Forest Reference Level (FRL) of Myanmar

Ministry of Natural Resources and Environmental Conservation

Myanmar

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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, Ministry of Planning and Finance (MOPF)
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	Myanmar 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 and Information System
NFMS	National Forest Monitoring System
NO_2	Nitrogen Dioxide
MRRP	Myanmar Reforestation and Rehabilitation Programme
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
REF	Removal Factor
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 for REDD+ (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

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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 FRL using a stepwise approach. Myanmar submitted its initial FREL report on January 2018 and current submission was revised one by following to the Assessment Team-AT of UNFCCC. The FRL submission will be a benchmark for assessing its performance in implementing REDD+ activities in contribution to climate change mitigation. The main objective of the FRL 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 FRL was initiated by a group of experts; REEDD+ 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 and reviewed by AT.

Myanmar FRL is national level as all the existing land and forest monitoring and measurement capacities are at the national level. In addition, Initial National Communication (INC) and Forest Resources Assessment (FRA) were also reported by national level. Myanmar prioritized two of the five REDD+ activities as the focus of the country's first FRL submission; deforestation and enhancement of forest carbon stock through afforestation/reforestation. The Government of Myanmar recognizes the potential importance of plantation and forest restoration measures to climate change mitigation efforts. January 2018 submission was focused mainly on deforestation due to the existing data limitations. It is converted from the FREL to the FRL in the present submission by the TWG's efforts on historical forest enhancement and comments from AT.

Three carbon pools; i.e. Above Ground Biomass (AGB), Below Ground Biomass (BGB) and Litter were included in this FRL, using allometric equations derived from district forest management inventory and according to IPCC Good Practice Guidance (2003). Due to the limitation of existing national data sources on soil organic carbon on forest soils are very localized, soil organic carbon was excluded in the submission. Deadwood carbon pool was also excluded due to limited information/data at national level. In absence of a reliable data sources for the estimation of non-CO_2 gases, this FRL has considered only CO_2 gas. Strategic planning is currently being developed to facilitate the inclusion of remaining carbon pools and non-CO_2 emissions and so expected in future submissions.

The reference period, from the year 2005 to 2015, was decided through a series of consultation meetings, based on availability of the most reliable national scale existing Activity Data (AD) and Emission Factors (EF), and to ensure the consistency with GHGs Inventory reporting. It is expected that the database generated through this FRL development process will benefit the SNC and the Biennial Update Report (BUR) to the UNFCCC.

AD has been developed by estimating the extent of forest change measured as gross area estimates of forest, non-forest and forest loss (deforestation) during 2005-2015, excluding forest degradation, forest improvement and forest area gain. The amount of 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 gross forest loss is about **428,984 ha per year** during the reference period 2005-2015.

This submission used 11,284 forest inventory plots data collected during 2005 to 2017 which were covered throughout the country. A combination of Tier 1 (for BGB and Litter) and 2 (for AGB) approaches were used in estimating the carbon pools. *A weighted mean value of* **125.43 *tCO_2 eq per ha*** is estimated for a national level EF in Myanmar**.** *Annual CO_2 emission from gross forest loss* during the historical reference period 2005-2015 is estimated as **53,807,463 *tonnes per year***.

This submission followed the IPCC Good Practice Guidance and Uncertainty Management of National Greenhouse Gas Inventories. The uncertainty only includes sampling-based error through the propagation of errors (tier 1 approach) but no other error sources (non-sampling errors). The *% uncertainty of AD, i.e.* Forest loss area is 8.97 *%* for this submission whereas the *% uncertainty of the EFs is 13.03%, thus the* resulting combined *overall error % of the emission estimate from deforestation is* ***15.06*** for this submission.

For the carbon stock enhancement from forest plantation establishment, the average annual removal for the ten-year reference period 2005 – 2015 has been calculated with **3,351,332 tonnes of CO_2e**. Statistical uncertainty assessment for this figure is not available since the data are not based on sampling but on aggregating records from subnational reports on plantation establishment.

Forest Reference Level (FRL) 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 16^{th} 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 FRL using a stepwise approach. Myanmar prepared the FRL submission as a benchmark for assessing its performance in implementing REDD+ activities in contribution to climate change mitigation. The proposed FRL 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 the FRL submission covers two REDD+ activities; Deforestation and Enhancement, three carbon pools (AGB, BGB and litter), and one gas as CO_2 only, with the final FRL calculation expressed in tonnes of carbon dioxide equivalent per year (tCO_2 eq). Since the submission covers emissions and removals of Greenhouse Gases (GHGs), it is considered as a Forest Reference Level (FRL), rather than, a Forest Reference Emission Level (FREL) and is referred to FRL throughout this document. Myanmar intends to expand the scope of the FRL as more extensive and better-quality data become available.

Moreover, the Government of Myanmar recognize the potential importance of plantation and forest restoration measures to climate change mitigation efforts. During the Technical Assessment (TA) process, there was improvement of data on historical forest enhancement. Calculations of enhancement estimation and then incorporation into the calculations was conducted as part of a revised submission in order to convert the FREL to FRL.

1.1. Objectives of FRL

The main objective of the FRL 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 REDD+. The country team interacted with AT of the UNFCCC through technical assessment process and followed the preliminary questions to improve the 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 for FRL 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 tonnes 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
- <u>Decision 13/CP.19 Warsaw</u> provides guidelines on procedures for the Technical Assessment (TA) of submissions of FREL/FRLs, including:
    - Each FREL/FRL submission shall be subjected 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 FRL was applied
- The FRL is based on historical data
- The FRL is consistent with the upcoming GHG inventory under development for the Second National Communication (coordinated by ECD),
- The FRL 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 this modified submission, Myanmar included two REDD+ Activities of Reducing Deforestation and Enhancement of forest carbon stock. Myanmar will try to include other remaining activities by the chance of getting the reliable data in the future.

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.

In Myanmar, forestry sector has traditionally played a critical role in the development and economic transformation of the country. Forest management is being focused on sustainability of forest resources; such as sustainable production of goods and services for local needs and export, and conservation of its ecosystem and environment. As provision of forest resources, especially timber and fuelwood from natural forests alone is insufficient to fulfill demands for forest products, establishment of forest plantation by various objectives and scales was conducted since 1970s. Under different reforestation and rehabilitation programs, FD has been establishing different types of forest plantations such as commercial plantation, watershed plantation, local supply plantation, industrial plantation within its limited manpower and budget. With the objective of promoting private investment in plantation forestry, private plantation program was launched in 2006. FD has been promoting community forestry program since 1995. FD introduced very specific plan of 10-year Myanmar Reforestation and Rehabilitation Program (MRRP) from 2017-2018 to 2026-2027 in order to enhance economic and environmental conditions of the country through national reforestation and rehabilitation program. Therefore, the establishment of new forest plantations on heavily depleted forests (land cover is not fit with forest cover definition) and the restoration of heavily depleted forests through reforestation, enrichment planting and natural regeneration through silvicultural operations will form an important part of the REDD+ strategy of Myanmar.

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

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 Myanmar 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 9' 55'' – 28' 15'' 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 the general description of 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 and dominant types of forests in Myanmar map is mentioned in Annex 1.

Table 2. 1: Forest Types and Vegetation Zones in Myanmar

Forest type according to Davis, 1960	**Corresponding forest types according to NFI field instruction, 1985[2]**	**Short description**	**Typical rainfall (mm/year) ***	**Distinct species types found**
Evergreen hardwood forests	Evergreen forest, giant; Evergreen forest, typical; Bamboo forest (degraded rain forests)	Occurs in Tanintharyi region and other lowland areas with high annual rainfall	2,500-4,000	Southern type: *Dipterocarpus, Hopea, Shorea, Parashorea,* In the Northern type Dipterocarpaceae are replaced by *Cedrela, Chukrasia, Dysoxylum*

[2] In use for district management plan inventories since the end of the last NFI

Forest type according to Davis, 1960	Corresponding forest types according to NFI field instruction, 1985[2]	Short description	Typical rainfall (mm/year) *	Distinct species types found
	Mangrove, typical; Mangrove, high (kanazo forest);	Tidal forests in Irrawaddy delta region and other Coastal areas	>3,500	*Avicennia, Bruguiera, Rhizophora, Sonneratia, Nipa, Heritiera,*
	Swamp forests; Evergreen forests, riverine;	On interior lowlands and some areas along the Coast covered by river and other non-saline water	>3,500 2,500-4,000	*Lagerstroemia, Amoora, Barringtonia, Xylia,* few if any Dipterocarpaceae
Mixed evergreen and deciduous hardwood forests	Mixed deciduous forest, lower; Mixed deciduous forest, upper moist; Mixed deciduous forest, upper dry;	In both, low land and upland formations characterized by teak, occurred north and south of the central dry zone, lower parts of Shan hills, Arakan Yomas, Chin hills and most of Bago Yoma	1,250-2,500	*Tectona grandis, Xylia xylocarpa, Pterocarpus macrocarpus, Gmelina arborea, Millettia pendula*
Dry deciduous hardwood forests and scrubs	Dipterocarp (indaing) forest, high; Dipterocarp (indaing) forest, low	Edaphic forest type occurring mostly on gravel and sandy soils, Best sites north of central dry zone on alluvial soils in river valleys	900-1,250	*D. tuberculatus, obtusifolius, turbinatus, alatus*, On drier sites *D. tuberculatus* with *Pentacme, Emblica* and other sp.
	Hill forest, dry	On dry slopes, ridges and shoulders of mountains best formations have teak too	>3,000	*Xylia xylocarpa, Pterocarpus, Adina, Shorea oblongifolia, Tectona hamiltoniana, Spondias, Terminalia, Vitex,*
	Dry forest, than-dahat; Dry forest, thorn; Dry forest, aukchinsa – thinwin (*Diospyros, Milletia*);	Different dry to xerophytic formations prevailing in the central dry zone and the foot hills and low mountains of Shan state	<900	Than-Dahat forests (*Terminalia oliveri, Tectona hamiltoniana*); Te scrub forests; (*Diospyros burmanica, Dalbergia, Acacia catechu, Limonia, Zizyphus*); Sha thorn and scrub forests (*Acacia catechu, A. leucocephala, T. hamiltoniana, Zizyphus, Limonia, Cassia*)
Coastal Conifer forests[3]	Beach and dune forests	*Casuarina equisetifolia* formations in Coastal areas of Rhakine and Tanintharyi, sea face of Ayeyarwaddy Delta	>3,500	*Rhizophora apiculata, Bruguiera gymnorhiza, Heritiera fomes*

[3] Not in Davis´ classification

Forest type according to Davis, 1960	**Corresponding forest types according to NFI field instruction, 1985[2]**	**Short description**	**Typical rainfall (mm/year) ***	**Distinct species types found**
Hardwood rain forests	Hill forest, evergreen	Similar to tropical type because of layered structure but distinctive because of mix between tropical and temperate genera. Occurs in areas with abundant rainfall, fog, clouds and moist soils on upper valleys and lower mountains of Kachin state, Naga hills, upper Chindwin river valley.	>3,000	Temperate genera of *Quercus, Castanopsis, Magnolia, Fraxinus, Celtis* mixed with tropical genera of *Dipterocarpus, Terminalia, Engelhardtia, Sterculia, Ficus*
Mountain forests and scrubs	Hill forest, evergreen	Occur on slopes and tops of hills and mountains where colder winter temperatures limit growth of typical tropical species,	>3,000	Common genera are *Quercus, Castanopsis, Magnolia, Acer, Alnus, Prunus, Pyrus, Ulmus, Salix*, *Podocarpus*, but also species of tropical genera such as *Bauhinia, Engelhardtia, Lagerstroemia, Cinnamomon, Ficus,*
	Hill forest, dry	On dry slopes and ridges, often subject to clearing and fire, mix of mainly deciduous with some evergreen species, sometimes scattered pine trees mixed with oak and chestnut, when open stands with savanna-like vegetation and bracken fern,	>3,000	*Quercus incana, Rhododendron arborea, Schima wallichii, Pinus keysia, Kydia*
	Hill forest, pine	Dominant species khasi pine (*pinus keysia*), often pure stands with open canopy, prevalent in Shan state, Chin hills, and a few in Arakan Yomas, Mostly in altitudes between 1350 m – 2450 m, sometimes mixed with a few hardwoods of low stature	>3,000	*Quercus griffithi, Q. incana, Q. serrata*), in some areas locally mixed with *Rhododendron maximum* and *Alnus nepalensis* (Kachin)

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 (Mon. M.S, 2017). 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)[4]. RF and PPF are given a similar legal status under the Forest Law. The status of land as PFE indicates administrative responsibility by FD but does not

[4] See annex 2, 2 (a) and 2 (b)

directly imply any information regarding tree cover. Table 2.2 shows major land categories defined by different Ministries and Departments which are concerning with management on land resources of Myanmar;

Table 2. 2: Major Land Categories Reported in Statistical Year Book compiled by 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[5]. 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

[5] 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[6] 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 FRL was initiated by a group of experts representing a cross-section of ministerial agencies and organizations. The REDD+ 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 FRL 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. It covers temporarily de-stocked land for which the long-term use remains forest. Therefore, it does not include land that is predominantly under agricultural or urban land use. This definition is also applied by FD, MONREC for satellite image classification in the national forest resource assessment. In the context of this submission, 'forest' refers to all areas under forest

[6] 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/.

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 to non–forest land use** (i.e., 100% loss of all three carbon pools[7] included in EF calculations of this submission). This FRL submission considers only 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 the reference period.

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

Enhancement of forest carbon stocks through reforestation/afforestation is defined as **the establishment of new carbon sequestration capacities resulting from the change of non-forest land use to forest land use.** Although enhancement of forest carbon stocks also occurs in forest land remaining as forest land, this submission excludes this latter aspect of enhancement due to data limitation. However, it will be included once the measuring capacities through an improved NFMS are established, most likely after completion of the first measurement cycle of the upcoming National Forest Inventory after 2022-23.

4. Scale

In accordance with the draft REDD+ strategy, Myanmar FRL is national level. A national scale FRL is appropriate as all the existing land and forest monitoring and measurement capacities are at the national level and there is currently limited MRV capacity at the sub-national level. In addition, the impact of the REDD+ strategy implementation is expected to be measured at national level.

[7] Only three carbon pools of AGB, BGB and Litter are only considered in this submission and the remaining two carbon pools will be likely to consider in the future.

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 FRL submission: (1) deforestation and (2) enhancement of forest carbon stock through afforestation/reforestation, 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;
- Measurement and monitoring in the impact and effectiveness of the existing Myanmar Reforestation and Rehabilitation Programme (MRRP) is critical.
- For the remaining REDD+ activities (forest degradation, sustainable forest management, and conservation of forest carbon stocks), not enough reliable data are available, since measurement capacities have not yet been fully established.
- Consistency with the Draft REDD+ strategy and Draft NDC which formulates quantitative targets for reducing deforestation and enhancement of forest carbon stocks through the targets of the 30-year Forestry Master Plan (2001-2030) and the MRRP (2017-2026).

In common with many other developing countries, Myanmar experiences both deforestation and forest degradation from various anthropogenic drivers. 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 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 measure and monitor 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 MRRP was initiated in 2017 and is intended to continue to 2026-2027. The MRRP has been accorded priority in national forestry 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 MRRP, 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 FRL submission for Myanmar, initially with a focus on afforestation/ reforestation.

5.2. *Pools and gases*

Three carbon pools of Above Ground Biomass (AGB), Below Ground Biomass (BGB) and Litter are included in this FRL, using the country district forest management inventory data. The allometric equations and the default values according to IPCC Guidances (IPCC 2003 and 2006) are used to calculate the country emission factor. This submission omitted Dead Wood (DW) and Soil Organic Carbon (SOC) carbon pools due to limited information/ data at national level. Plans are currently being developed to facilitate the inclusion of the remaining two carbon pools in forthcoming submissions. Because of the following reasons, Myanmar decided to exclude the SOC in this FRL submission:

- The existing national data sources on SOC on forest soils are very localized and only conducted for a few selected areas prior to forest plantation establishment.
- The data collection protocols for SOC are not standardized and are inconsistent over the years, depending on the project and on the involved technical personnel.

- The use of Tier 1 default emission factors for SOC stocks as provided by IPCC guidelines (IPCC-GPG, 2003)[8] appear as substantially high in C-stock and do not seem to represent average conditions of forest soils in Myanmar. The application of default reference values of SOC stocks under native vegetation of between 31 and 66 tonnes of C per ha for different tropical ecoregions (dry, moist, wet) and different soil types (high and low activity clay, sandy soils) would result at average in higher below ground SOC stocks than the average C-stocks in above ground living biomass, which is very unlikely to be the case. The only conditions where below ground SOC stock is likely higher than the above ground C-stock is in mangroves and peatlands which both represent minor parts of the forest vegetation in Myanmar, when compared with total forest cover.

Therefore, the inclusion of SOC, will be postponed until Myanmar is in the condition to present more reliable data on SOC in forest and non-forest soils. Presently the Forest Department, through the Forest Research Institute, FRI, is working on developing standardized methodologies for soil data collection in upland mineral soils and in Mangroves, which will be applied in the upcoming National Forest Inventory. Results from the soil data analysis will likely not be available before the years 2022/ 2023.

The default values for dead organic matter stocks, particularly DW, are not provided since these are highly variable and site-specific, depending on forest type and age, disturbance history and management regime. In addition, data on coarse woody debris decomposition rates are scarce and thus, IPCC explains, it was deemed that globally applicable default factors and associated uncertainty estimates cannot be developed (IPCC 2006, Volume 4 Chapter 2.2.1).

Myanmar submitted only CO_2 gas in this initial FRL 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

[8] Table 3.2.4 page 3.43 GPG, 2003

and NO_2 and the total combined emissions were 637 Gg[9] 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 FRL

Through a series of consultation meetings, the proposed reference period was identified as the period from the years 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 IPCC GL 2006 in order to ensure consistency with the development of AD and EF for the FRL.

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 projected data from FRA reports. This FRL used AD estimation based on an un-biased sampling approach and EF calculations from plot data of available inventories of district management plans. The EFs are therefore considered as nationally specific data and more accurate compared to the previous GHGs inventory. Data generated in this FRL development process will also benefit the current process of developing a Second National Communication (SNC) and the Biennial Update Report (BUR) to the UNFCCC.

7. Data used in the FRL

7.1. Deforestation

7.1.1 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

[9] **1** Gg = **1000** ton

include human activities resulting from deforestation and from forest degradation while the removals include forest gain or enhancement of canopy cover. In this report the AD has been developed by estimating the extent of forest change measured as area estimates of forest, non-forest and forest loss 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 AD are listed in Annex 3.

7.1.1.1 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 (RS/GIS) unit of Myanmar Forest Department (FD) (see Annex 3). These wall-to-wall maps are pixel-based and were 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. Those maps were classified according to FRA categories (Annex 4).

The post-classification change detection method is recognized as a suitable option to estimate changes within and across different land cover types (IPCC, 2006), using the available temporal maps. 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*.

However, while preparing the AD for FRL, several problems with these wall-to-wall maps (Annex 5) have been detected. For instance, they were produced by different people in the RS & GIS unit of FD without defining standard operating procedures that could be followed to maintain quality control or could be reproduced in the context of a long-term NFMS. Moreover, the mapping datasets (satellite imagery) used to produce those land cover maps were not from the same reference year. For example, the year 2005 map was produced using Landsat imagery collected during 2004-2006.

Following a detailed evaluation, errors in the wall-to-wall maps (see Annex 6) appeared to be substantial because the maps have shown inconsistencies in geolocations both within individual maps and across the three temporal maps (2005, 2010, 2015). 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 General Guidelines (GL) (2006), 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 accuracies (error matrix) can inform only about thematic error issues but they do not produce the information necessary for calculating sampling errors and the associated confidence intervals (Olofsson et al., 2013). Therefore, the pixel-counting-based wall-to-wall approach provides no quantification of sampling errors and no assurance that estimates are unbiased or that uncertainties are reduced (Stehman, 2005; GFOI, 2016). The bias resulting from applying pixel counting to obtain the area of a land cover class is labeled as “measurement bias” rather than as “estimator bias” because a pixel count represents a complete census of the region and therefore is not a sample-based estimator. Gallego's (2004) review provides an excellent summary of many of the area estimation options, including a critique of pixel counting and an overview of estimators combining ground and remote sensing information, as well as a review of methods for small area estimation applicable when interest lies in small geographic regions that receive few sample units.

We therefore used a sample-based approach as an independent and consistent method to derive estimates on areas of stable forest, stable non-forest and forest loss between the years 2005 and 2015. 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 proportional to the total area and reduce the standard errors of the class-specific accuracy estimates for comparatively rare classes such as deforestation. In addition, STRS is one of the easier survey designs to implement having unbiased variance estimators (Olofsson et al., 2014).

In order to develop an appropriate sample survey design, a notion of the existing variability distribution of our parameters of interest is necessary. For this purpose, a combination of multiple maps within the same period where used to identify a spatially-explicit forest change map for the period of interest. 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[10] (Hansen et al., 2013) were used to generate the strata map for the years 2005-2015. The freely available GFC maps, year 2000 tree canopy cover map and annualized loss map, have been produced following a transparent and consistent methodology and, therefore, offer a complete application of the independent sample-based approach. 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. Figure 7.1 illustrates the steps 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 GFC gain map has not been separated by the years of gain, which was 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[11]), a total of 1,884 stratified random samples were generated using the GFC-based strata map of 2005-2015.

[10] https://earthenginepartners.appspot.com/science-2013-global-forest
[11] https://sepal.io/

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 3: Sample Assessment

Sample assessment:

Using Collect Earth Tool in Open Foris. 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.

Step 1: Forest Change Map 2005-2015

Forest/NonForest Map 2005

Forest/NonForest map 2000 (≥10% canopy cover threshold from the tree cover 2000 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

7.1.1.2 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. The sample size is much higher than a sample size of 50-100 suggested by Olofsson et al. (2014) for change stratum using the variance estimator for user's accuracy. Figure 7.2 shows the distribution of the samples across Myanmar.

Equation 1

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

Where: n= the number of required sample units

N= total number of all possible sample units in the area of interest

$S(\hat{O})$= 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

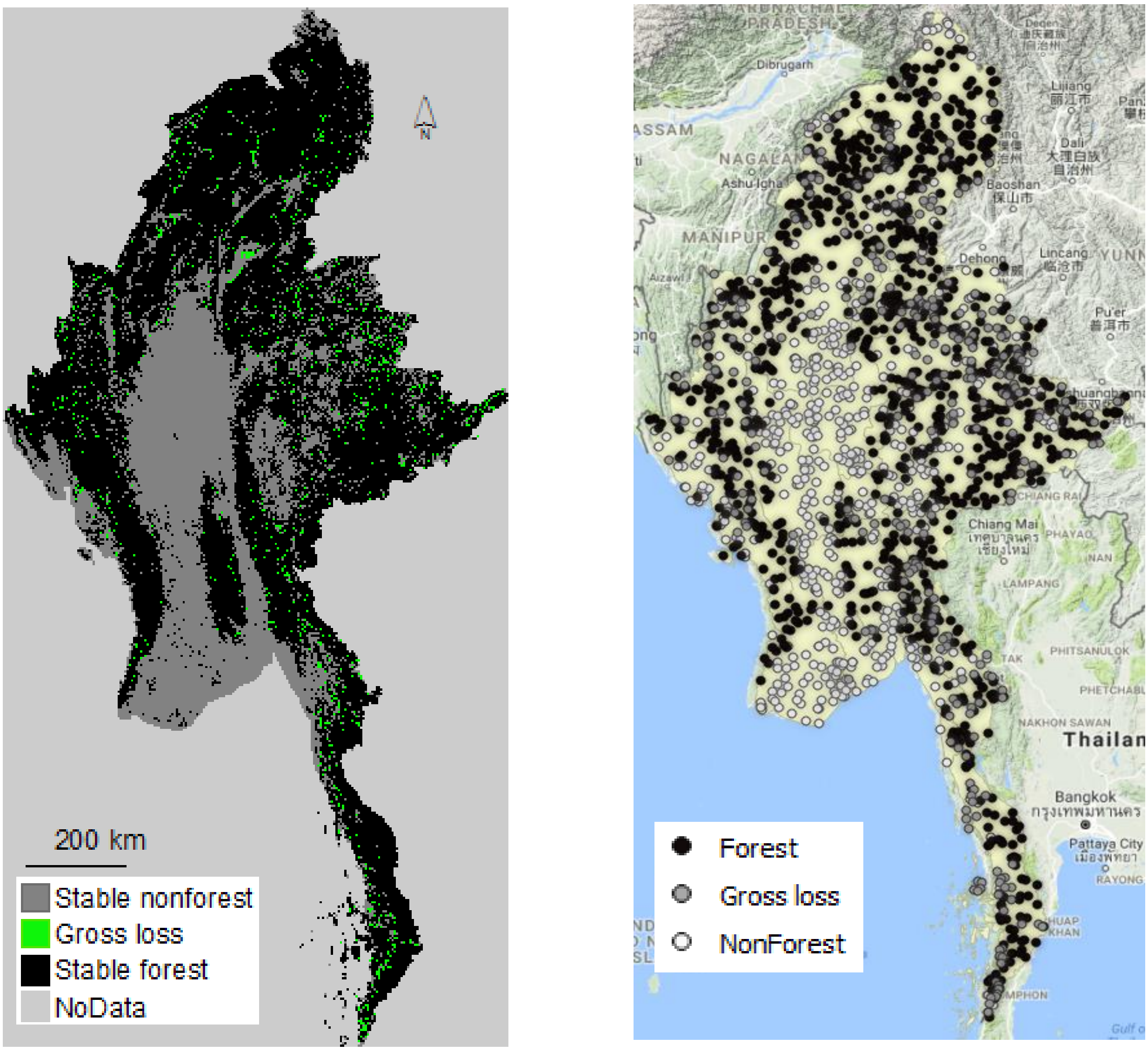
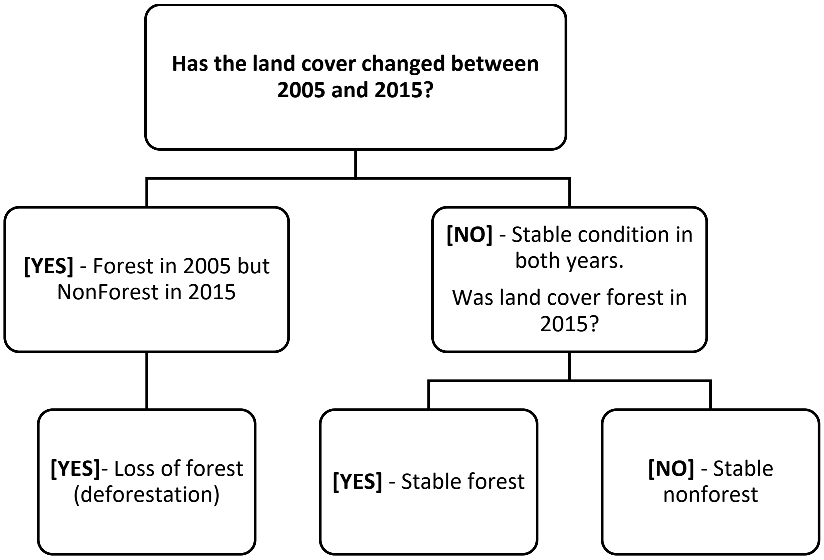


Figure 7.3 illustrates a change decision tree where the 2005 land cover is forest. There will be equivalent decision trees for other scenarios e.g. intact forest to degraded forest, and forest to non-forest land cover types. These assessments allow change in major land cover categories to be reported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

Figure 7.3: Decision tree for sample change analysis



7.1.1.3 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, 2016), 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.

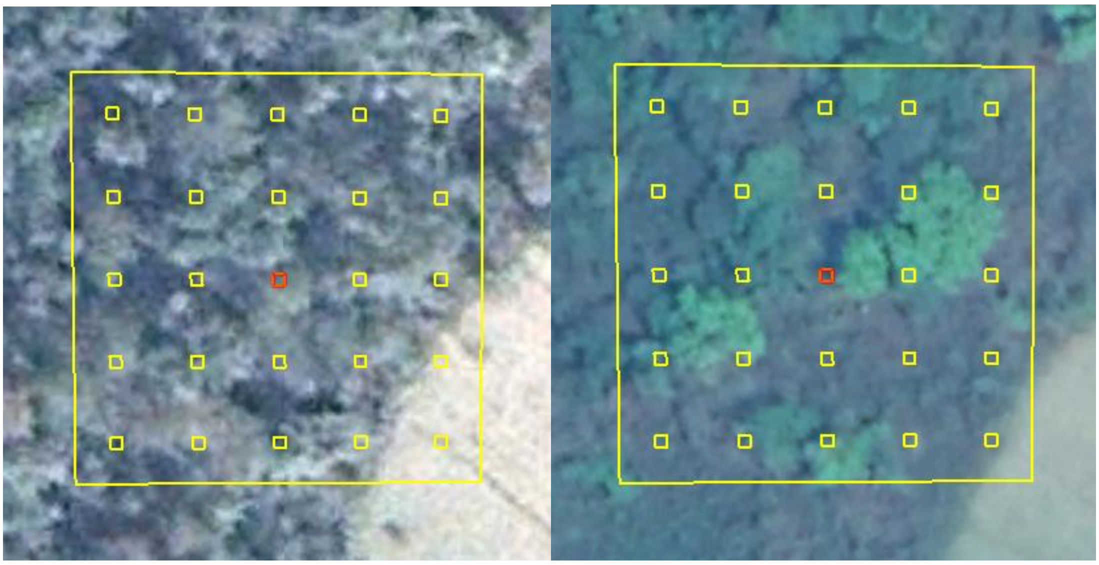
Through a collect survey design form using *Open Foris Collect*[12], the two Land cover types (forest and non-forest) were assessed within each sample through an expert image interpretation of medium (15m pan-sharpened Landsat) to very high (<1m) spatial resolution satellite data. The map and reference datasets used in the change 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[13] used to interpret land use/cover and monitor changes with time. The figure also 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

[12] http://www.openforis.org/tools/collect.html
[13] http://www.mdpi.com/2072-4292/8/10/807/html

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



2005 2015

The Collect Earth system works through a combination of freely available platforms includes Google Earth, Google Earth Engine and Bing Maps. The temporal consistency of the system has been ensured through the Google Earth Engine (GEE) script, prepared for the assessment of 1884 samples, to produce reference data using the best available cloud-free pixels during the end of the year. Therefore, it produces annual composite for each sample in GEE and the composite is bias towards the end of each year within the reference period. The composite was designed to produce a false colour composite (FCC) imagery through a combination infra-red, short-wave infra-red and red spectral reflectance in the red, green and blue channels, respectively. The FCC imagery from infra-red, short-wave infra-red and red reflectance bands in the red, green and blue channels produce the best visualization to discriminate between forest and non-forest. The high-spatial resolution imagery in Google Earth and Bing Maps also helped to cross-check the samples with uncertainty in discrimination. Figure 7.4 illustrates the process of consistency check between the two years (year 2005 and year 2015) through the provision of freely available high-spatial resolution imagery from Google Earth and Bing Maps. It is important to note that the sample assessment protocol also has the provision to record the type of reference data used (e.g. Digital Globe or Landsat) to take decisions on a sample by the interpreter.

The forest cover assessment team in the RS-GIS unit of FD took special care on quality control and on quality assurance. To ensure consistency among different interpreters, Myanmar has taken the advantages of in-house capacities and followed two approaches, includes: consistency check among interpreters before sample assessment and quality check after the sample assessment. Figure 7.1 Sample Assessment (Step 3) explained the methods followed before and after the sample assessment. It is important to note that the forest cover assessment team has received several national trainings from FAO on sample-based assessment through the Myanmar UN-REDD national programme (Sep 2015; Nov-Dec 2016 and August-Sep 2017) and a few members in the team have also attended various international training programmes, all of which were specifically designed to interpret and validate change areas (such as changes of Forest to Non-Forest or changes of Non-Forest to Forest) and/or across the different IPCC land cover/use categories from imagery using Collect Earth. All interpreters, moreover, have sound knowledge on Myanmar forest conditions and so have provided additional advantages to separate forest from non-forest.

7.1.1.4 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 enough 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 confusion 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)		$\frac{p_{11}}{p_{.1}}$	$\frac{p_{22}}{p_{.2}}$	$\frac{p_{33}}{p_{.3}}$		$Overall\ accuracy = p_{11} + p_{22} + p_{33}$

7.1.1.5 Estimation and uncertainty

GFOI 2016 methods guidance document (MGD) version 2 was used to derive sample-based area estimates and uncertainty of the sample-based area estimates using reference data label of the 1,884 samples. The reference data of each sample derived from sample assessment is defined as the best available determination of the ground condition at a specified location. The reference data label is assumed to be correct, but it is well-known that reference inference error could often occurs and could impact greatly on evaluations of land cover and land cover change by remote sensing (Foody, 2010). The way uncertainty is addressed depends on the inference framework employed. In this report, a design-based inference has been used (Särndal et al., 1992) in which the uncertainty associated with the estimator is defined as the variability of the estimates over the set of all possible samples that could have been obtained for the chosen sampling design and population sampled. Other sources of uncertainty could often be present. For example, error in the reference class label, geo-location error, and mis-matched classification legends may generate additional uncertainty. But only the variability attributable to sampling in the uncertainty analysis was considered. Stratified estimators were used to derive sample-based estimates and a brief description of the stratified random sampling estimators has been described in Annex 7.

7.1.1.6 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, 188 samples out of 831 were detected as forest cover when they were not. Specifically, 49 of these samples were actually forest loss in 2015. Three examples of sample assessment using different validation datasets have been illustrated in Annex 8, 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	0.10	0.44	0.71
	Loss	0.04	0.07	0.05	0.16	0.44
	Non-forest	0.16	0.02	0.22	0.40	0.55
Total		0.52	0.11	0.37	1.00	
Producer's accuracy		0.61	0.62	0.60		0.61

Table 7.4 provides stratified area estimates of forest and non-forest for the years 2005 and 2015, respectively. 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 strata. This corresponds to the interpretation of the results from the perspective of the reference data. In general, it indicates that the forest loss stratum has

comparatively lower producer's accuracy in spatial detection of information. Therefore, the sample-based estimates showed a much wider (25%) confidence interval in the forest loss stratum compared to stable forest and stable non-forest strata. 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: Stratified 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)	MOE (%)
Year 2005								
Stable forest	0.71	0.77	0.77	44705401	44107555	999206	1958444	4.4
Non-forest	0.60	0.53	0.55	22952351	23550197	999206	1958444	8.3
Year 2015								
Stable forest	0.61	0.57	0.71	42894890	39841930	1082252	2121216	5.3
Non-forest	0.74	0.77	0.63	24762862	27815821	1082252	2121216	7.6

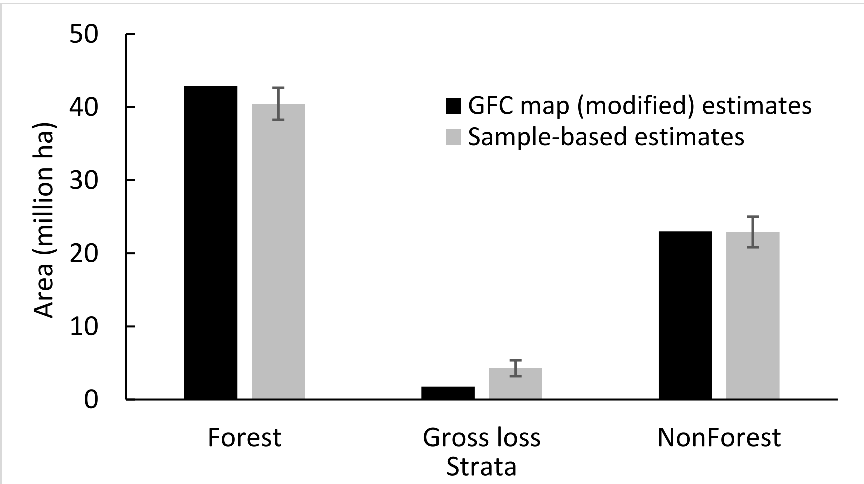
Table 7. 5: Stratified area estimates in hectare (ha) with confidence intervals (CI), weighted producer's accuracy and user's accuracy for three land cover classes during 2005-2015.

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)	MOE (%)
Stable forest	0.61	0.76	0.71	42894890	40446950	789576	1547568	4
Loss	0.62	0.18	0.44	1766799	4289839	392682	769656	18
Stable non-forest	0.60	0.55	0.55	22996062	22920963	751052	1472062	6

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 stratified 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 area of forest loss is about 428,984 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 which is about 793 ha per year lower than the sample-based estimates and has been found comparable between the two independent 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 *stratified area estimated of forest loss 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



7.1.2 Emission factors

The first national scale ground survey-based forest inventory with a probability sampling approach was initiated in 1980-81 under a UNDP/FAO project (first phase) which eventually was extended until 1992 (second phase). The target precision for the key parameter (timber volume) was an error margin of 20% (at 95% confidence level) at the 50,000-ha level. However, the NFI work was never fully finished for several reasons.

Since then, the FD has carried out district level inventories for periodic management planning purposes including the definition of annual allowable cut (AAC) planning and the development of stand and stock tables at the forest management unit (FMU) level. The inventory design is based on the former NFI design with a systematic distribution of plots within two basic strata: closed forests (>= 40% tree cover) and open forests (>=10% - <40% tree cover). For the plot design, over the years four different types were in use: (1) the 1.05 ha L shape original NFI plot, (2) a nested rectangular 1 ha plot with two sub-plots in the upper right edge of the main plot area, (3) a circular 50 m radius plot and (4) a rectangular 1-acre size plot.

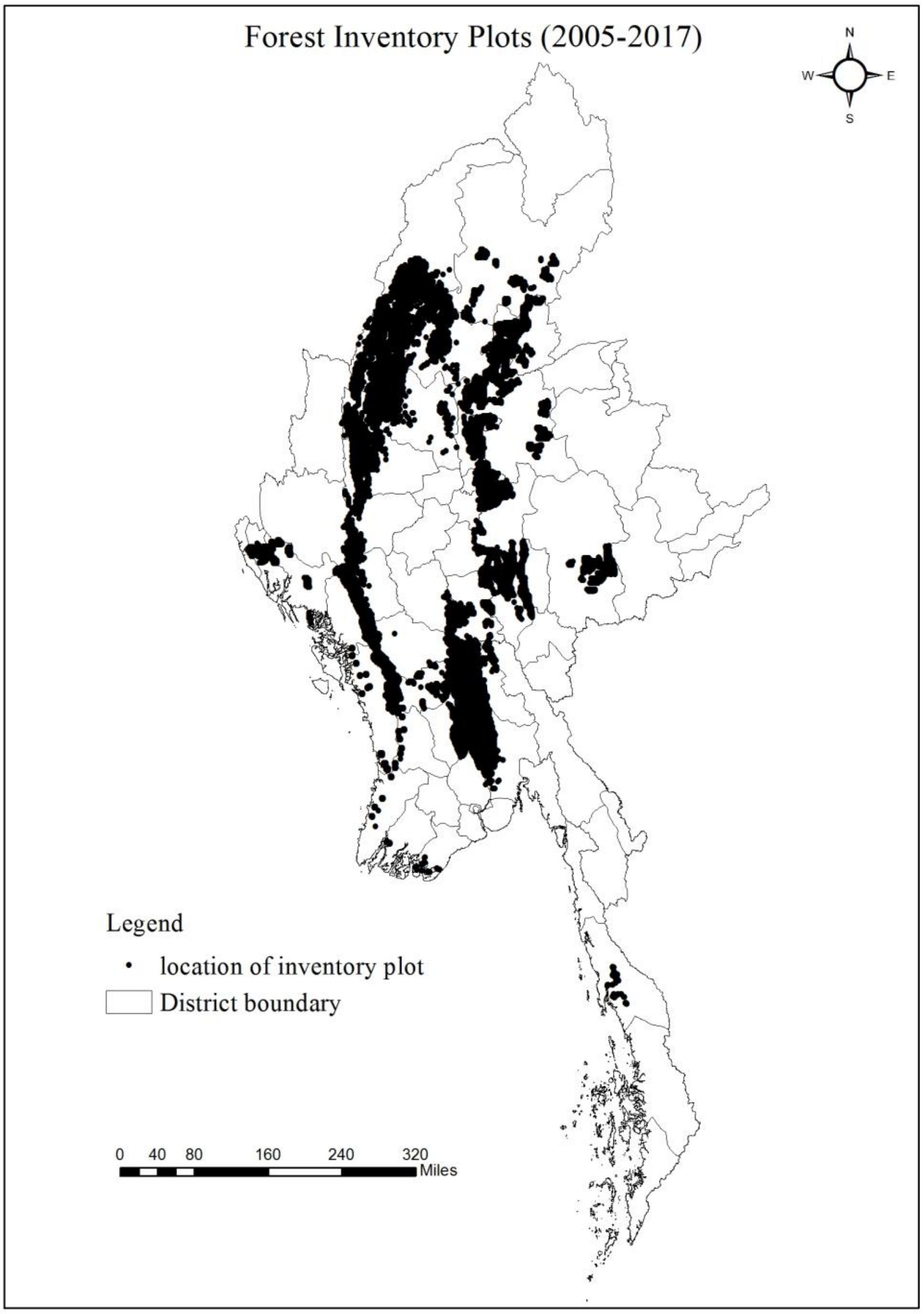
For the emission factor calculation in this FRL, the best available data are therefore the management plan inventory data, roughly for the same reference period as the activity data. District level inventories were carried out in 40 districts out of 68 districts during 2005 and 2017. For the remaining 28 districts, no full inventory data are available yet. However, the management plan inventory data covered 11 out of 15 states and regions of Myanmar. The inventories also represented all tropical and sub-tropical forest types. There were included most of the areas where forest cover change has occurred during the reference period.

When the first cycle of upcoming NFI is finalized and the measurement results are available, Myanmar will replace the EF calculated on existing data by more accurate and unbiased values covering the full national scale. Notwithstanding, this will probably not be possible before the year 2022/23.

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). Some of the sample plots are also located outside PFE. The sample size, sample design, tree measurement and the prorated per ha value for four different sample plot designs for

40 districts are described in the Annex 9. Detailed description of different sample plot designs is mentioned in Annex 10.

Figure 7. 6: Location of forest inventory plots collected during 2005 to 2017



7.1.2.1 Methodology for Emission Factor Calculation

As described above, Myanmar decided to report three carbon pools, i.e. AGB, BGB and Litter in FRL. A combination of Tier 1 and 2 approaches were used in estimating these carbon pools using the following information from the management plan inventory datasets 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 FD)
- Diameter at Breast Height (DBH) in cm

Tree height was not collected in previous district management inventories. DBH is only recorded as key parameter and timber volume estimation was done based on existing national bole volume equations. Therefore, the equation with DBH only as entrance variable can be used for choosing the allometric equation to estimate AGB.

Different allometric equations for AGB value were tested as well as the national bole volume equations with corresponding expansion factors. Finally, the equation[14] of $AGB = EXP((-2.289 + 2.649 * LN(DBH) - 0.021 * (LN(DBH))^2)$ were chosen since no major differences seemed to exist between this equation and more elaborate calculations based on national bole volume equations or other pantropical equations (e.g., Chave et al, 2005, Chan et al, 2013 and Table 4.A.1 GPG-LULUCF, IPCC 2003 according to each forest types in Myanmar).

The Below Ground Biomass (BGB) value is estimated by multiplying the mean AGB and the ratio of BGB to AGB (R) for each forest types. Myanmar uses the forest types classification according to Field Instruction 1985 as mention in Section 2.3. Although the forest types in the instruction are different to the global forest types, they have similar characteristics so the forest types in Myanmar are simplified according to global categories in order to select the appropriate ratio of BGB to AGB.

[14] 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

The sum the AGB and BGB values (tonnes per ha) were converted into carbon tonnes per ha by the multiplication with the default value of carbon fraction of dry matter; i.e. 0.47. The default values (Carbon tonnes per ha) for litter, according to respective forest types, are used and then later the total emission in Carbon tonnes per ha value for each district is got by summing of the Carbon tonnes per ha values of all three carbon pools. The default factor of 3.67 is used to convert the Carbon tonnes per ha value to carbon dioxide tonnes per ha value. The brief step by step calculation for three carbon pools are mentioned in the Annex 11. The respective allometric equations applied in AGB calculation, the correspondent values of R and Litter in accordance with Myanmar forest types are mentioned in the Annex 12.

Weighting is necessary because areas of districts are different as well as forest cover areas are also different. Therefore, there were not the same number of forest inventory samples. Weighting is carried out to get the EF values of different districts as a proportional weight rather than just calculating an arithmetic mean of the sum of the district values. Weighting is calculated as per the following steps:

$$Sample\ Size\ in\ ha\ for\ each\ districts = total\ number\ of\ sample\ plots\ x\ plot\ size \ldots (1)$$

$$Total\ CO2\ Ton\ Per\ Ha\ for\ each\ districts \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$Weighted\ CO2\ mean\ value\ per\ ha\ for\ each\ districts = \frac{Equation\ (2)}{total\ no\!:of\ sample\ plots} \ldots\ldots\ldots\ldots.(3)$$

$$Overall\ weighting\ value\ for\ each\ districts\ = Equation\ (3)\ x\ Equation\ (1) \ldots\ldots\ldots\ldots\ldots..\ldots.(4)$$

$$\boldsymbol{Weighted\ Mean\ (National\ Emission\ Factor) = \frac{total\ overall\ weighting\ value}{total\ sample\ size}}$$

Only one national level EF will be used since national data sources for stratification by forest type are currently unavailable. In future FRL submissions, some stratification maybe available to develop more disaggregated data and improve the resulting emission and removal estimates.

7.1.2.2 Results

After using the steps mentioned in the methodology, the following table gives the values of tCO_2 eq per ha representing for three carbon pools, 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 ***tCO_2 eq per ha*** (Table 7.6)**.**

Table 7. 6: Results of the CO2 eq Mean Value tonnes per ha and weighted mean CO2 eq tonnes per ha

No.	District Name	Total No of sample plots:	Plot Size	Sample Size in Ha	Total CO2 Ton Per Ha (for all sample plots)	Weighted CO2 Mean Value per ha	Overall weighting
1	Bago	567	1	567	32,353.79	57.06	32,353.79
2	Dawei	109	0.4047	44.11	58,412.59	535.90	23,639.58
3	Falam	159	0.4047	64.35	39,151.93	246.24	15,844.79
4	Hinthada	68	0.7854	53.41	8,756.80	128.78	6,877.59
5	Bhamo	427	1.05	448.35	84,784.33	198.56	89,023.55
6	Myitkyina	200	1.05	210	49,934.00	249.67	52,430.70
7	Katha	661	1	661	65,077.32	98.45	65,077.32
8	Shwebo	174	1	174	16,122.59	92.66	16,122.59
9	Monywa	190	1	190	20,930.61	110.16	20,930.61
10	Magwe	8	1	8	511.32	63.92	511.32
11	Gangaw	311	1	311	38,631.23	124.22	38,631.23
12	Minbu	467	1	467	51,309.52	109.87	51,309.52
13	Pakkoku	33	1	33	2,661.06	80.64	2,661.06
14	Thayet	274	1	274	29,057.04	106.05	29,057.04
15	Myaungmya	10	0.7854	7.85	224.74	22.47	176.51
16	Dakinathiri	105	1.05	110.25	13,792.70	131.36	14,482.34
17	Ottarathiri	67	1.05	70.35	7,948.02	118.63	8,345.42
	Taungoo: Nay Pyi Taw	10	1.05	10.5	1,001.73	100.17	1,051.82

	Taunggyi: Nay Pyi Taw	20	1.05	21	2,959.88	147.99	3,107.87
18	Pyarpon	47	0.4047	19.02	704.34	14.99	285.05
19	Pyay	430	1	430	35,286.86	82.06	35,286.86
20	Sittwe	6	1.05	6.3	5,063.63	843.94	5,316.81
21	Taungoo	962	0.7854	755.55	77,606.43	80.67	60,952.09
22	Thandwe	147	0.7854	115.45	12,852.01	87.43	10,093.97
23	Tharyarwaddy	446	0.7854	350.28	31,618.45	70.89	24,833.13
24	Kalay	869	1	869	103,861.64	119.52	103,861.64
25	Khamti	951	1	951	80,905.13	85.07	80,905.13
26	Mawlaik	971	1	971	141,341.44	145.56	141,341.44
27	Tamu	45	1	45	3,295.45	73.23	3,295.45
28	Linkhay	234	1.05	245.7	22,868.07	97.73	24,011.47
29	Taunggyi North	225	1.05	236.25	44,405.31	197.36	46,625.58
30	Taunggyi South	334	1	334	50,596.34	151.49	50,596.34
31	Kyaukme	519	1.05	544.95	163,846.43	315.70	172,038.75
32	Pathein	76	0.7854	59.69	4,854.90	63.88	3,813.04
33	Kyaukphyu	219	0.4047	88.63	20,536.31	93.77	8,311.04
34	Maungdaw	52	1.05	54.60	5,159.97	99.23	5,417.97
35	MyaukOo	77	1.05	80.85	7,672.97	99.65	8,056.62
36	KyaukSe	163	1	163	20,389.03	125.09	20,389.03
37	Mandalay	19	1	19	1,362.88	71.73	1,362.88
38	Meiktila	90	1	90	5,882.73	65.36	5,882.73
39	Pyin Oo Lwin	465	1	465	52,438.86	112.77	52,438.86
40	Yamethin	77	1	77	4,955.61	64.36	4,955.61
		11,284		10696.46	1,421,126	5,884.26	1,341,706.12
					Arithmetic mean	147.11	**125.43**
							weighted mean by sample size

7.2. Enhancement of forest carbon stocks

Following the discussions and recommendations of the first technical assessment (TA) during 19-23 March 2018, Myanmar has developed a reference level for enhancement from the establishment of forest plantations. During the technical exchange with the AT, Myanmar questioned the necessity of using historical average removals as benchmark for performance on enhancement as a result of REDD+ implementation. The reason to question this is that for calculating the amount of removals achieved since REDD+ implementation, removals from the past bear no influence on the amount of new removals as a result of REDD+. As such, Myanmar was wondering whether it would not be the best and most straightforward to assume a zero baseline, accounting only new removals from REDD+ implementation and no removals from continued growth in existing plantations. In response to Myanmar's proposal, the AT noted that decision 12/CP.17 (annex) requires Parties to present accurate information on their FRLs. The AT further indicated that a zero baseline would not be accurate because forest enhancement efforts have been ongoing since at least 2004. Secondly, the AT suggested that a zero baseline would not take into account the effect of forest age and areas available for forest plantation in the reference period and in the future. The AT argued that the growth rate of young forests is higher than that of old forests and, hence, achieving removals with younger forests is easier than with older forests. Ignoring this would likely result in an overestimation of enhancements. The AT also commented that a similar limitation applies to the area available for forest enhancement, since if a significant extent of area suitable for plantation is already used for reforestation or afforestation in the reference period, it would be more difficult to increase the area available for forest enhancement, thus impacting the carbon removals in the future. Following the suggestions by the AT, Myanmar therefore calculated historical removals during the reference period.

Forest plantations in Myanmar are established on land that was normally heavily degraded or on grass, savannah and bush/scrub land, often accompanied by bamboo with only occasional occurrence of small trees, i.e. areas that fall outside of the definition of forests. During the establishment of plantations, site preparation takes place that includes the removal of existing above ground biomass on the area usually with the use of fire.

As mention in Section 2.1, plantations are established for different purposes (e.g. commercial timber production, watershed protection, industrial and fuelwood use, village forests and for Mangrove restoration etc). The species used are normally native tree species which also occur in natural forests, such as teak (*Tectona grandis*), ironwood/pyinkado (*Xylia xylocarpa)*, rosewood (*Dalbergia* sp.), padauk (*Pterocarpus macrocarpus*), mangrove species (*Rhizophora* sp., *Avicennia* sp, *Bruguiera* sp.), among others. To a minor extent, fast growing exotic tree species such as Eucalypts or Acacias are also planted, mostly for fuelwood and for industrial purposes.

7.2.1 Activity data

There are four major types of state-owned forest plantation established by the FD under the government budgets (here after government plantation) from 1980s and plantation database are managed by Natural Forest and Plantation Division of FD. Starting from 2006, government policies encouraged private sector investment in establishing commercial forest plantations. Following table presents forest plantation areas of FD established and that of private sector;

Table 7. 7: Forest plantation areas as recorded by the Forest Department 2000- 2015

Year	Total Government Plantation Area	total private Plantation Area	total area ha	Cumulative plantation area	Cumulative 2005 - 15
2000-2001	30,718		30,718	30,718	
2001-2002	30,756		30,756	61,474	
2002-2003	31,396		31,396	92,870	
2003-2004	30,441		30,441	123,310	
2004-2005	31,974		31,974	155,285	
2005-2006	33,201		33,201	188,486	188,486

2006-2007	28,328	113	28,441	216,927	216,927
2007-2008	25,670	2,765	26,666	243,593	243,593
2008-2009	26,504	5,087	29,373	272,966	272,966
2009-2010	25,349	9,933	32,271	305,237	305,237
2010-2011	17,729	11,189	26,189	331,426	331,426
2011-2012	14,253	13,110	24,846	356,273	356,273
2012-2013	9,248	11,032	17,264	373,536	373,536
2013-2014	11,281	12,283	18,354	391,890	391,890
2014-2015	8,806	10,895	14,133	406,023	406,023
2015-2016	7,805	10,371	12,354	418,377	
total	**363,458**	**86,779**	418,377		
Average 05-15					**308,636**

For the enhancement estimation, data available in FD were checked against consistency with other recordings and reporting (FRA, statistical year book), the results of which are presented in table 7.7. Unlike the INC, which considered all accumulated plantation areas from 1963 up to 2000, a cut has been made and a zero baseline effectively been established for the year 2000 for the present reference level of carbon stock enhancement in this submission. The reasons for this are: (1) the difficulties to assume the level of reliability of area data for the years before 1990s and (2) an unknown number of older plantations have likely been disappeared and transformed in other land uses according to expert judgements from FD. Therefore, it can be assumed to be on the safe side with carbon stock calculations from enhancement if only the more recent plantations are considered and the likelihood of overestimating the carbon removal from forest plantations for the reference period 2005-2015 substantially be reduced.

7.2.2 Emission/ Removal factors

For the emission/ removal factors (EF/ REF) from enhancement by forest plantations two aspects need to be considered:

- Biomass consumption during site preparation, and
- Net biomass increments per year and per ha on the plantation sites

For the biomass consumption from fire during site preparation, the mean default value for tropical savannah grassland of 10 tonnes of dry matter biomass per ha is used (table 3A1.13, page 3.181, IPCC, 2003 since this figure appears as more realistic than the rather high value of 42.2 tonnes per ha used for similar calculations in the INC.

For the net biomass increment from plantations, the lower default value from table 4.10, IPCC Guideline, 2006 for tropical dry forests and tropical moist deciduous forests with 7 tonnes biomass dry matter per ha has been used. This value is lower than the one used in the INC where approximately 10 tonnes of dry biomass increment per ha were applied, thus eventual loss, mortality and removal during the rotation period is cautiously accounted for.

Although the calculations start from the year 1999-2000, only the accumulated carbon stock between 2005 and 2015 is included in the reference level. For the details of the calculations, please refer to the Annex 13.

7.2.3 Methodology of calculation

The actual C-removal in this reference level has been calculated with the equation[15] as follows:

[15] Based on equation 2.9 (Annex 2: Summary of Equations page A2.5 of 2006 IPCC guidelines for National Greenhouse Gas Inventories) but modified and adapted.

Equation 2: for CO_2 removal calculation from historic enhancement efforts in Myanmar

$$aR_{t1-t2} = \frac{\left(\sum_{t_1}^{t_2}(A_t \times Bm_{ic} - S_t \times Bm_{Co})\right) \times Cvf_C \times Cvf_{CO2}}{t_2 - t_1}$$

Where

aR_{t1-t2}	Average net removal of CO2 from forest plantations for the reference period
t_1	First year of the reference period
t_2	Last year of the reference period
A_t	Accumulated area planted in year t in ha
S_t	Area of site preparation in year t in ha (for plantation in year t+1)
Bm_{ic}	Net biomass increments per ha and year (table 4.10, IPCC 2006; table 3A.6, IPCC 2003)
Bm_{co}	Biomass consumption during site preparation per ha and year (table 3A1.13, IPCC 2003)
Cvf_C	Conversion factor biomass dry matter in C (0.47)
Cvf_{CO2}	Conversion factor C in CO_2 (44/12)

7.2.4 Results on reference level from enhancement measures

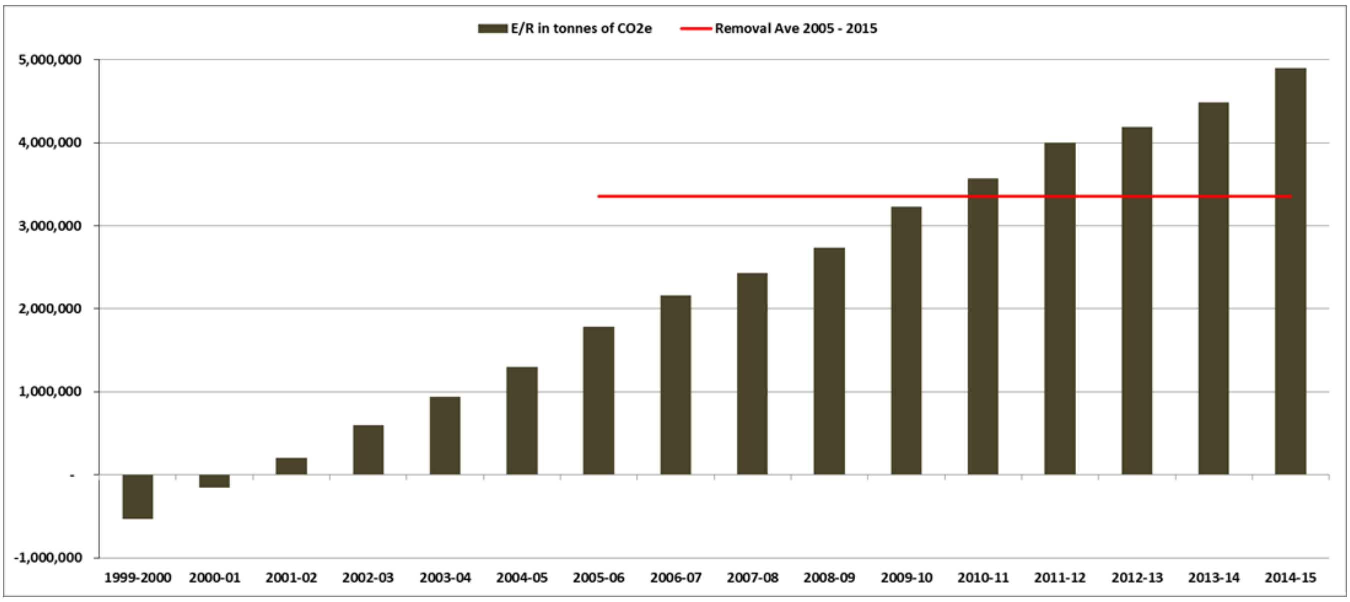
For calculating the reference level from enhancement measures, the historical average method is applied for the same reference period of deforestation. The accumulated carbon stock from plantations in this period amounts to 33,513,321 tonnes of CO_2e with an annual mean over the reference period of 10 years of **3,351,332 tonnes of CO_2e as showed in the following table;**

Table 7. 8: Accumulated CO_2e removal from forest plantations

Year	Accumulated CO_2e removal in tonnes
1999-2000	-529,857
2000-2001	-159,613
2001-2002	200,717
2002-2003	596,270
2003-2004	937,362
2004-2005	1,302,264
2005-2006	1,785,250
2006-2007	2,159,285
2007-2008	2,434,561
2008-2009	2,739,229
2009-2010	3,233,790
2010-2011	3,573,172

2011-2012	4,003,959
2012-2013	4,193,607
2013-2014	4,488,027
2014-2015	4,902,442
Sum 2005 - 2015	33,513,321
Average Annual CO_2e removal	3,351,332

Figure 7. 7: Carbon stock enhancement from forest plantations 2000-2015 and reference level 2005-2015 in tonnes of CO2e



8. Myanmar Initial FRL

Myanmar proposes an initial FRL by historical average of emissions during the reference period from 2005 to 2015. The *stratified area estimate of **annual deforestation** is estimated with **428,984 ha per year** during 2005-2015. Weighted mean values of tCO_2 eq per ha* result in a national EF value of **125.43 *tCO_2 eq per ha***. Therefore, *annual CO_2 emission from deforestation* during the historical reference period 2005-2015 is estimated as **53,807,463 *tonnes of CO_2 eq per year*** with an associated uncertainty of +/- 15.06%.

From sample-based estimation, it was not possible to develop a forest gain map for the period 2005 to 2015 and therefore development of a reference level for enhancement of forest carbon stocks based on existing forest areas is impossible.

Efforts are ongoing to improve the data available and this will be added to future submission in due course.

For carbon removal from historic **enhancement** efforts based on forest plantation establishment and for the same historic reference period the proposed amount is: **3,351,332 tonnes of CO_2e**. This level would be used to measure additional carbon removal as a result of the 10-year MRRP that is also part of the national REDD+ strategy of Myanmar.

Table 8. 1: Summary on proposed FRL of Myanmar with reference period of 2005-2015

	Annual area of deforestation	Average accumulated afforestation area in ha	EF/REF in tonnes CO2e/ ha	Total tonnes CO2e	Upper limit tonnes CO2e	Lower limit tonnes CO2e
Deforestation	428,984		125.43	53,807,463	63,243,891	44,371,035
Enhancements		308,636	10.86	3,351,332		

9. Uncertainty assessment of emission estimates

The uncertainty assessment for activity data and emission factor (deforestation) was conducted at tier 1 level according to the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000, 2006). The calculations include only uncertainty derived from sampling and do not include other error sources (e.g., errors from allometric equation, human errors or others).

Uncertainty estimation for activity data and removal factors from enhancement cannot be conducted since the data are not derived from sampling, but from annual records of the FD of planted areas from subnational offices, which then are aggregated at national level.

In calculation of the % uncertainty of activity data (deforestation estimate), the following equation was applied, *Equation 3*[16]

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

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

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

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

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

The uncertainty of the overall estimates for AD and EF was calculated by error propagation with the following equation,

Equation 5

$$U_{total}{}^{17} = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}}{x_1 + x_2 + \cdots + x_n}$$

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.

Table 9.1 shows the *% uncertainty of AD*, forest loss area, i.e. *8.97%* for this submission whereas the *% uncertainty of Emission factor from 40 district forest-inventories* is 13.03% (detail calculation in Annex 14).

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

[17] 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: Uncertainty Result for Activity Data in %

	Area in ha (estimate)	Standard Error (ha)	**Uncertainty %**
Forest	40,446,950	789,576	1.92
Forest loss (deforested area)	4,289,839	392,682	**8.97**
Non-forest	22,920,963	751,052	3.21
Total area	**67,657,752**		

Combined uncertainty was finally estimated by using the uncertainty of AD, i.e., uncertainty % of forest loss (deforestation) and the uncertainty of EF estimates 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 *8.97 % and 12.10%* respectively and therefore, *combined uncertainty % of* ***15.06 %*** is estimated for this submission.

10. Future improvement opportunities

10.1. For Activity *Data*

In absence of a reliable baseline map of forest gain during the reference period 2005-2015 as a gain stratum, much uncertainty exists in identification of forest gain (enhancement) classes while using remote sensing technologies. Only based on remote sensing, there are difficulties in distinguishing between afforestation and growing cycles of the forest plantations, and also difficulties in identifying the ecological pattern of forest regrowth following deforestation. 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 eventually 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 a combination of remote sensing-based and ground-based information to provide a 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 area estimated through generation of national maps is a priority. National maps will be developed with a standard mapping procedure and so is expected to reduce uncertainty in next reporting.

Further developments may include analysis of forest degradation with a particular attention to the definition in the national context (e.g. the types of plantations which can be classified as forest). The coming NFI will include other woodland and areas with trees outside forests. Therefore, data sets concerning with values for areas which have lost forest cover in the past, will be developed in the future.

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 almost from satellite images, perennial crops and home gardens cannot be clearly distinguished from forest cover. 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 RapidEye imagery which is carried out under the guidelines of National Land Use Policy 2016, will assist in the development of these maps.
- AD calculations will be refined based on administration boundaries, i.e. states and on regions.
- FD is also now recording spatial data of plantations. Plantation areas will also be included in the future NFI. The NFI results of which may make it easier to subdivide plantation areas in age classes.
- Stepwise approach should be applied to improve the current FRL over time through incorporating more REDD+ activities, better quality data, higher tier level in terms of methodologies and inclusion of 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 FRL submissions may be divided into sub-national levels based on the available improved datasets.
- Spatially explicit area estimates for plantation data is also an area of future improvement. Plantations will be included in the upcoming National Forest Inventory as a distinct stratum for which data and results be produced.

  The REDD+ MRV team will set-up better coordination between FD and ECD to avoid inconsistencies of data sources for the AD between the FRL and the GHG inventory included in Myanmar's INC. FD is planning to achieve consistency in data and methods between the FRL and the national GHG inventory to be included in the future NC/BUR.

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 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.

Although Myanmar has partially collected soil data, the confidence of using those data is still limited. But in the future, the national data on soil organic carbon will be possible to be collected with the support of the Finland Forest Research Institute (LUKE) and the NFI/NFMIS project. The future NFI will include SOC measurements in uplands and in also Mangroves. Special attention will be given to SOC in Mangroves as soil organic carbon pools in soil sediments of Mangroves are very important and currently data are not available.

Removal factor calculation for enhancement measures can be improved once results from further cycles of the NFI are available[18]. In the meantime, default values for biomass increment and biomass consumption from site preparation need to be applied.

10.3 Uncertainty assessment

For future uncertainty assessment, the possibility of moving to tier 2 assessment will be evaluated applying an analysis based on the Monte Carlo approach once the NFI data are available.

[18] From the second cycle onwards, when first results from permanent sample plots in plantations allow for stock difference measurements.

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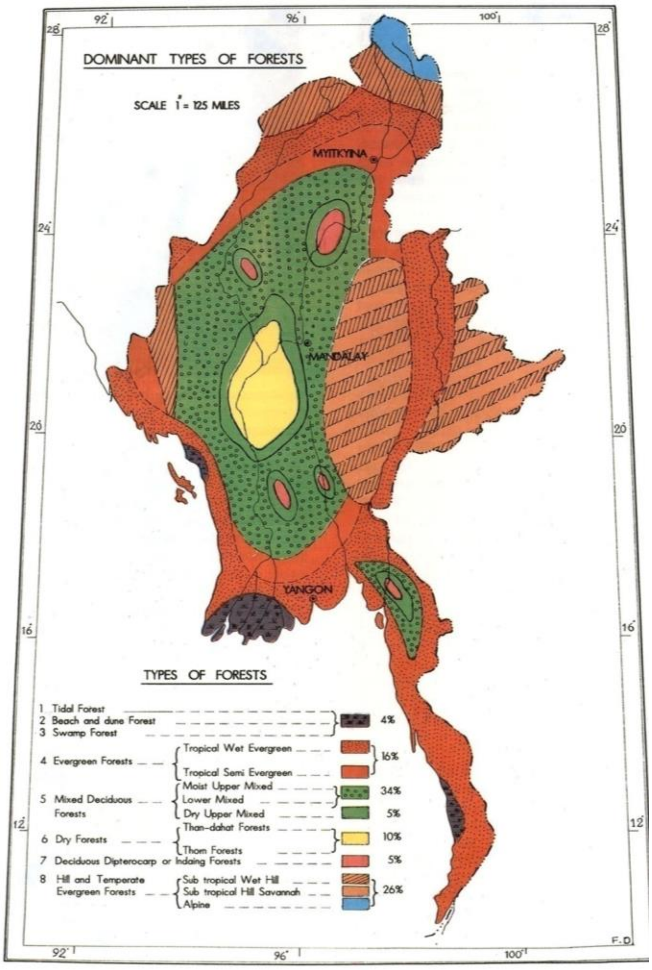
Annex

Annex 1: Dominant Types of Forests in Myanmar

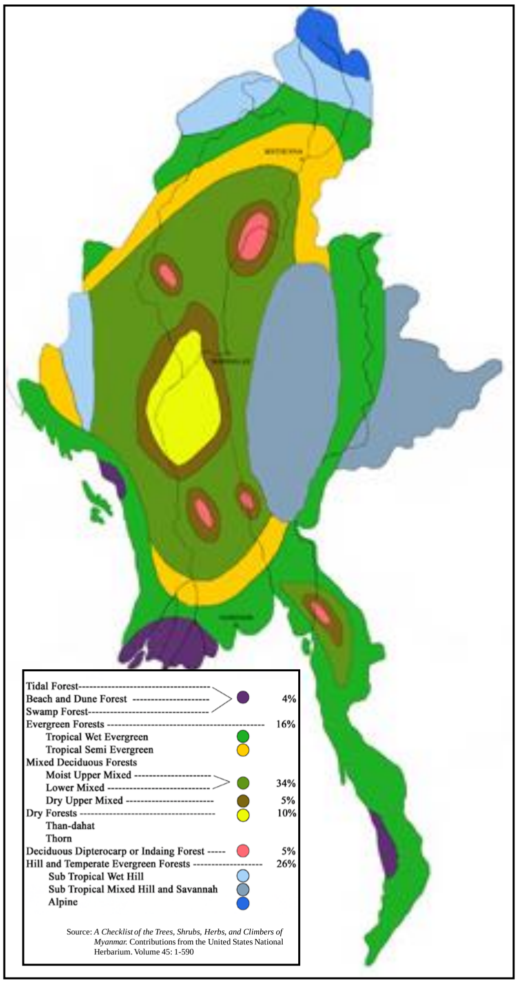
(a) Sources from Departmental Instructions

(b) A Checklist of the Trees, Shrubs, Herbs, and Climbers of Myanmar: contributions from the United States National Herbarium: Volume 45:1-590

(a)



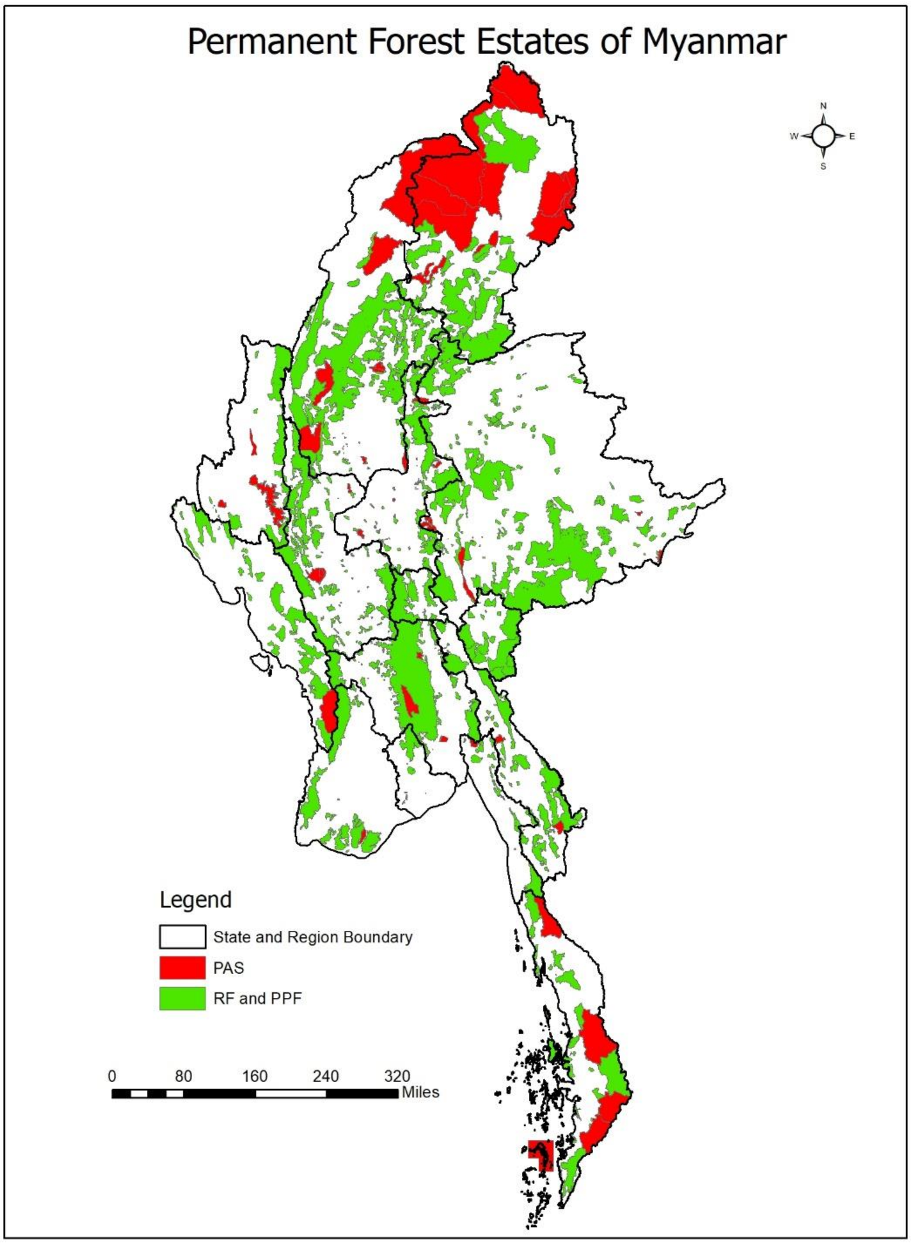
(b)



Annex 2: Comparison of forest cover area and its percentage within and outside PFE (based on 2015 National Forest Cover Map)

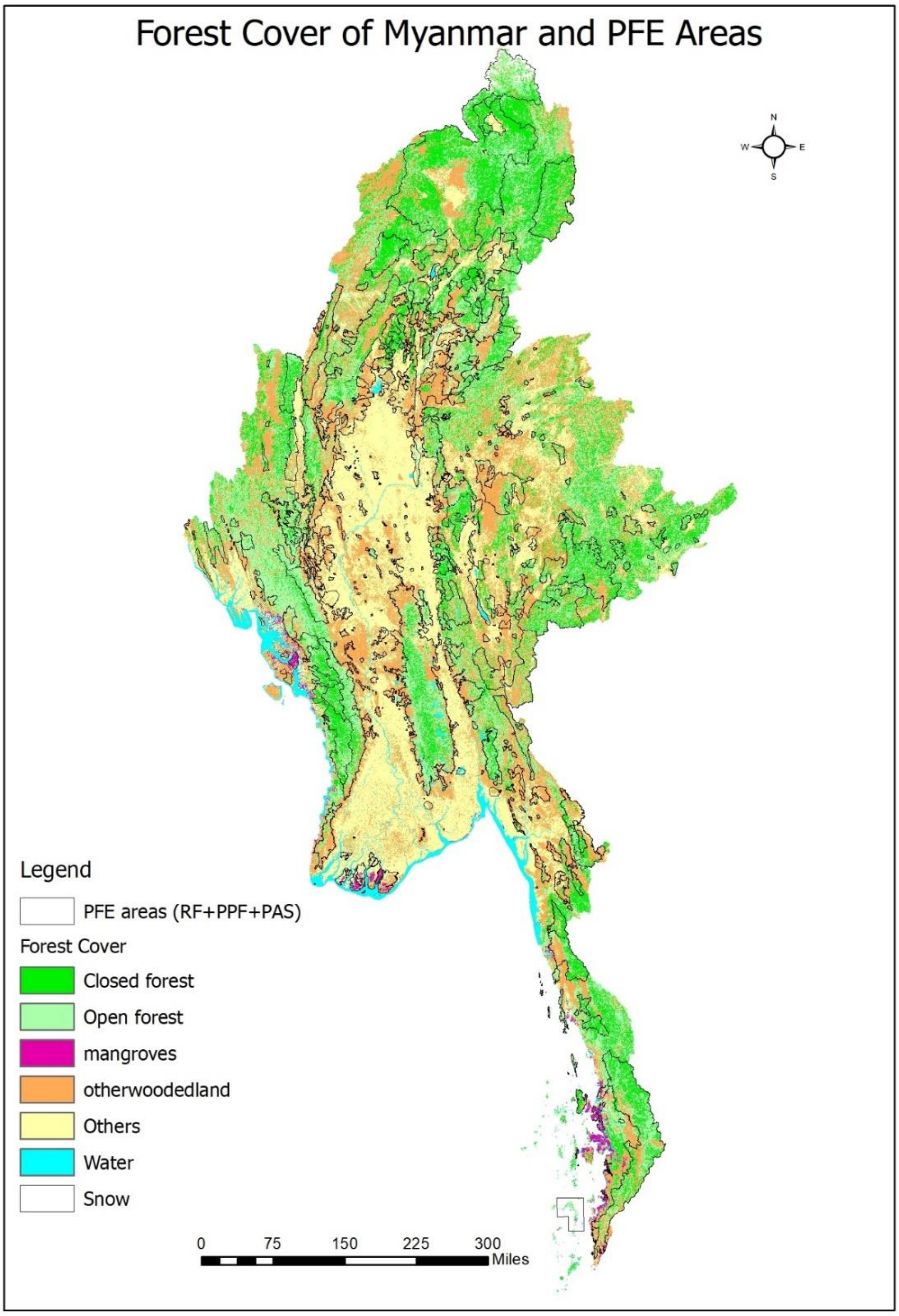
Land Cover	All Areas (ha)	Inside PFE Forest Areas (ha)	Outside PFE Forest Areas (ha)
Closed Forest	12160128.74	5229098.53	6931030.21
Open Forest	16914653.10	6570101.26	10344551.84
Mangrove	486935.54	148968.45	337967.09
Other wooded land	19528356.46	5695377.45	13832979.00
Other lands	16737085.37	1579981.09	15157104.29
Water Body	1694333.67	209363.00	1484970.67
Snow	127075.42	101890.75	25184.68
Total Area	68248983.33	19534780.52	48714202.81
% of country area	**100.00**	**28.62**	**71.38**
Total Forest Area	29561717.38	11948168.24	17613549.15
% of forest cover based on country area	**44.13**	**16.69**	**27.44**

Annex 2 (a):



Permanent Forest Estates of Myanmar
N
W
E
S
Legend
State and Region Boundary
PAS
RF and PPF
0
80
160
240
320
Miles

Annex 2 (b)



Forest Cover of Myanmar and PFE Areas
N
W
E
S
Legend
PFE areas (RF+PPF+PAS)
Forest Cover
Closed forest
Open forest
mangroves
otherwoodedland
Others
Water
Snow
0
75
150
225
300
Miles

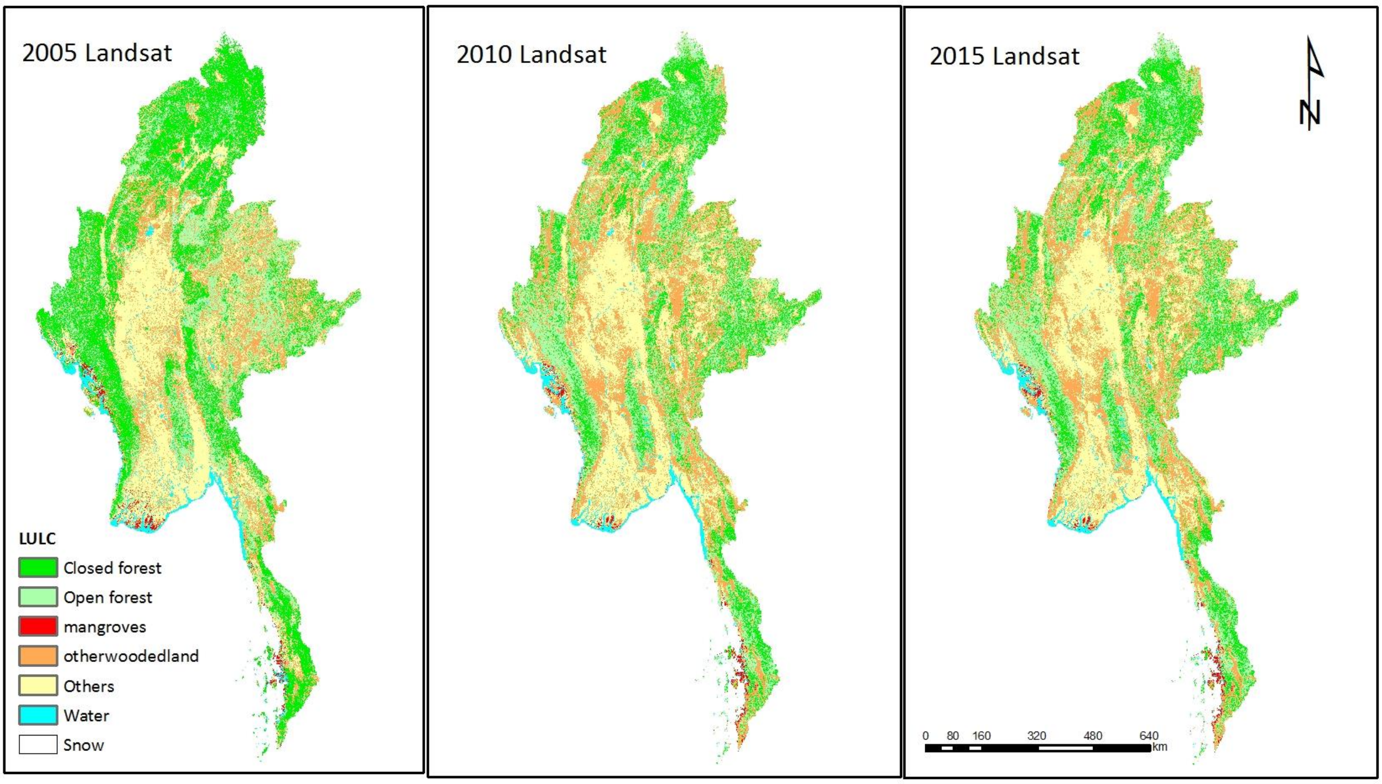
Annex 3: Datasets used to generate activity data for establishing a forest reference emission level in Myanmar during 2005-2015

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.

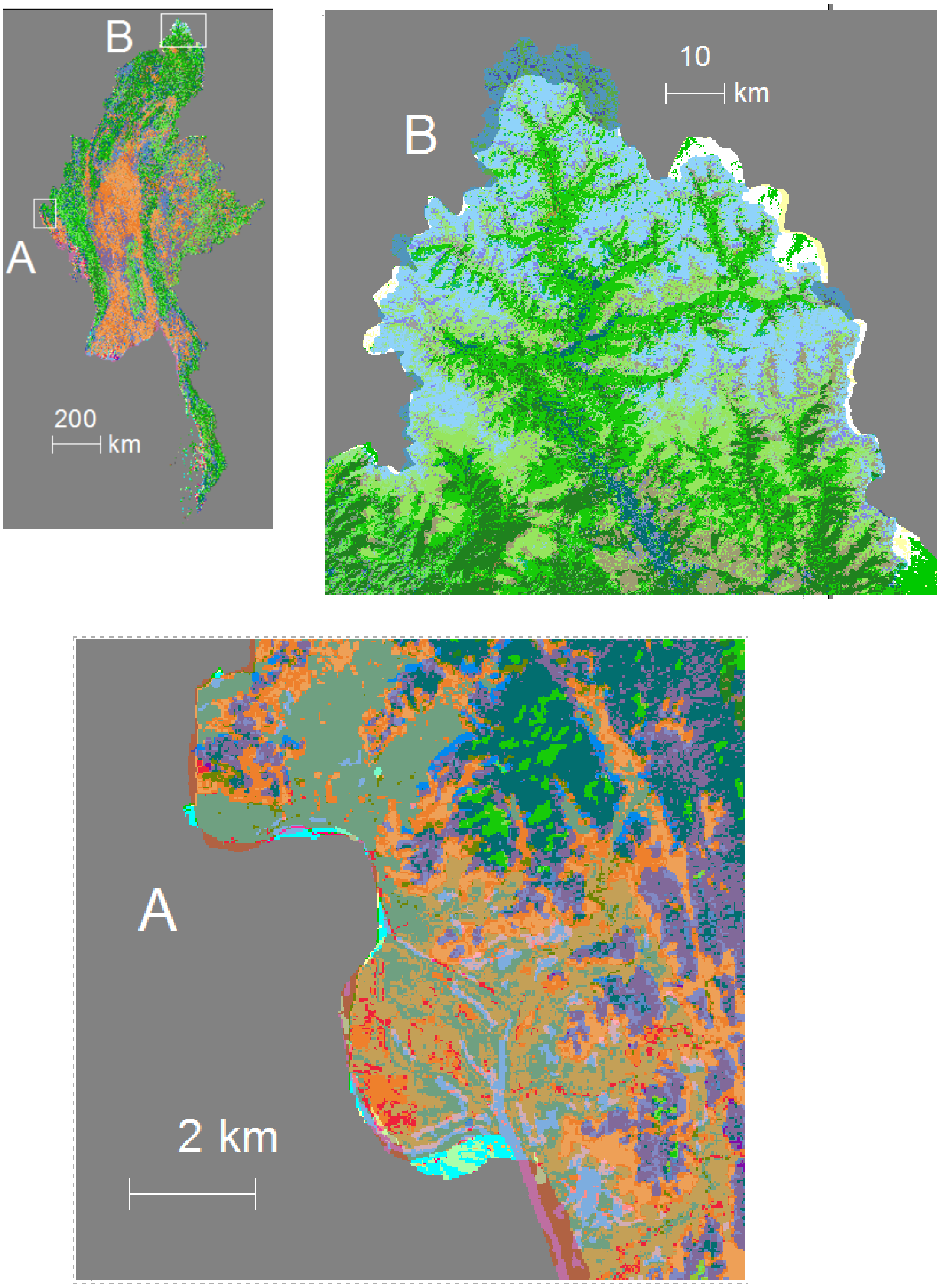
Annex 4: Harmonizing national land use categories with FRA and IPCC land use categories

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
5	Other lands	Other lands	Other land
9	Snow		
6	Settlements	Settlement	
7	Wetland	Wetland	
10	Water		Inland water bodies

Annex 5: Wall-to-wall thematic raster maps of Myanmar under seven national land use/cover categories at three years: 2005, 2010 and 2015



Annex 6: Maps showing the positioning error in the wall-to-wall maps of Myanmar boundary



Annex 7: 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*

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

$$= \sum_{h=1}^{H} \frac{w_h . \hat{p}_{hj} - \hat{p}_{hj}^2}{n_{hj} - 1} \text{-----------}(Eq. 12)$$

And standard error,

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

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

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

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

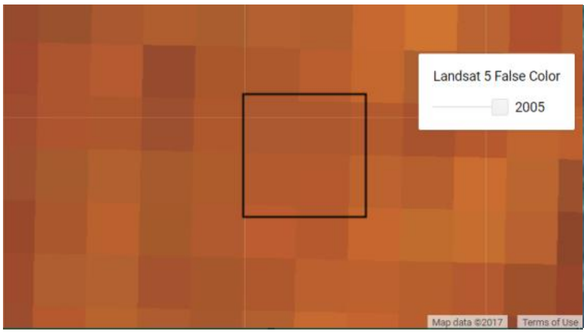
Strata (j)	$\hat{\mu}_j$ (proportion)	$SE(\hat{\mu}_j)$ (proportion)	$\hat{\mu}_j$ (ha)	95% Confidence interval	
				Lower (ha)	Upper (ha)
Stable Forest					
Stable Non-Forest					
Loss					

Annex 8: Examples of sample assessment using validation datasets:

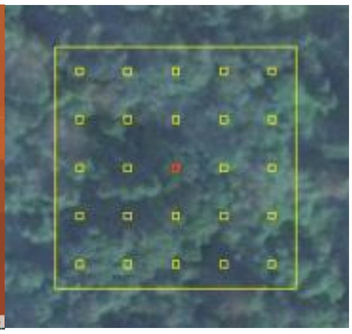
(i) Forest 2005 > Forest 2015; (ii) Non-Forest 2005 > Non-Forest 2015; (iii) Forest 2005 > Non-Forest 2015 (sample # 408). 30-m spatial resolution Landsat False Color Composite (NIR_SWIR1_R) and high spatial resolution Google Earth natural color (RGB) imagery were used as validation datasets.

(i) Forest 2005 > Forest 2015

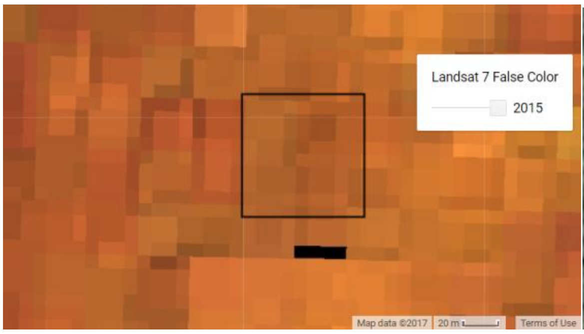
2005 Landsat 5 TM



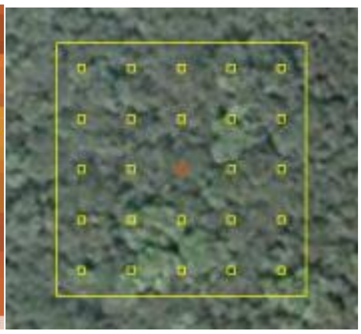
2005 Google Earth Imagery



2015 Landsat 7 ETM+

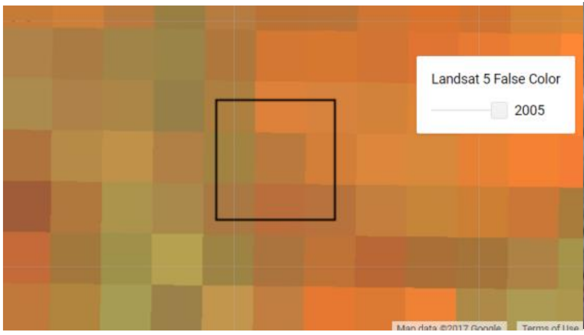


2015 Google Earth Imagery

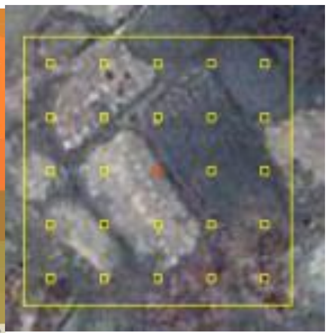


(ii) Non-Forest 2005 > Non-Forest 2015

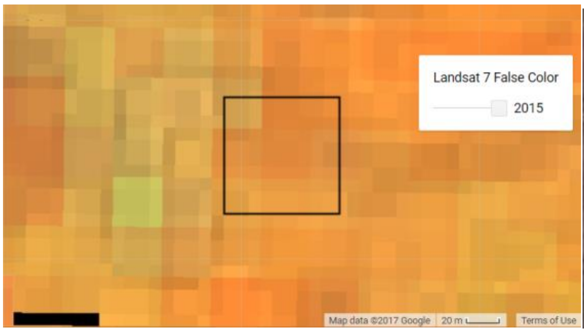
2005 Landsat 5 TM



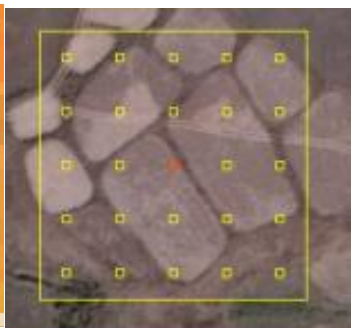
2005 Google Earth RGB Imagery



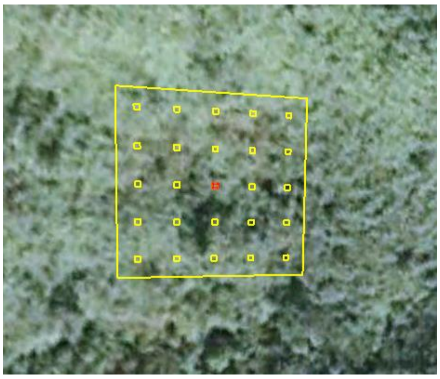
2015 Landsat 7 ETM+



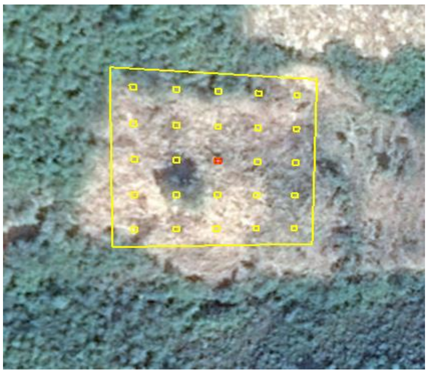
2015 Google Earth Imagery



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

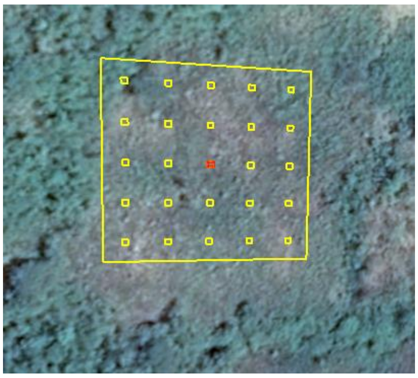


2005



2014

2013



2017

Annex 9: Sample Plot Design for 40 Districts from Forest Management Inventory mentioning the conversion factor to per ha

Sr. No.	State/ Region	District	Year	Sample Design	Interval	Sub-Plots	Shape	Size	Measurement
1	Kachin State	Myitkyina 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, Mawlaik and Kalay Khamti	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	Tharyarwaddy	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
		Gangaw	2013				Square	25m x 25m	< 5 cm, Regen & Bamboo

		Magwe Pakkoku	2013 2013						
5	Nay Pyi Taw	Ottarathiri Dakinathiri 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	Kyaukme 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 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
		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	1.05 ha	DBH >= 20 cm
							IL RU 1, 4, 7 IL RU 1, 4, 7	15m radius 10m radius	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)
		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

Summary on Plot Design

Plot Design	Plot Area	Plot Dimensions
Systematic (Square)	• 1 ha • 0.25 ha	• 100mx100m • 50mx50m
One Shot (Circular)	• 0.7854 ha	• 50m radius
One Shot (Square)	• 0.4047 ha	• 1 acre (0.4047 ha)
Systematic (L-shaped)	• 1.05 ha • 0.0707 ha	• 30 m x 50 m for each of the seven sub-plots) • 50 m radius for each of three sub-plots

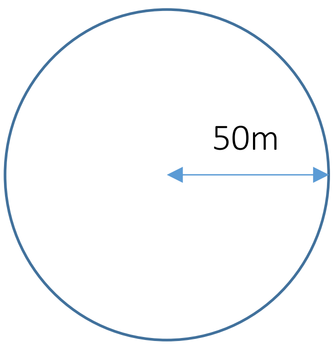
Annex 10: Plot Designs and Description

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.

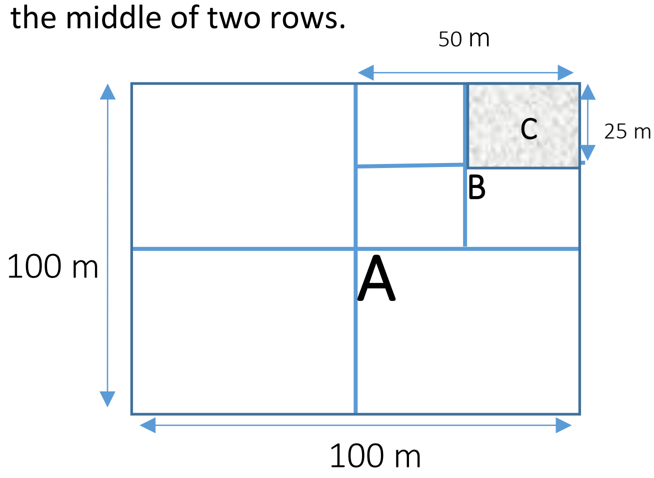
A sample tree is considered to fall inside a plot of given boundaries, if the center of the bole at the base of the tree falls inside the plot. Consequently, each sample plot contains edge trees with a growing space which is partly located outside the plot boundaries. One of the important non-sampling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

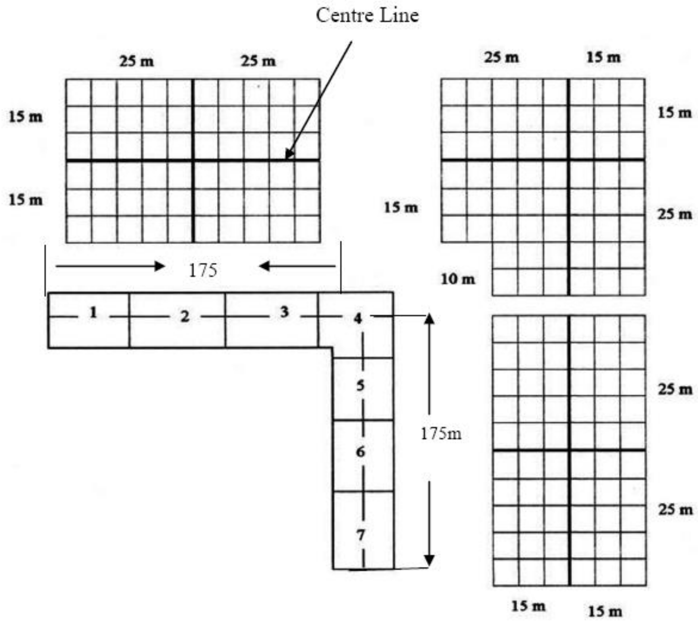


Circle shape Design



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 11: Summary of calculation steps for three carbon pools and National Emission Factor value for Myanmar

District Management Inventory Data	**Three Carbon Pools (AGB, BGB and Litter)**						
	A	B	C	D	E	F	G
DBH in cm (National Data)	**Above Ground Biomass (Kg Per Ha)**	**Below Ground Biomass (Tonnes Per Ha)**	**AGB and BGB (C Tonnes Per Ha)**	**Litter (C Tonnes Per Ha)**	**Emission C Tonnes Per Ha**	**Emission CO_2 Tonnes Per Ha**	**CO2 for sample plots**
>= 20 cm 10 cm to 19 cm	EXP ((-2.289+2.649 x LN (DBH) - 0.021 x (LN (DBH)) ^2)[19] Tree data base, summarize Per Plot to get Per Ha	Mean AGB Tonnes Per Ha x R (Ratio of below ground biomass to above ground biomass) (in each forest type)	(AGB+BGB) x 0.47	Table 2.2: Tier 1 default values for Litter: 2006 IPCC Guidelines	C + D	E x 3.67	G x sample number of each forest types of each district

The above step by step approach is used to get the total CO_2 Tonnes Per Ha for each district.

For the National Emission Factor value, the following steps are taken:

$$Sample\ Size\ in\ ha\ for\ each\ districts = total\ number\ of\ sample\ plots\ x\ plot\ size \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$Total\ CO2\ Ton\ Per\ Ha\ for\ each\ districts \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$Weighted\ CO2\ mean\ value\ per\ ha\ for\ each\ districts = \frac{Equation\ (2)}{total\ number\ of\ sample\ plots} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$Overall\ weighting\ value\ for\ each\ districts\ = Equation\ (3)\ x\ Equation\ (1)\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\boldsymbol{Weighted\ Mean\ (National\ Emission\ Factor) = \frac{total\ overall\ weighting\ value}{total\ sample\ size}}$$

[19] 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

Annex 12: Description of the forest types and respective value of R (Ratio of BGB to AGB) and Litter Range for each district

No.	Forest Type according to NFI Field Instruction 1985 of Myanmar	Districts	Forest Type for BGB Calculation	R Value Range	Litter Range (Tonnes C per ha)
1	Mangrove, typical	Kyaukphyu	Tropical Rain Forest	0.37	2.1
	Mangrove, high (kanazo forest)	Pyarpon			
3	Swamp forest	Bago, Dawei, Bhamo, Katha, Shwebo, Minbu, Thayet, Myaungmya, Kalay, Mawlaik, Taunggyi South, Kyaukme, Pathein, Maungdaw, MyaukOo, Pyin Oo Lwin	Tropical Rain Forest	0.37	2.1
	Evergreen forest, riverine	Bago, Myaungmya, Thandwe, Kalay, Khamti, Mawlaik, Tamu, Taunggyi South			
4	Evergreen forest, typical	Bhamo, Myitkyina, Katha, Thayet, Myaungmya, Pyay, Thandwe, Khamti, Kyaukme, Pathein, Kyaukphyu	Tropical Rain Forest	0.37	2.1
	Evergreen forest, giant	Bago, Bhamo, Myitkyina, Katha, Minbu, Thayet, Myaungmya, Kalay, Khamti, Mawlaik, Tamu, Pathein			
	Bamboo forest (degraded rain forests)	Bago, Katha, Minbu, Thayet, Pyay, Tharyarwaddy, Kalay, Khamti, Mawlaik, Tamu, Pathein, Pyin Oo Lwin			

5	Mixed deciduous forest, lower	Bago, Hinthada, Bhamo, Katha, Shwebo, Monywa, Magwe, Gangaw, Minbu, Thayet, Dakinathiri, Ottarathiri, Pyay, Taungoo, Tharyarwaddy, Kalay, Khamti, Mawlaik, Tamu, Linkhay, Taunggyi North, Taunggyi South, Kyaukme, Maungdaw, MyaukOo, KyaukSe, Pyin Oo Lwin, Yamethin	Tropical Moist Deciduous Forest	AGB< 125 Tonnes/ Ha = 0.20 (0.09-0.25) AGB> 125 Tonnes/Ha = 0.24 (0.22-0.33)	2.1
	Mixed deciduous forest, upper moist	Bago, Hinthada, Bhamo, Myitkyina, Katha, Shwebo, Monywa, Gangaw, Minbu, Pakkoku, Thayet, Dakinathiri, Ottarathiri, Taungoo: Nay Pyi Taw, Taunggyi: Nay Pyi Taw, Pyay, Sittwe, Taungoo, Thandwe, Tharyarwaddy, Kalay, Khamti, Mawlaik, Tamu, Linkhay, Taunggyi North, Taunggyi South, Kyaukme, Kyaukphyu, Maungdaw, MyaukOo, KyaukSe, Meiktila, Pyin Oo Lwin, Yamethin			

6	Mixed deciduous forest, upper dry	Bago, Hinthada, Bhamo, Myitkyina, Katha, Shwebo, Monywa, Magwe, Gangaw, Minbu, Pakkoku, Thayet, Dakinathiri, Ottarathiri, Taungoo: Nay Pyi Taw, Pyay, Taungoo, Tharyarwaddy, Kalay, Khamti, Mawlaik, Tamu, Linkhay, Taunggyi North, Taunggyi South, Kyaukme, Pathein, MyaukOo, KyaukSe, Mandalay, Meiktila, Pyin Oo Lwin, Yamethin	Tropical Moist Deciduous Forest	AGB< 125 Tonnes/ Ha = 0.20 (0.09-0.25) AGB> 125 Tonnes/Ha = 0.24 (0.22-0.33)	2.1
7	Dipterocarp (indaing) forest, high	Bhamo, Myitkyina, Katha, Shwebo, Monywa, Gangaw, Minbu, Pakkoku, Thayet, Dakinathiri, Pyay, Taungoo, Tharyarwaddy, Kalay, Khamti, Mawlaik, Tamu, Linkhay, Taunggyi North, Taunggyi South, Kyaukme, KyaukSe, Mandalay, Pyin Oo Lwin	Tropical Dry Forest	AGB< 20 Tonnes/ Ha = 0.56 (0.28-0.68) AGB> 20 Tonnes/Ha = 0.28 (0.27-0.28)	2.1
	Dipterocarp (indaing) forest, low	Bhamo, Myitkyina, Katha, Shwebo, Monywa, Gangaw, Minbu, Pakkoku, Thayet, Dakinathiri, Ottarathiri, Pyay, Taungoo, Tharyarwaddy, Kalay, Khamti, Mawlaik, Tamu, Linkhay, Taunggyi North, Taunggyi South, Kyaukme, KyaukSe, Mandalay, Meiktila, Pyin Oo Lwin, Yamethin			
8	Dry forest, than-dahat	Shwebo, Gangaw, Minbu, Pakkoku, Taungoo, Taunggyi North, Taunggyi South, KyaukSe, Pyin Oo Lwin	Tropical Dry Forest	AGB< 20 Tonnes/ Ha = 0.56 (0.28-	2.1

	Dry forest, thorn	Bago, Gangaw, Minbu, KyaukSe, Pyin Oo Lwin		0.68) AGB> 20 Tonnes/Ha = 0.28 (0.27-0.28)	
	Dry forest, aukchinsa-thinwin	Shwebo, KyaukSe, Mandalay, Pyin Oo Lwin			
9	Hill forest, evergreen	Falam, Bhamo, Katha, Minbu, Thayet, Ottarathiri, Pyay, Kalay, Khamti, Mawlaik, Taunggyi North, Taunggyi South, KyaukSe, Meiktila, Pyin Oo Lwin, Yamethin	Tropical Mountain Systems	0.27 (0.27-0.28)	2.8
10	Hill forest, dry	Bago, Katha, Shwebo, Gangaw, Minbu, Thayet, Pyay, Taungoo, Kalay, Khamti, Mawlaik, Linkhay, Taunggyi North, Taunggyi South, KyaukSe, Meiktila, Pyin Oo Lwin, Yamethin	Tropical Dry Forest	AGB< 20 Tonnes/ Ha = 0.56 (0.28-0.68) AGB> 20 Tonnes/Ha = 0.28 (0.27-0.28)	2.1
11	Hill forest, pine	Monywa, Gangaw, Minbu, Kalay, Taunggyi North, Taunggyi South	Temperate: Conifers	AGB< 50 Tonnes/ Ha = 0.40 (0.21-1.06) AGB 50-150 Tonnes/ Ha = 0.29 (0.24-0.50) AGB >150 Tonnes/ Ha = 0.20 (0.12-0.49)	4.1

Annex 13: Net Biomass Increment and Removal Factor Calculation for Enhancement

Notes:

Planting/ site preparation	**Plantation area**	**total net biomass d.m accumulated**																**Total biomass d.m tonnes**	**Total C in tonnes**	**Total CO2e in tonnes**
Year	**Ha**	**1999-2000**	**2000-2001**	**2001-2002**	**2002-2003**	**2003-2004**	**2004-2005**	**2005-2006**	**2006-2007**	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**	**2014-2015**	**2005 - 2015**		
2000-01	30,718	- 307,181	215,027	215,027	215,027	215,027	215,027	215,027	215,027	215,027	215,027	215,027	215,027	215,027	215,027	215,027	215,027	**2,150,268**	1,010,626	3,708,998
2001-02	30,756		- 307,562	215,293	215,293	215,293	215,293	215,293	215,293	215,293	215,293	215,293	215,293	215,293	215,293	215,293	215,293	**2,152,931**	1,011,878	3,713,591
2002-03	31,396			- 313,956	219,769	219,769	219,769	219,769	219,769	219,769	219,769	219,769	219,769	219,769	219,769	219,769	219,769	**2,197,689**	1,032,914	3,790,794
2003-04	30,441				- 304,405	213,084	213,084	213,084	213,084	213,084	213,084	213,084	213,084	213,084	213,084	213,084	213,084	**2,130,835**	1,001,493	3,675,478
2004-05	31,974					- 319,743	223,820	223,820	223,820	223,820	223,820	223,820	223,820	223,820	223,820	223,820	223,820	**2,238,199**	1,051,953	3,860,669
2005-06	33,201						- 332,013	232,409	232,409	232,409	232,409	232,409	232,409	232,409	232,409	232,409	232,409	**2,324,089**	1,092,322	4,008,821
2006-07	28,441							- 284,414	199,089	199,089	199,089	199,089	199,089	199,089	199,089	199,089	199,089	**1,507,392**	708,474	2,600,100
2007-08	26,666								- 266,659	186,661	186,661	186,661	186,661	186,661	186,661	186,661	186,661	**1,226,630**	576,516	2,115,814
2008-09	29,373									- 293,730	205,611	205,611	205,611	205,611	205,611	205,611	205,611	**1,145,548**	538,407	1,975,955
2009-10	32,271										- 322,712	225,898	225,898	225,898	225,898	225,898	225,898	**1,032,679**	485,359	1,781,267
2010-11	26,189											- 261,892	183,324	183,324	183,324	183,324	183,324	**654,729**	307,723	1,129,342
2011-12	24,846												- 248,461	173,923	173,923	173,923	173,923	**447,231**	210,198	771,428
2012-13	17,264													- 172,638	120,846.69	120,847	120,847	**189,902**	89,254	327,562
2013-14	18,354														- 183,538	128,476.48	128,476	**73,415**	34,505	126,634
2014-15	14,133															- 141,326	98,928.32	- **42,398**	- 19,927	- 73,132
	406,023	- **307,181**	- **92,535**	**116,364**	**345,684**	**543,430**	**754,980**	**1,034,988**	**1,251,832**	**1,411,422**	**1,588,051**	**1,874,770**	**2,071,524**	**2,321,270**	**2,431,217**	**2,601,905**	**2,842,160**	**19,429,138**	9,131,695	**33,513,321**
																		19,429,138	9,131,695	***3,351,332***

annual net increment rate (Y) in biomass dry matter tonnes per ha = 7 (according to Table 4.10, IPCC 2006; Table 3A.6, IPCC 2003)

biomass consumption from site preparation biomass dry matter tonnes per ha = 10 (according to Table 3A1.13, IPCC 2003)

Annex 14: Uncertainty Result for Emission Factor in %

No	Districts	Plots (n)	Plot Size	Sample Size in Ha	Mean CO_2 eq Tonnes Per Ha[20]	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	Magwe	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	Pakkoku	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	Myaungmya	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	Dakinathiri	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: Nay Pyi Taw	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: Nay Pyi Taw	20	1.05	21	116.92	37.29	132.86	100.97	31.90	13.64	1,594.75	2,543,236.62
18	Pyarpon	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

[20] Mean CO_2 eq ton per ha is only for Above Ground Biomass Pool as national data are used only for AGB calculation and other remaining four pools are IPCC default values

23	Tharyarwaddy	446	0.7854	350.2884	52.55	71.39	60.03	45.07	14.95	14.23	747.60	558,911.31
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**

$$U_{total}{}^{21} = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}}{x_1 + x_2 + \cdots + x_n}$$

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

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