius circular plots numbered 1, 4 and 7 as in the figure, trees having diameters of 10 cm and above are enumerated. In the special circular plots, the enumerated trees are also labelled with aluminum tags and their position is recorded. (Source: Brief on National Forest Inventory, NFI, Forest Resources Development Service, Rome, June 2007)

Annex 7: Summary of information of afforestation/reforestation during reference period of 2005-2015, as a benchmark for estimating GHG removals from the NRRPM (enhancement of forest carbon stocks)

Due to the increasing demands of forest products, planting of forest trees in different means and scales is taking place to supplement the production role of natural forests in Myanmar. Under several reforestation and rehabilitation programmes, the FD has been supporting the establishment of both government-owned and private forest plantations. A private plantation programme was launched in 2006 with the objective of promoting private investment in plantation forestry. To estimate the impact of this programme during the FREL reference period of 2005-2015, Myanmar uses the established plantation data of FD for each year, and assumes a survival rate of 70% for each year of plantation at the beginning of the subsequent year, based on FD field observations. Thinning operations are introduced in plantations at 5 years after establishment, and 40% of the stand is removed. Success rate of plantation is estimated at 50%, and IPCC default value of 7 tons of dry biomass per year per ha, according to chapter 3 of LULUCF Sector Good Practice Guidance (IPCC, 2003).

Table . Total Plantation area in hectares and tCO_2eq per ha from each year

Year	**Government plantation total (acres)**	**Private plantation area (acres)**	**Total plantation (acres)**	**Total plantation (ha)**
2004-5	79,010		79,010	31,974
2005-6	82,042		82,042	33,201
2006-7	70,000	4,422.5	74,422.5	30,118
2007-8	59,060	5,641.95	64,701.95	26,184
2008-9	60,011	7,583.04	67,594.04	27,354
2009-10	55,200	6,882.9	62,082.9	25,124
2010-11	37,065	6,173.32	43,238.38	17,498
2011-12	29,000	7,433.38	36,433.38	14,744
2012-13	15,400	12,830.1	28,230.1	11,424
2013-14	15,000	13,600.41	28,600.41	11,574

2014-5	8,000	12,848.22	20,848.22	8,437
		Total	**587,203.82**	**237,633**

Table . Estimation on the **tCO_2eq** of the established Plantation area

Year	Total biomass in tons	Tons carbon	tCO_2eq	Notes
2004-5	15,486,561	7,278,683.72	26,669,097.14	
2005-6	12,782,490	6,007,770.43	22,012,470.84	
2006-7	9,847,096	4,458,935.28	16,337,538.87	
2007-8	6,598,366	3,101,232.10	11,362,914.42	
2008-9	5,361,459	2,519,885.67	9,232,861.08	
2009-10	3,693,243	1,735,824.01	6,360,059.16	
2010-11	1,837,285	863,524.12	3,163,952.36	
2011-12	1,032,086	485,080.55	1,777,335.15	
2012-13	479,822	225,516.37	826,291.97	
2013-14	243,058	114,237.30	418,565.45	
2014-15	59,059	27,757.69	101,704.19	
Total	**57,060,526**	**26,818,447**	**98,262,791**	**Total Removal for 10 years**
		Average /year	**9,826,279**	**tCO_2eq per year**

For conversion of the targets of the 10-year NRRPM in terms of GHG removal, the following activities were selected (by reason of ease of assignment of a C value):

- Forest plantations by the government (commercial, watershed, mangrove, fuelwood, mountain, other greening purposes)
- Forest plantations by private actors (teak and other hardwoods)
- Establishment of community forests

The following IPCC default values for annual biomass growth and the related C content[15], the following amounts of C removal in terms of tons of CO_2 eq can be expected over the period of 2017 – 2026:

Plantation types	**Time periods/ Figures in ton of CO_2 eq**	
	Phase 1 (2017 – 2021)	**Phase 2 (2022 – 2026)**
Forest plantations, government	2,642,000	9,607,000
Forest plantations, private	2,726,000	8,983,000
Community forests	3,096,000	10,301,000
Total	**8,464,000**	**28,891,000**

Thus, if 10-year NRRPM is rolled out and implemented as expected then the annual average increase in carbon removal for reported activities according to the planned duration of the Programme (2017 – 2026) will be around 28 million tCO_2 eq.

[15] For plantations 7 tons of dry biomass per year and ha (table 3A.6), for community forests 3 tons of dry biomass per year and ha (half of rate for natural regeneration) from Annex 3A.1 of chapter 3 LULUCF Sector Good Practice Guidance from IPCC, 2003.