Sri Lanka's Forest Reference Level submission to the UNFCCC

Sri Lanka UN-REDD Programme

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SUMMARY

As a signatory to the UN Framework Convention on Climate Change (UNFCCC) and in recognition of Decision 12/CP.17 of the UNFCCC, Sri Lanka intends to submit its Forest Reference Level (FRL) as benchmark for performance measuring and monitoring of implementation of policies and measures in forestry sector. Sri Lanka's forests, which currently cover 29.7% of the total land area, can make a significant contribution to both adaptation and mitigation of climate change impacts.

Ministry of Mahaweli Development and Environment (MoMDE) in collaboration with the Forest Department (FD), seeks to maximize this contribution by developing a national strategy for Reducing Emissions from Deforestation and forest Degradation, plus conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+), in accordance with the guidance set out in section III-C of Decision 1/CP.16. Sri Lanka submitted a Nationally-Determined Contribution (NDC) to the UNFCCC in September 2016, which includes a target to increase the national forest cover from 29.7% to 32% by 2030.

Sri Lanka submits this FRL to the UNFCCC on a voluntary basis, as a benchmark for assessing performance, in terms of Greenhouse Gas (GHG) emission reductions and removals, of the implementation of the national REDD+ Strategy. The FRL may also be used in future for the purpose of obtaining results-based payments.

Sri Lanka intends to submit national FRL using deforestation and reforestation as REDD+ activities, above ground biomass, below ground biomass and litter as three carbon pools and CO_2 as Greenhouse Gas. Forest definition used for FRL construction is consistent with the definition used for Second National Communication. Activity data were generated using Sri Lanka's forest department forest cover map (year 1999) and Global Forest Change (GFC) products (year 2000 and 2010) (Hansen et al., 2013). These maps were subjected to change detection study to analyse forest loss and forest gain. IPCC default values for emission factors were selected for preparation of emission estimates. Based on the study carried out, it was suggested that forest loss happened in natural forest areas whereas forest gain (reforestation) was mainly confined to forest plantations. A disaggregation of forest loss data suggested that 64% if forest loss happened in dense forest areas while 36% forest loss happened in open and sparse forest areas. Reforestation data of forest plantation also suggested that teak, eucalypts, pinus and other plantation are 32%, 35%, 17% and 17% respectively.

As explained in above, Sri Lanka's FRL consists of historical annual deforestation and reforestation estimates for the period 2000 - 2010 combined with IPCC default emission and removal factors. Total emission from deforestation is estimated to be 4365 ('000 tonnes of CO_2 Eq.) whereas total removals from forest gain is -72 ('000 tonnes of CO_2 Eq.).

Sri Lanka also proposes improvements for future FRL in a stepwise manner. It intends to replace EFs from national studies with EFs derived from NFI data, include emissions from forest degradation, enhancement of forest carbon stocks, and all five carbon pools in due course of time after implementation of its two-full cycle NFI.

1 INTRODUCTION

As a signatory to the UN Framework Convention on Climate Change (UNFCCC) ratified on 23 November 1993 and entered into force on 21 March 1994, Sri Lanka is committed to addressing the threat of human-induced climate change in all sectors, both by increasing the resilience of its people and ecosystems through adaptation measures, and by decreasing the intensity of climate change itself through mitigation measures.

Sri Lanka's commitment was further highlighted by submitting two national communications to the UNFCCC in 2002 (based on data of year 1994) and in 2012, and the third national communication is expected to be done in the near future.

Sri Lanka's forests, which currently cover 29.7% of the total land area, can make a significant contribution to both adaptation and mitigation of climate change impacts. The Government, under the leadership of the Ministry of Mahaweli Development and Environment (MoMDE) in collaboration with the Forest Department (FD), seeks to maximize this contribution by developing a national strategy for Reducing Emissions from Deforestation and forest Degradation, plus conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+), in accordance with the guidance set out in section III-C of Decision 1/CP.16.

Sri Lanka submitted a Nationally-Determined Contribution (NDC) to the UNFCCC in September 2016, which was a revised description of its Intended Nationally-Determined Contribution submitted in the run-up to Paris, which includes a target to increase the national forest cover from 29.7% to 32% by 2030. Sri Lanka considers that there should be a relationship between its NDC and the performance measured through FRL.

This document is developed in recognition of Decision 12/CP.17 of the UNFCCC, wherein Parties were invited to submit information on the development of Forest Reference Emission Levels (FRELs) and/or Forest Reference Levels (FRLs). Sri Lanka submits this document to the UNFCCC on a voluntary basis, as a benchmark for assessing performance, in terms of Greenhouse Gas (GHG) emission reductions and removals, of the implementation of the national REDD+ Strategy. The FRL may also be used in future for the purpose of obtaining results-based payments.

Stakeholder participation in the development of the FRL for Sri Lanka began with a two-day workshop on 3-4 September 2015 in Colombo with the participation of 16 representatives of government and non-government institutions. A Technical Working Group (TWG) was subsequently formed to assist in the development of the FRL for Sri Lanka. A study on national circumstances was then conducted, followed by a FRL writeshop in September 2016.

2 DEFINITION OF FRL

FRLs are expressed in tonnes of CO_2 equivalent per year. In Sri Lanka's case, the FRL corresponds to average emissions and removals from selected REDD+ activities during a reference period against which the emissions and removals of these same activities during a results period will be compared. UNFCCC defines FRLs as benchmarks for assessing each country's performance in implementing REDD+ activities. FRLs need to maintain consistency with the country's greenhouse gas inventory estimates.

3 SCALE

Noting that Decision 1/CP.16 requests countries to develop national FRLs, with sub-national FRLs as a potential interim measure, Sri Lanka has decided to submit a national FRL. The extent of forest area in Sri Lanka is small, relative to neighbouring countries, and administration of forests is centralized within the Forest Department (FD) of Ministry of Mahaweli Development and Environment (MoMDE) and the Department of Wildlife Conservation of the Ministry of Sustainable Development and Wildlife. Hence there is no justification to develop interim sub-national FRLs at the current stage of REDD+ implementation.

4 FOREST DEFINITION USED

The Forest Ordinance defines forest as 'all land at the disposal of the State'. Land at the disposal of the State, includes the following:

a) all forest, waste, *chena* (shifting cultivation), uncultivated, or unoccupied land, unless proof is adduced to the satisfaction of the court that some person –

i. has acquired, by some lawful means, a valid title thereto, or

ii. has acquired a right thereto as against the State by the issuance of any certificate of no claim by the State under the State Lands Encroachments Ordinance or the Definition of Boundaries Ordinance to such person, or

iii. is entitled to possess the same under a written grant or a lease made by or on behalf of the British, Dutch, or Sri Lanka Governments, which is duly registered in accordance with law.

b) all lands resumed by the State under the provisions of the Land Resumption Ordinance, and all lands which have been declared to be the property of the State by any order passed under the Waste Lands Ordinances, 1897 to 1903, the Land Settlement Ordinance, or to which the State is otherwise lawfully entitled.

Thus the definition of 'forest' under the Ordinance does not reflect the forested state of the land. Potentially any State land, falling within the definition of 'land at the disposal of the State' irrespective of its forest cover can fall within the definition. The objective appears to have been to bring a broad category of land within the regulatory regime under the Forest Ordinance. However, the concern would be that this definition could also constrain the identification of deforestation since both land with good forest cover and deforested land could be accommodated within the definition of 'forest' under the Forest Ordinance and the definition would not reflect any change in forest cover or degradation of the land.

Hence, Sri Lanka has decided to use the same forest definition used for GHG inventory for second National Communication to UNFCCC, for the purposes of this FRL, as follows:

"Land with tree crown cover of more than 10% and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. Forest Plantations are included in this definition and agricultural land, oil palm and rubber plantations are excluded."

This definition is used for the Greenhouse Gas (GHG) inventory and for national communications to UNFCCC.

5 SCOPE OF FRL

The table below shows the scope considered in this first submission of Sri Lanka's FRL.

Table 5-1: Scope of FRL

Activities	Deforestation
	Enhancement of forest carbon stocks (Afforestation and Reforestation)
Pools	Above Ground Biomass
	Below Ground Biomass
	Litter
Gases	CO_2

6 REDD+ activities in the FRL

Sri Lanka includes the following activities in the FRL:

6.1 Reducing emissions from Deforestation (referred to hereafter as "Deforestation")

This activity refers to the reduction of GHG emissions that occur due to conversion of forest land (according to the national forest definition above) to other land use categories, as identified by comparison of forest cover data between year 2000 and year 2010. Deforestation does not comprise the temporary de-stocking of forest land which in the Sri Lankan context happens mainly in forest plantations owned by the Forest Department. Loss in forest plantations consists of timber harvesting after which the plantation is again planted. The annual area clear felled and replanted during the same year amounts to 800 to 1000ha. The area of forest plantations privately managed are negligible in comparison to forest plantations owned by the state. Forest plantations owned by Regional Plantation Companies (RPCC) amounts to 12,764ha and they are managed under management plans prepared approved by Forest Department. Due to high demand of fuel wood for estate operations the felled areas are generally replanted. The agro-forestry woodlots covering 9,771ha have not yet reached the maturity for harvesting and would be managed under FD's guidance. For these reasons, loss in plantations is considered as no change in land-use and not part of deforestation.

6.2 Enhancement of forest carbon stocks from afforestation and reforestation (referred to hereafter as "Reforestation")

This activity refers to the conversion of non-forest land use categories to forest, as identified by comparison of forest cover data between year 2000 and year 2010. This includes conversion of land which –as far as can be confirmed with the available information- has not

been forested previously (afforestation) and of land which had been forested at some point in the past (reforestation). No distinction is made between these two sub-categories (afforestation and reforestation) for the purposes of this FRL due to the lack of data to distinguish between these two sub-categories.

6.3 REDD+ activities which are not included in the FRL

The activities reducing emissions from forest degradation, enhancement of forest carbon stock in forest land remaining forest land, sustainable management of forests and conservation of forest carbon stocks are not included in this FRL as explained in the following sections.

6.3.1 Reducing emissions from Forest Degradation (referred to hereafter as "Degradation")

This activity refers to a reduction in carbon stocks in forest land that remains as forest land. Such changes cannot be identified by the comparison of forest cover data between year 1999 and year 2010 and is therefore not possible to include in the FRL at this time. The main causes of forest degradation in Sri Lanka comprises illicit felling of trees, shifting cultivation, cattle damage – livestock grazing, illegal cultivation, encroachment and extraction of gravel, minerals and metals. It is difficult to estimate the actual emissions associated with these causes and no proxy estimates are available.

6.3.2 Enhancement of forest carbon stocks from forest restoration (referred to hereafter as "Restoration")

This activity refers to an increase in carbon stocks in forest land that remains as forest land. Such changes cannot be identified by the comparison of forest cover data between year 1999 and year 2010 and is therefore not possible to include in the FRL at this stage. However, in future when large scale forest type maps are available with the forest department, an attempt can be made to estimate enhancement of carbon stocks through restoration for inclusion in the FRL.

6.3.3 Conservation of forest carbon stocks

In the Sri Lankan context, this is understood either as (a) activities that ensure that forest lands are not converted to other land use categories, in which case it is covered by the Deforestation activity, (b) activities that ensure that carbon stocks in forest lands are not reduced over time, in which case it is covered by the Degradation activity or (c) activities that enhance forest carbon stocks in protected areas, in which case it is covered by the Restoration activity. There is therefore no need to further define or use this activity in the context of this FRL.

6.3.4 Sustainable management of forests

In the Sri Lankan context, this is understood either as (a) activities that replace formerly unsustainable forest management strategies that were resulting in reduction of forest carbon stocks, in which case it is covered by the Degradation activity or (b) activities that are introduced to increase carbon stocks in formerly unmanaged forest areas, in which case it is

covered by the Restoration activity. There is, therefore, no need to define or use this activity in the context of this FRL.

7 Carbon pools in the FRL

In the development of the FRL for Sri Lanka, the carbon pools of above-ground and below-ground biomass and litter will be considered for both REDD+ activities included in the FRL (deforestation and reforestation). National data on litter and humus, carbon content of mineral soils and of dead wood are not available as they have not been assessed (in a regular manner) in the past. The newly-designed National Forest Inventory (NFI) for Sri Lanka has included these pools to be assessed during periodical plot sampling in forests. Once the NFI is fully operational, these additional data would enable Sri Lanka to modify the FRL and to undertake GHG inventories on a higher tier. Considering the present situation of data scarcity, it was decided that tier 1 values will be used for estimation of all carbon pools considered in Sri Lanka FRL. A literature review has been performed by Sri Lanka as well as a compilation of national emission factor values from IPCC's Emission Factor Data Base (www.ipcc-nggip.iges.or.jp/EFDB/main.php) and the use of this national data has been evaluated (Anex-1). However, expert judgement from a group of Sri Lankan scientists suggested that these studies were biased towards higher carbon stock forests and may result in an over-estimation of emissions and removals in the FRL calculation. Therefore, Sri Lanka has opted not to consider these national studies but use IPCC default values instead in attendance of nationally representative values from the NFI. This was endorsed unanimously by the TWG for construction of FRL during the road map preparation.

IPCC 2006 currently does not provide estimates of regional default values for litter including fine woody debris (< 10 cm diameter) and dead wood (> 10 cm diameter) carbon stocks. As such only litter pool estimates excluding fine woody debris are used as proposed in table 2.2 of IPCC 2006. The value appropriate to Sri Lankan forest is "Tropical Broadleaved Forest" for the calculation of emissions from litter after deforestation. This IPCC value was used for this study.

On the other hand, actual measurements of carbon stocks in litter fall and floor litter by Kuruppuarachchi et al. (2016) have shown that the combined carbon stocks in the above components contribute only 4.02% and 7.74% of the total ecosystem carbon stocks in the dry- and wet zones of Sri Lanka respectively. A table consisting of national emission factors is presented in annex-1. But it was decided that to keep consistency in input data, IPCC default EF should be used.

7.1.1 Above Ground Biomass (AGB)

The definition of Above Ground Biomass carbon pools according to IPCC (2006) is given as "All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds and foliage". AGB is the pool which contains the greatest proportion of biomass within Sri Lanka's forests (Kuruppuarachchi et al., 2016; De Costa and Suranga, 2012; Saatchi et al., 2011; Mokani et al., 2006; IPCC, 2006), and is subject to the most significant, measurable change in carbon stocks as a result of deforestation or

reforestation/restoration. No NFI has been carried out in Sri Lanka since 1985. NFIs are planned for implementation in 2017 and in regular 5-year cycles thereafter, which will provide the data required for direct measurement of the AGB pool.

7.1.2 Below Ground Biomass (BGB)

Below-ground biomass (BGB) or live root biomass is expressed as tonnes of biomass or carbon per hectare. Roots play an important role in the carbon cycle as they transfer considerable amounts of carbon to the ground, where it may be stored for a relatively long period of time. Although roots can extend to great depths, the greatest proportion of the total root mass is confined to the top 30 cm of the soil surface. Research indicates that this pool constitutes from 0.2 to 1.0 times the mass of the AGB pool, depending on the forest type, and therefore is a significant pool. This pool is often estimated indirectly via a root-to-shoot (R/S) ratio.

Actual measurements of below-ground biomass and carbon stock in two selected natural forests in the wet zone and dry zone of Sri Lanka by Kuruppuarachchi et al. (2016) have shown that the below-ground biomass carbon stock contributes 19.3% and 21.9% to the total biomass carbon stock in wet and dry zones respectively. This is on the low-end of the IPCC default value range for root:shoot biomass ratio for the tropical forests which suggests ratios between 0.20 to 0.56 (IPCC, 2006). In this study, IPCC 2006 values were used to estimate below ground biomass for consistency of data sources used.

7.1.3 Justification to include forest litter carbon

Sri Lanka decided to include forest litter carbon pool estimation using IPPC default values. This will be modified once NFI is properly implemented.

7.1.4 Justification for exclusion of SOC and dead wood:

7.1.4.1 Justification of exclusion of SOC

The total soil carbon stock in the dry- and wet zone forests, measured by Kuruppuarachchi et al. (2016) constituted 53.3% and 29.9% respectively. However, there is no information on carbon emission from soil carbon stocks in case of conversion of forest land to other land specific to Sri Lanka. The exclusion of SOC in FRL construction should be treated as temporary as the newly established NFI for Sri Lanka has an in-built component for SOC estimation and newly acquired data would provide additional inputs for future FRL estimation.

7.1.4.2 Justification of exclusion of dead wood

Calculation of deadwood carbon emission is difficult without having national data. IPCC doesn't provide default values for deadwood carbon emission. Hence it was decided that until Sri Lanka completes two full cycle of NFI, it is better to exclude from FRL.

8 Gases in the FRL

Carbon Dioxide (CO_2) is the only GHG included in Sri Lanka's FRL. Methane (CH_4) is emitted from clearance and conversion of peat land and wetlands. Peat is not a land type that is

significant in Sri Lanka. The peatlands of Sri Lanka are located mostly at or near the west coast (Shier 1985 and cover only 160 km^2 (aprox. 0.3% of geographical land area) of the country. Muthurajawela Swamp lies north of Colombo with another at Kotte to the southeast; peatland also occurs on interior mountains (Page et al. 2011).

Other non-CO_2 GHGs are emitted during forest fires. Sri Lanka faces nearly 50 to 200 forest fire incidents depending upon prevailing weather conditions. Almost all fires reported are in forest plantations which are subsequently replanted leading to no net emissions in the long term. The area burnt by a single fire varies from 0.2 to 150 ha (compared to total geographical area 65,000 sq km) with an average of 10 ha. Nearly 2 percent of newly planted areas are burnt annually. Most of the forest plantations are of small size and scattered over the country. Therefore, the risk is also scattered. However, the risk of a big fire is not very high due to the small size of the plantations. Almost all fires are surface fires and crown fires are very rare. Nearly 55 percent of all fires reported are in pine plantations while 20 percent are in eucalyptus plantations. Young plantations are more vulnerable compared to old plantations. Nearly 60 percent of all fires reported are in plantations that are less than five years of age. Very few fires last longer than 24 hours and most are in the range of 3 to 10 hours. On an average total area burnt under forest fire ranges from 119 to 323 ha per year (Ariyadasa K.P. 2001) while maximum of 900 ha was reported for the year 2012 in FRA 2015, which is less than 0.05% of the country's forest area.

The above default calculation approximating emissions from non-CO_2 GHGs indicates that this corresponds to less than 0.15% of all Sri Lanka's GHG emissions associated with deforestation.

9 CONSISTENCY WITH GHG INVENTORY REPORTING

Sri Lanka's second national communication did not report emissions from deforestation. In this FRL calculation, forest department's year 1999 forest cover map has been used (aggregated in Forest/Non-Forest classes) as proxy to 2000 Forest Cover prepared using The Global Forest Change (GFC) product (Hansen et al., 2013). These data are open source and can be used as a first step to indicate where potential losses and gains within forest lands have occurred at the national scale. The UMD Global Forest Change data provides an estimate of tree cover percentage for each 30m Landsat pixel.

New data sets have been collected for the FRL construction replacing the older data in the NC. Sri Lanka will update its subsequent NCs and BUR with this new data ensuring consistency between the FRL and GHGI reporting. The Sri Lanka REDD Programme has produced much of the activity data required for a new GHGI in the LUCF sector. They are as follows.

- Forest cover changes in several categories (1992, 1999, 2010 and 2015). The accuracy of change will be estimated in due course of time and depending on the results, these data may be utilized for GHGI.
- Land use and land cover changes (1985, 2000, 2005, 2010 and 2015)
- NFI data of the first cycle (at the end of 2017)
- Relevant inputs of the FRL construction.

Climate Change Secretariat (CCS) has initiated preparations for the third national communication. It covers 4 sectors, namely Energy, Industries, LUCF and Waste. Findings of the MRV component could be valuable inputs for their task, as more activity data are available than at the previous communication.

10 INFORMATION USED FOR FRL CONSTRUCTION

10.1 Methodology of Activity Data Generation

For the generation of activity data for deforestation and afforestation, Sri Lanka used the methodology described in Olofsson et al 2014, FAO 2016 and GFOI 2016 which is a combination of a wall-to-wall map (input map) and sample interpretation (reference data). This methodology corrects for the effects of map classification errors (or bias). The resulting area estimates are therefore also referred to as "bias-corrected area estimates". This methodology allows for the calculation of confidence intervals around the area estimate, the width of which is closely related to precision, therefore providing a measure of the uncertainty of the area estimate. As such, according to GFOI 2016[1], this methodology is in line with IPCC good practice of neither over- nor underestimating so far as can be judged and transparently providing a measure of uncertainties. The methodology uses an input map which has information on the location of classes of interest (deforestation, afforestation, stable forest, stable non-forest) and which is used to stratify the distribution of sample points for the collection of reference data. Reference data is collected through the interpretation of aerial photography and satellite data. The distribution of the reference data points follows a probability sampling design increasing the likelihood of a given class being included in the sample. The probability sampling design chosen is stratified random sampling which is a simple random sampling within strata and recommended by Stehman 2009. An adequate overall sample size is calculated following equation 13 in Olofsson et al 2014 which is based on Cochran (1977 in Olofsson et al 2014). The map classes are used to get a statistically sufficient number of samples in each of the classes of interest and especially to ensure sufficient samples are located in the rare classes (deforestation and afforestation).

10.1.1 Input map preparation

For construction of the FRL, Sri Lanka has decided to use the forest definition used in the second national communication to the UNFCCC, as described above; "minimum tree crown cover of 10%, a minimum tree canopy height of 5 m and a minimum area of 0.5 ha". The definition excludes land which is predominantly under agricultural use. Due to the exclusion of land predominantly under agricultural use, a large amount of Sri Lanka's tree cover does not qualify as forest land. This means that statistics derived from products that detect tree cover only, without considering the land-use aspect (such as Hansen et al. 2013), cannot be directly used for deriving statistics on forest cover[2]. Sri Lanka's Forestry Department (FD) has

[1] See section 5.1.5 Estimating uncertainty of area and change in area https://www.reddcompass.org/mgd-content-v2/dita-html/en/s5_1_5.html#s5_1_5

[2] This map was prepared by visual interpretation of LANDSAT TM data of year 1996. It was an update of the previous forest cover map prepared for Sri Lanka in 1992 using a similar procedure (Legg et el, 1995). Due to the restricted time available, ground truth verification was limited only to areas with a high potential for deforestation. During field verification confusion between forest cover and other land use types with dense tree vegetation was detected. Most of the young forest plantations could not be identified on imagery and the published data includes only the natural forest cover (*Forest Department Manual 2008*). This forest cover map was published in 1999 known as Forest Cover map of 1999. Reference: **Legg, C, and Jewell, N.**, 1995, 'A 1:50,000-scale forest map of Sri Lanka: The basis for a National Forest Geographic Information System, *Sri Lanka Forester*, Special Issue.

prepared a forest map for the year 1999 which provides more reliable statistics for forest cover. For the purpose of performing an accuracy assessment of the map, the detailed classes have been aggregated to Forest/Non-Forest classes following the conversion table provided by the country (Table-10.1). In order to provide preliminary statistics on deforestation/reforestation area estimates for the period considered, tree cover loss and tree cover gain have been used from the Global Forest Change (GFC) product (Hansen et al., 2013). These data are open source and can be used as a first step to indicate where potential losses and gains within forest lands have occurred at the national scale. The Forest/Non-Forest map has been applied as a mask to the GFC modified map in order to obtain results for actual forest cover, reflecting the national forest definition of Sri Lanka (e.g. excluding trees or tree crops on agricultural land). Tree cover loss was considered deforestation if it happened on forest land in the FD 1999 map, but was considered as stable non-forest if it occurred on non-forest land. Tree cover loss in forest plantations is not considered as deforestation since this concerns harvesting which will be succeeded by replanting and as such the land use remains to be forest. Tree cover gain was considered reforestation if it happened on non-forest land in the FD 1999 map. The UMD Global Forest Change data provides an estimate of tree cover percentage for each 30m Landsat pixel.

Table 10-1: Conversion of the original LC classes of the Forest map year 1999, in Forest/Non Forest

Map class name Year 1999 Forest Cover Map of Sri Lanka	Aggregation of original LC classes into Forest (1) Non Forest (0)
Acacia	1
Alastonia	1
Albizzia	1
Conifers	1
Dry Monsoon	1
Eucalyptus	1
Hora	1
Lowland Rain	1
Mahogany	1
Mangroves	1
Margosa	1
Mixed Plantations	1
Moist Monsoon	1
Montane	1
Riverine Dry	1
Sparse & Open	1
Sub-Montane	1
Teak	1
(blank)	0
Brackish & Saline Water	0
Fresh Water	0
Non Forest	0

A tree cover threshold of 10% has been used in the UMD Global Forest product, filtering out zones of change with less than 0.5 ha (MMU= 0.5 ha MMU=0.5 ha ~5 pixels).

10.1.2 Reference data collection

A total of 902 sample plots (figure-1) were generated using the Collect tool of OpenForis. The FD has carried out an assessment of the sampling plots using Collect Earth to access VHRI images available in Google Earth, Bing map and Google Earth Engine, together with the time series provided using the OpenForis accuracy assessment tools[3] to improve the quality of the change detection through visual interpretation of the samples. This script creates screenshots

[3] The *OpenForis Accuracy Assessment Tools* (which includes the script for the time series) is available at https://github/openforis/accuracy-assessment. This tool is constantly upgraded, therefore it is recommended to access to this link for the latest version.

of the available satellite images for each plot and therefore it is useful when facing problems of internet connection.

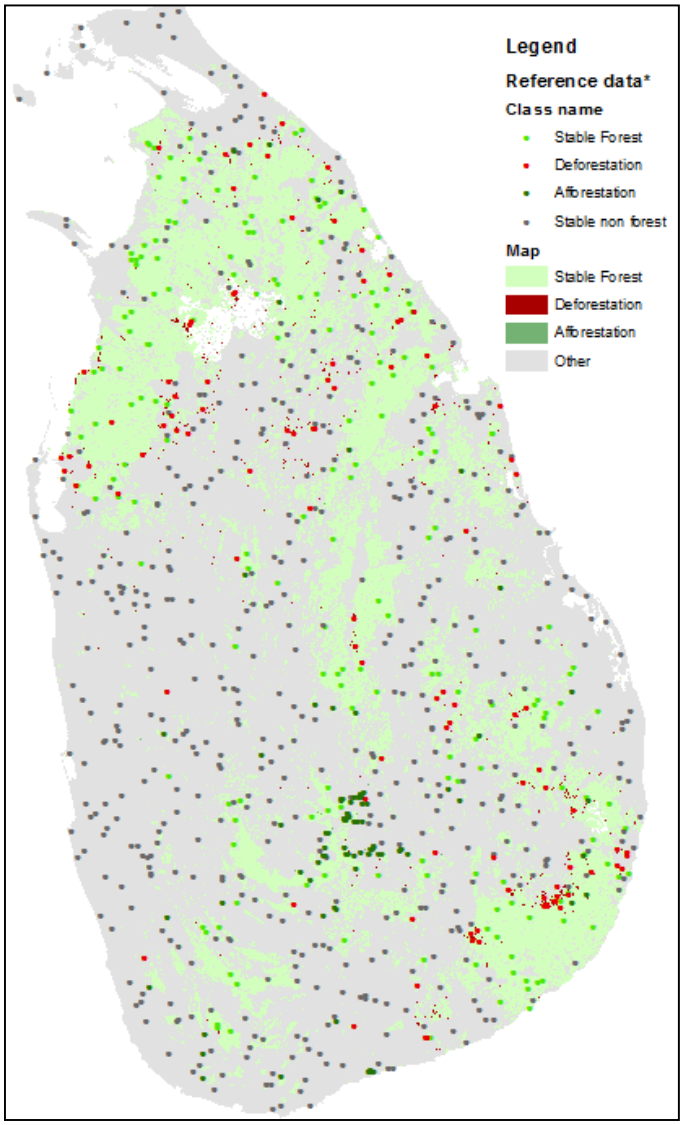

Figure 10-1 Forest change map with the sampling plots for reference data

The interpretation and classification of the sampling plots in the four classes has followed two criteria of the national Forest definition: Minimum tree cover (of 10%) and dominant Land Use (Forest Land), as shown in Figure 10-2 The sample plot is designed to cover almost 0.5 ha (the MMU) and contains 7 × 7 (49) sample points. Therefore, on VHRI images, when 5 points fall under tree cover and the main Land Use is Forest Land, the sample plot can be classified as Forest. For example, in Figure 10-2 on the right side, 18 points (indicated with a black circle) fall over trees and therefore the sample plot has approximately 36% tree cover. Comparisons between the two years (2000-2010) allow the identification of forest change dynamics.

Figure 10-2 Rules applied during the assessment: on the left side (major Land Use is Forest, plot #837), on the right side, (plot # 783) the counting of the points gives an indication of the % tree cover.

10.1.3 Review of reference datasets

The overall review of the reference dataset has been carried out with particular focus on the application of these rules (minimum tree cover of 10% and dominant Forest Land Use) for the classification of the sampling plots. The review was carried out keeping in mind technical issues such as possible shifts in image registration, image quality, seasonality etc. to ensure optimum quality of the reference datasets.

For example, if a reference plot has been classified as forest loss but in reality the image shows forest permanence with loss occurring in its proximity or after the reference period, the interpretation has been modified as stable forest. For example, #plot 154 (Figure **10-3**) has been classified as deforestation but the actual change is happening next to the sampling plot, hence it has been reclassified as stable forest. The FD reviewed the revised datasets and accepted them as the final version of reference datasets.

Figure 10-3 Plot # 154 initially classified as deforestation, but reclassified as stable forest, because the change in vegetation cover occurs mainly near the plot, not within it.

10.1.4 Accuracy assessment

The reference datasets were used for accuracy assessment. This assessment not only assesses accuracy but provides area estimates which are corrected for map bias and gives associated confidence intervals for these bias-corrected area estimates. The results of this analysis are summarized in the table below (table-10.2), known as an error matrix (or confusion matrix) which shows the user's accuracy per forest change class. The user's accuracy provides a measure of the commission errors, which represent the over-detection of the map interpretations per class. For example, for Stable Forest, 177 plots are in 'agreement' with the reference data, but 10 were over-detected, in particular 2 sample plots were actually Forest Loss and 8 were Stable Non Forest.

Table 10-2: Confusion matrix with user's accuracy of forest loss / gain map

	Forest Cover Class	Reference data					
Map data		Stable Forest	Forest loss	Forest gain	Stable Non Forest	Total samples in map class	User's accuracy
	(1) Stable Forest	177	2	0	8	187	95%
	(2) Forest loss	9	81	0	12	102	79%
	(3) Forest gain	75	3	9	13	100	9%
	(4) Stable Non Forest	101	5	1	404	511	79%
Total ref. samples per class		362	91	10	437	900	
Overall accuracy							75%

Table 10-2 provides more details on the analysis, considering the weighted producer accuracy (proportional to the area per class). This corresponds to the interpretation of the results from the reference data point of view. In general, it provides a better understanding of which classes have comparatively lower accuracy in spatial detection of the information. Therefore, it gives an indication on which classes the interpreter should focus to improve the map and/or the area estimates.

Table 10-3: Bias-corrected area estimates in ha with confidence intervals, Weighted Producer Accuracy and User accuracies for each class

Bias-corrected areas and accuracies							
Class	Producer's Accuracy, PA, (%)	Weighted PA (%)	User's Accuracy, UA, (%)	Map areas (ha)	Bias corrected areas (ha)	CI	CI (%)
(1) Forest loss	89	23	79	24,571	**84,947**	48,303	57
(2) Forest gain	90	2	9	1,764	**9,454**	18,219	193

As shown in the results of table 10-3[4], weighted Producer's Accuracy for Loss and Gain are low (23 and 2% respectively) because of the weighting of the area extent per class (over the total area). In fact, the omission detection of Gain and Loss in the map correspond in total to only 11 plots (out of 101) but since some of these omissions are in the stable classes which are very large compared to the rare change classes, the weighted omission error is relatively large. Producer Accuracy of the Stable Forest class gives higher values (64%), which means that most of the detected Stable Forest in the map is correct. However, of the overall 362 plots classified as Stable Forest in the reference data, 185 were incorrectly classified in the map as: 9 Loss, 75 Gain and 101 Stable Non-Forest.

The main reason for the misclassification of the 75 Gain is explained by the difficulty to distinguish between afforestation and growing cycles of the forest plantations, using RS technologies (table–10.2). Indeed, seasonality (leaf phenology) and soil moisture variations may have played a role in the other misclassifications.

The map is accurate (≥ 80%) in detecting Forest, Non-Forest and Deforestation, while uncertain for Afforestation (or Forest gain). As the above shows, the map systematically under-estimates forest gain due to difficulties in detecting its spectral signals with remote sensing. On the other hand, the assessment may systematically over-estimate forest gain due to misclassification of newly planted agricultural tree crops. As such, it currently cannot be determined whether the estimate for gain is over- or underestimating actual gain. To provide better estimates Sri Lanka will focus on improving the forest gain layer. Distinguishing increases in agricultural tree crops from increases in forest cover should be part of this improved assessment. Sri Lanka is in the process of conducting a GPS based boundary survey of all forest areas including forest plantation managed by forest department. This will result in considerable increase in accuracy of the gain estimate. Sri Lanka confirms that the actual existing country data does not allow precise estimates of afforestation. Yet this is an important REDD+ activity in which the county is investing as part of its REDD+ strategy making it a priority for inclusion in the FRL.

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4 Producer's Accuracy is the proportion of area that is reference class j (e.g. Forest loss) and is also class j (e.g. Forest loss) in the map, reading the columns of the error matrix table 10.2. In other words, it is the probability that class j on the ground is mapped as the same class. In general, it provides a better understanding on which class is worst and not accurate in the spatial detection of the information. Omission error is the complimentary measure to producer's accuracy, calculated by subtracting 100% from the producer's accuracy for each class. Omission error, calculated for each of the map classes, is the probability that the spatial unit classified into a given category in the reference data represents that category in the map data (FAO, 2016 p. 17).

User's accuracy is the proportion of the area classified as class i (e.g. forest loss) that is also class i in the reference data. It provides users with the probability that a particular area of the map of class i is also that class on the ground (FAO 2016, p. 18). Commission error is the complimentary measure to user's accuracy, calculated by subtracting 100% from the user's accuracy for each class. Commission error, calculated for each of the map classes, is the probability that the spatial unit classified into a given category on the map represents that category in the reference data (FAO 2016, p.17)

Bias corrected areas in ha is the most important result of the accuracy assessment which aims not only to quantify the accuracy of the map but also to generate new area estimates to correct for bias in the map, with confidence intervals.

More specifically, the accuracy assessment serves to derive the uncertainty of the map area estimates. Whereas the map provides a single area estimate for each land cover class without confidence interval, the accuracy estimates adjusts this estimate (according the results analysing reference more reliable data) and provides confidence intervals as estimates of uncertainty (see Fig.3 pg. 22 in FAO 2016). The adjusted area estimates can be considerably higher or lower than the map estimates. Therefore, map areas are defined 'corrected' because of the use of better quality (reference) data.

Confidence interval gives an estimated range of values which is likely to include an unknown population parameter, the estimated range being calculated from a given set of sample data, in our case the range of values referring to the bias corrected area estimates

To reduce uncertainty and improve confidence intervals, a possible option is intensification of the number of samples of gain using local knowledge/information on areas of afforestation, and/or investigating on existing national maps that can be used as proxy for the detection of afforestation, as well as applying training points of gain on satellite images. By converting the error matrix of sample counts into proportion of agreement/disagreement between the map and the reference data, and weighing it by the area in the class5 it is possible to correct the original area estimates. Therefore, from the map area and the error matrix an estimation of a bias-corrected area with confidence intervals is calculated, which is the approach recommended by GFOI's Methods and Guidance Document version 2.06. It is important to underline that the map estimates are bias-corrected ('adjusted') considering the national forest definition which includes the Land use component, beside the tree cover.

10.1.5 Activity data

The accuracy assessment has shown that the map is accurate (≥ 80%) in detecting Forest, Non-Forest and Deforestation, while uncertain for Afforestation (or Forest gain). However, since for the FRL construction efforts focused on getting accurate estimates of activity data (forest gain and forest loss), Sri Lanka is still evaluating which data source provides the most accurate estimate of forest cover and therefore the forest cover obtained from this exercise is not reported here. The forest area for the year 2010 reported to FRA 2015 was 2.1 million ha.

Disaggregation of forest loss shows that almost 60% of the forest cover loss was classified as Dense Forest, 35% associated with Open and Sparse forest and 5% comes from forest plantation (table 10.4).

Table 10-4: Forest cover loss in different forest classes

Forest Class	Map areas	Bias corrected areas	%
Dense Forest	14,862	51,381	60
Open Forest	8,522	29,462	35
Forest Plantations	1,177	4,068	5
Mangroves	10	36	0
Total	24,571	84,947	100

Considering forest loss associated with plantations are a temporary phenomenon and this is a rotational cycle (planting and harvesting) these areas can be considered as temporary cover loss and could not be added in deforestation loss. This case has been considered as forest land remaining in forest land hence it was not considered as deforestation. Forest loss is not considered to happen in mangroves and the minor area (36 hectares in 10 years) detected in mangrove is expected to be due to a misinterpretation of forest type and therefore the 36 ha are attributed proportionally to dense and open forest. The resulting assessment of deforestation by forest type is provided in Table 10-5.

[5] Divided by total samples in map class

[6] GFOI 2016, see section 5.1.5. of the MGD 2.0 available here: www.gfoi.org/reddcompass

Table 10-5: Deforestation by forest types

Activity	Forest classes	Biass Corrected Area in ha	% of total forest cover loss
Deforestation	Dense forest	51,404	64
	Open forest	29,475	36
	TOTAL	80,879	100

In conclusion, the bias-corrected area of annual deforestation is about 8,088 ha/yr over the period 2000-2010. For comparison, net forest loss between 2000-2010 reported to FRA 2015 was 8,900 ha/yr. Due to the fact that afforestation is under-detected in the map, the bias-corrected statistics presented here have high uncertainty (CI of 193%) but Sri Lanka suggests they can nonetheless be used as activity data for the submission of the national FRL which is relevant since this concerns an important REDD+ activity targeted by Sri Lanka's National REDD+ Investment Framework Action Plan.

Overall, the analysis has shown the importance of the quality assessment using reference data and a consistent application of the definitions (criteria) to describe the map classes. Further developments may include analysis of degradation with particular attention to the definitions provided (e.g. types of plantations included as forest). In view of the safeguards[7], the frequency and locations of natural forests converted into forest plantations is always analysed in FRL assessments, so it is important to mention that these changes do not occur in the Sri Lankan context due to legal constraints to convert natural forest into plantations. Conversion of forests to other land uses is governed by the regulations under National Environmental Act No.47 of 1980. It covers (a) Extraction of timber from a land exceeding 5ha (currently applied only for forest plantations for thinning and for regeneration felling) and (b) Conversion of forests exceeding 5ha to other land uses. Under both circumstances EIAs are needed for project approval. As a policy decision of the FD natural forests are not converted to forest plantations. Considering the above explained situation it was decided to use bias corrected forest loss estimates removing (temporary) loss in plantations and gain estimate as activity data.

Table 10-6: Activity data

Activity Data Class	**Biass Corrected Area (in ha/yr)**
Deforestation	8,087.9
Afforestation/reforestation	945.4

[7] See Decision 1/CP 16, Appendix I, p2(e)

10.2 Emission Factors

In order to select emission factors which provide better results for carbon emission and removals in Sri Lanka's forest, an effort was made to collect national data but it was understood by a group of scientists and FRL Technical Working Group that these national studies seem biased towards higher carbon forests and therefore, to avoid over-estimation of emissions, Sri Lanka opts to use IPCC default values. A summary table prepared for national emission factors is given in annex-1. Following are the details of default IPCC emission factors used in FRL construction.

10.2.1 Emission factors for deforestation

Below given tables present emission factors and corresponding values ranges used for estimation of emission from deforestation but only average emission factor was utilized for emission calculation.

Table 10-7: Above ground biomass in natural forests. Data extracted from IPCC 2006, table 4.7.

Domain	**Ecological Zone**	**Continent**	**Above Ground Biomass (Tonnes d.m. ha^{-1})**	**References**
Tropical	Tropical rain forest	Asia (continental)	280 (120-680)	IPCC, 2003
	Tropical moist deciduous forest	Asia (continental)	180 (10-560)	IPCC, 2003
	Tropical dry forest	Asia (continental)	130 (100-160)	IPCC, 2003

Table 10-8: Ratio of below ground biomass to above ground biomass (R) in natural forest. Data extracted from IPCC 2006, table 4.4.

Domain	**Ecological Zone**	**Above Ground Biomass**	**R (Tonne root d.m. (tonne shoot d.m.)$^{-1}$**	**References**
Tropical	Tropical rain forest	------	0.37	Fittkau and Klinge, 1973
	Tropical moist deciduous forest	AGB < 125 tonnes per ha	0.20	Mokany et. al. 2006
		above-ground biomass >125 tonnes ha-1	0.24	Mokany et al., 2006
	Tropical dry forest	AGB < 20 tonnes per ha	0.56	Mokany et. al. 2006
		above-ground biomass >20 tonnes ha-1	0.28	Mokany et al., 2006

Under afforestation/reforestation (which includes plantations of less than 10 years old) the assumption is that AGB of land converted to Forest Land in Tropical moist deciduous zone is < 125 t/ha and that AGB of land converted to Forest Land in Tropical Dry zone is <20 t/ha,

therefore the R values used are 0.2 and 0.56, respectively. Regarding deforested land (that is, conversion from forest to other land use), the assumption is that AGB in Tropical moist deciduous forest is 180 t/ha (tier 1 default value) and AGB in Tropical Dry forest 130 (tier 1 default value). Therefore, the chosen values for R, are 0.24 and 0.28, respectively.

Table 10-9: Default values for litter and dead wood carbon stocks. Data extracted from IPCC 2006, table 2.2.

Climate	**Forest Type - Broadleaf deciduous Litter carbon stocks of mature forest (tonnes C ha^{-1})**
Tropical	2.1 (1-3)

10.2.2 Removal factors for reforestation

To calculate removals, Sri Lanka used forest gains which are mainly reforestation in plantation sectors. Out of total Sri Lanka's plantation area majority is Teak and Eucalyptus followed by Pinus and other mixed plantation. Below given table shows plantation and their respective ecological zones and removal factors utilized for removal calculation.

Table 10-10: Plantation area percent out of total plantation area

Plantation Type	**Percent Area out of total Plantation area**	**Ecological Zone**
Teak	32%	Tropical Moist Deciduous Forest
Eucalyptus	35%	Tropical Rain Forest
Pinus Caribaea	17%	Tropical Rain Forest
Other Plantation	17%	Tropical Rain Forest

Table 10-11: Above ground net biomass growth in plantation. Data extracted from IPCC 2006, table 4.10.

Domain	**Ecological Zone**	**Continent**	**AGB Growth (tonne $d.m.ha^{-1}$ yr^{-1})**	**AGB Growth used for Corresponding Plantation**	**References**
Tropical	Tropical moist deciduous forest	Asia	8	Teak	IPCC, 2003
	Tropical rain forest	Asia Eucalyptus sp.	5	Eucalyptus	IPCC, 2003
	Tropical rain forest	Asia other	5	Pinus Caribaea	IPCC, 2003
	Tropical rain forest	Asia other	5	Other Plantation	

Note: AGB means Above Ground Biomass.

Table 10-12: Below ground biomass in plantation. Data extracted from IPCC 2006, table 4.4.

Domain	Ecological Zone	Above Ground biomass	Root to Shoot Ratio R	AGB Growth used for Corresponding Plantation	References
Tropical	Tropical moist deciduous forest	AGB < 125 tonnes per ha	0.20	Teak	Fittkau and Klinge, 1973
	Tropical rain forest	---	0.37	Eucalyptus	Mokany et. al. 2006
	Tropical rain forest	---	0.37	Pinus Caribaea	Mokany et. al. 2006
	Tropical rain forest	---	0.37	Other Plantation	Mokany et. al. 2006

Table 10-13: Default values for litter in plantation

Domain	Ecological Zone	Growth in Litter Carbon (tonnes of C per ha per year)	AGB Growth used for Corresponding Plantation
Tropical	Tropical moist deciduous forest	0.1050	Teak
	Tropical rain forest	0.1050	Eucalyptus
	Tropical rain forest	0.1050	Pinus Caribaea
	Tropical rain forest	0.1050	Other Plantation

Note: Growth in litter biomass of plantation is 2.1 tonnes per ha up to age of 20 years hence for getting per year rate 2.1 (data derived from IPCC 2006 table 2.2) is divided by 20 which equals to 0.1050. AGB means Above Ground Biomass.

11 DETAILS ON NATIONAL CIRCUMSTANCES

A National Circumstances study was carried out to assess if the specific circumstances applicable to the Sri Lankan context, in terms of its development trajectory, needed to be accommodated in the calculation of the FRL. It is argued that the observed deforestation rates will be unable to predict the future forest cover losses if planned or unplanned development activities will greatly change the distribution of forest cover in the future years. Therefore, there is a need to investigate whether predictions of forest cover need to take into account national development circumstances.

This study examined the potential for statistical prediction of forest cover over time based on social, demographic and economic variables, using a dataset of district-year observations. Based on the available published data, 25 district units are included in the construction of the panel.

The adopted methodology enables estimation of sub-national level variation and national level aggregate variation as well. It enables the application of regression methodology appropriately whether the time trends or other predictors are considered for the prediction of future forest cover. It further enables the comparison of alternative prediction models in order to choose a model with high predictive success.

The results of the time trend analysis report that for the open and dense forest the time trends are not statistically robust predictors. If we are to still consider the evidence from the time trend model, we observe that, over the next 15 years, 85,500 Ha of dense forests and 16,875 Ha of open forest will be cleared keeping in line with the historical time trend.

Other variables show statistically robust predictive success. Among the three models tested both in terms of linear and nonlinear specifications, the number of industrial establishments/firms by district emerges as the more successful statistically robust predictor. The study generated a forest area change estimate for a 2030 scenario based on this model. The prediction from the industrial establishment model is supplemented with expected forest cover losses due to the future Mahaweli plan operations. Both the estimates together suggest an expected loss of forest cover of 88,793 Ha by 2030.

The next step of the calculation was to supplement both the above scenarios with two alternative forest enhancement strategies that FD has included in its future operations. This would include policies and measures for implementing REDD+ so this approximation would not provide a benchmark for performance but rather predict (part of) the performance. The first strategy would result in enhancement of forest cover by 8,000 ha and the second by by 11,000 ha. Both strategies will generate gains in forest cover by 2030 compared to the current level.

Therefore, based on the industrial activity based model, a case for an adjustment of FRL to reflect national circumstances is not evident. This study concludes that, even though the predictive power of the industrial activity model is statistically significant , it does not make a substantive case for an upwards or downwards adjustment to the FRL and confirms that a historical average would be an acceptable benchmark for assessing performance of Sri Lanka's REDD+ implementation.

12 PROPOSED FRL

As explained in above sections 10 and 11, Sri Lanka's FRL consists of historical annual deforestation and reforestation estimates for the period 2000 - 2010 combined with IPCC default emission and removal factors. As presented in below given table 12-1, total emission from deforestation is estimated to be 4378 ('000 tonnes of CO_2 Eq.) whereas total removals from forest gain is -72 ('000 tonnes of CO_2 Eq.).

Below given are the proposed FRL for Sri Lanka.

Table 12-1: Sri Lanka's proposed FRL

LOSS/GAIN	Carbon Pools	Unit (Tonnes of C per ha per year)	CO_2 Eq in 1000 tonnes	CO_2 Eq in 1000 tonnes per year
LOSS	Above ground carbon	870,421	3,192	4,365
	Below ground carbon	303,049	1,111	
	Litter	16,985	62	
Gain	Enhancement in Above Ground Biomass	14,566	-53	-72
	Enhancement in Below Ground Biomass	4,326	-16	
	Enhancement in Litter	679	-2.49	

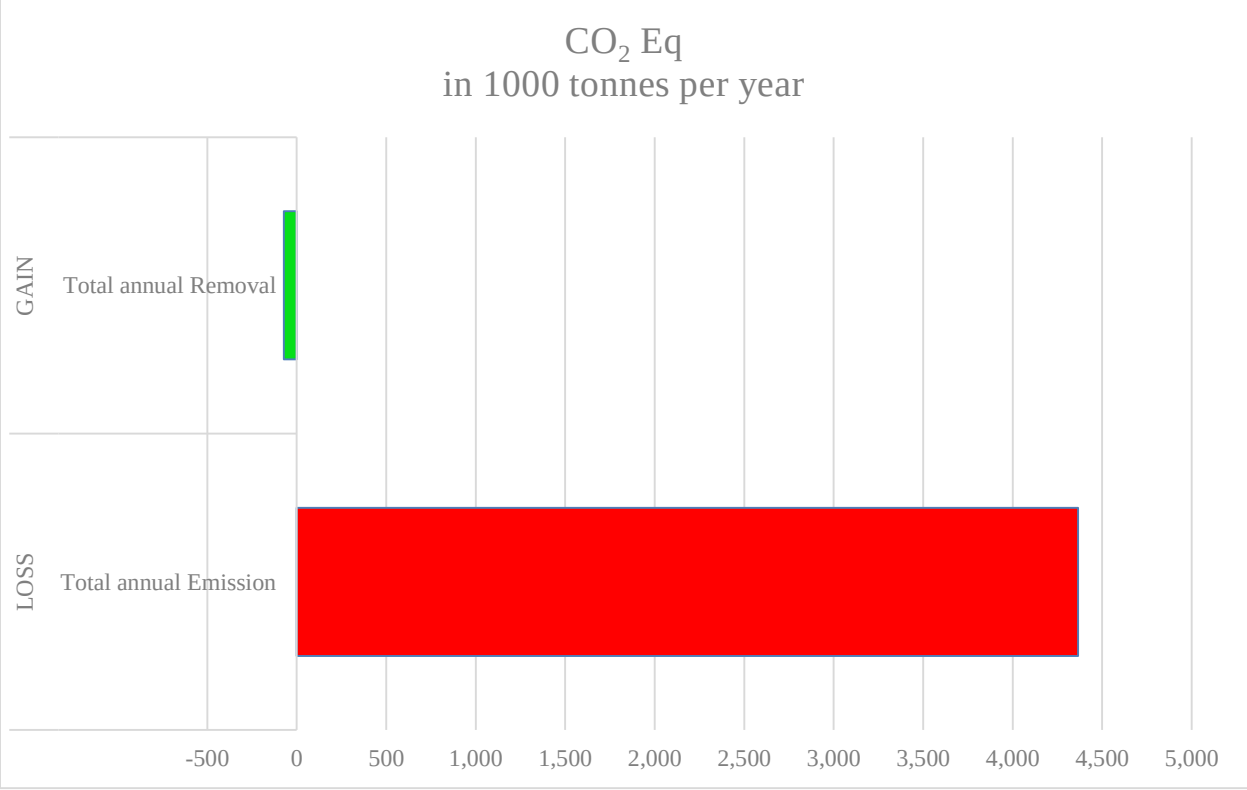

Figure 12-1: Graphical representation of emission and removals per year as part of FRL

Year 2000 and 2010 were considered as historical period for FRL construction. The validity period of the FRL will be 5 years after which Sri Lanka will re-calculate and submit a new FRL.

13 FUTURE IMPROVEMENTS

Diversified topographic features, varying climatic conditions and different edaphic factors have led to the development of different forest types in Sri Lanka. The forest vegetation is distributed within the 3 major climatic zones in the island (Wet Zone, Intermediate Zone and Dry Zone) and the Forest Department stratifies it using a classification system developed by Koelmeyer8. The natural forests of the island are not harvested to extract timber since the last three decades and the local supply for timber and firewood is met from forest plantations and tree resources outside forests. The high floral biodiversity contributes to the utilization of Non-Timber Forest Products from forests bringing fringe dwellers substantial income[9]. The analysis of forest cover change between 1992 and 2010 shows that the overall rate of deforestation has slowed down. Deforestation however appears to be more scattered and widespread all over the country instead of being concentrated largely into few selected areas, and takes place at a higher rate in the dry zone compared to the wet zone. Since 1992 when its systematic forest cover assessment was first conducted, key drivers of deforestation and forest degradation have been broadly characterised as: 1) encroachments, 2) infrastructure development projects, 3) large scale of private agriculture ventures, and 4) localized small-scale degradation activities scattered around the country.

In April 2016, the Government of Sri Lanka – through its Intended Nationally Determined Contribution (INDC) acknowledges the role of the forestry sector as a key mitigation strategy. INDC recommend an increase of the current forest cover up to 32%. This includes (i) Improvement of the quality of growing stock of Natural Forests and Forest plantations, (ii) Restoration of degraded forests and hilltops (shrubs, grasslands and state lands), (iii) Increase river basin management for major rivers of Sri Lanka, (iv) Forestation of underutilized private lands and marginal Tea lands, (v) Urban forestry (Tree planting along roadside, temple lands, schools and other govt. lands), (vi) Establishment/ reactivating of National Forest Monitoring System (NFMS), (vii) Promote private and public sector companies for investment in environmental conservation projects through CSR programs. (Sri Lanka INDC, 201610). Following are the PAMs for REDD+ implementation in phase-2.

Policy Area 1: Forest, Wildlife and Watershed	
PAM 1:	Improvement of law enforcement & monitoring on the ground
PAM 2:	Forest boundaries survey and demarcation as well as declaration in appropriate managerial categories
PAM 3:	Restoration of degraded forests and wildlife ecosystems
PAM 4:	Sustainable Forest Management (natural forests)
PAM 5:	Sustainable management of forest plantations
PAM 6:	Protection of watersheds

8 Koelmeyer, K.O., 1957, 'Climatic Classification and the Distribution of Vegetation in Ceylon', Ceylon Forester, Vol. III, No. 2 (New Series)
[9] See the final report on 'Non-carbon benefits in the context of REDD+ in Sri Lanka', UN-REDD Programme in Sri Lanka, 2016.
10 See INDC of Sri Lanka, http://www4.unfccc.int/submissions/INDC/Submission%20Pages/submissions.aspx

Policy Area 2: Land Use Planning

PAM 7:	Support inclusion of Strategic Environmental Assessment under Land Use Planning (LUP)
PAM 8:	Strengthening of Environmental Impact Assessment process
PAM 9:	Improve land productivity and rehabilitation practices
PAM 10:	Improve the tree cover of non-forested lands (home gardens, urban centre, public lands and settlements)

Policy Area 3: Other Forested Lands

PAM 11:	Protection of Vihara Devalagam, Janataha Estate Development Board (JEDB), Sri Lanka State Plantations Cooperation (SLSPC), Regional Plantation Companies (RPCs) & Land Reform Commission (LRC) forested lands
PAM 12:	Identify local supply chain for fuelwood demand
PAM 13:	Development of agroforestry models for addressing forest degradation

Building upon the MRV activities implementation in REDD+ phase-2 and national priorities expressed in INDC, Sri Lanka intends to improve following activities in stepwise manner. This will help in inclusion of all five carbon pools in future FRL.

- Strengthening NFI in Sri Lanka
    - To replace EFs from national studies with EFs from NFI
    - To include emissions from forest degradation
    - To include enhancement of forest carbon stocks
- Strengthening Satellite Land Monitoring Systems for enhanced monitoring, measuring, reporting and verification purposes
- Strengthening GHGI procedure

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ANNEX

Annex-1

Carbon pools and their emission factors – Comparison of national estimates and IPCC default values.

Carbon Pools	National Range	IPCC Range	Reference
Aboveground biomass	• **Tropical rainforest –** o 357.9 t ha-1 (Chave et al., 2008) o 463 t ha-1 (De Costa, 2009) o 364.3 (Kumarathunga et al., 2011) o 436.0 t ha-1 (Mattsson et al., 2012)	Above-ground biomass (tonnes d.m. ha-1) (160 to 350)	Table 4.7, chapter – 4, Tropical rainforest, Tropical moist deciduous forest, Tropical dry forest
	• Tropical moist forest – o 292.8 t ha-1 (Pathinayake et al., 2009) o 410.2 t ha-1 (Kuruppuarachchi et al., 2016)		
	• **Tropical dry forest –** o 122.9 t ha-1 (Kuruppuarachchi et al., 2016)		
	• **Forest Plantations –** o Evergreen Needle-leaved (Pinus) 94.5 – 264.9 t ha-1 (De Costa and Suranga, 2012)		
	• **Evergreen broad-leaved (Eucalyptus spp.; Swietenia macrophylla, Acacia spp.)** o 36.5 – 253.2 t ha-1 (De Costa and Suranga, 2012)		
	• **Deciduous broad-leaved (Tectona grandis)** o 26.1 t ha-1 (De Costa and Suranga, 2012)		
Belowground biomass	• **Tropical rainforest –** o 89.5 t ha-1 (Chave et al., 2008) o 115.8 t ha-1 (De Costa, 2009) o 91.1 (Kumarathunga et al., 2011) o Root-Shoot Ratio = 0.33 (Phillips et al., 1998) • **Tropical moist forest –** o 58.6 t ha-1 (Pathinayake et al., 2009) o 82.0 t ha-1 (Kuruppuarachchi et al., 2016)	Root to shoot ratio, 0.20 to 0.56	Table 4.4, chapter – 4, Tropical rainforest, Tropical moist deciduous forest, Tropical dry forest

Carbon Pools	National Range	IPCC Range	Reference
	○ Root-Shoot Ratio = 0.33 (Phillips et al., 1998) • **Tropical dry forest –** ○ 24.6 t ha-1 (Kuruppuarachchi et al., 2016) ○ Root-Shoot Ratio = 0.20 (Mokany et al., 2006) • **Forest Plantations –** ○ Root-Shoot Ratio = 0.31 (Birdsey, 1992) • **Evergreen Needle-leaved (Pinus)** ○ 41.5 – 116.5 t ha-1 (De Costa and Suranga, 2012) • **Evergreen broad-leaved (Eucalyptus spp.; Swietenia macrophylla, Acacia spp.)** ○ 16.0 – 111.3 t ha-1 (De Costa and Suranga, 2012) • **Deciduous broad-leaved (Tectona grandis)** ○ 59.3 t ha-1 (De Costa and Suranga, 2012)		
Litter	• **Tropical moist forest –** ○ 292.8 t ha-1 (Pathinayake et al., 2009) ○ 7.74 t ha-1 (Kuruppuarachchi et al., 2016) • **Tropical dry forest –** ○ 7.08 t ha-1 (Kuruppuarachchi et al., 2016)		
SOC	• **Tropical moist forest –** ○ 108 t ha-1 (Kuruppuarachchi et al., 2016) • **Tropical dry forest –** ○ 94 t ha-1 (Kuruppuarachchi et al., 2016)		

Annex-2: FRL Calculation:

Activity Data for deforestation	
Total area deforested over the inventory period (ha)	**Annual area deforested (ha/yr)**
80878.7	8087.9

Emission from Deforestation:

Emission from Above Ground Biomass

Annual loss in carbon stocks in aboveground biomass							
Vegetation type	**ecological zone**	**Annual area of Land deforested (ha)**		**EF (average biomass stocks before the conversion) (tonnes d.m. ha^{-1})**	**Annual loss in aboveground Biomass (tonnes d.m. yr^{-1})**	**Carbon fraction of dry matter (CF) [tonnes C (tonne dm)$^{-1}$]**	**Annual loss in carbon stock in aboveground biomass (tonnes C. yr^{-1})**
		%	**Area (ha)**				
Dense Forest	TRF (100%)	64%	5176.236363	280	1449346.182	0.47	681193
Open Forest	TMDF (20%), TDF (80%)	36%	2911.632954	140	407628.6136	0.47	191585
TOTAL							872778

Note:

1) Open forest

Emission from Below Ground Biomass

Annual loss in carbon stocks in belowground biomass								
Vegetation type	ecological zone	Annual area of Land deforested (ha)		EF (average biomass stocks before the conversion) (tonnes d.m. ha^{-1})	Annual loss in aboveground Biomass (tonnes d.m. yr^{-1})	Root To Shoot Ratio [tonnes bg dm (tonne ag dm)$^{-1}$] (ipcc 2006 table 4.4)	Carbon fraction of dry matter (CF) [tonnes C (tonne dm)$^{-1}$]	Annual loss in carbon stock in belowground biomass (tonnes C. yr^{-1})
		%	Area (ha)					
Dense Forest	TRF (100%)	64%	5176.236363	280	1449346.182	0.37	0.47	252041
Open Forest	TMDF (20%), TDF (80%)	36%	2911.632954	140	407628.6136	0.272	0.47	52111
							TOTAL	**304153**

Note:

2) For dense forest "Tropical Rain Forest", volume -4, table 4.7 Emission factor, IPCC 2006 was used

3) For Open forest a combination of weighted emission factor was used considering 80% of open forest in dry zone and 20% in wet or intermediate zone based on national observations. Hence weighted emission factor (180*0.2+130*0.8)=140 was used for open forest. Reference, volume -4, table 4.7 Emission factor, IPCC 2006.

4) For calculation of emission from below ground biomass root to shoot ratio of dense forest was taken from the value of "tropical rain forest" while value for open forest was computed using weighted average method by considering 80% of open forest in dry zone and 20% in wet or intermediate zone based on national observations. 80% area of dry zone forest resembles to "tropical dry forest having AGB < 20 tonnes per ha " and Tropical moist deciduous forest having AGB < 125 tonnes per ha. Hence (0.2*0.2+0.56*0.8)= 0.488 value was used.

Emission from forest litter

Annual loss in carbon stocks in litter					
Vegetation type	**ecological zone**	**Annual area of Land deforested (ha)**		**Litter carbon stocks of mature forests (tonnes C ha^{-1}) (ipcc 2006 table 2.2)**	**annual loss in carbon stocks in litter (tonnes C yr^{-1})**
		%	**Area (ha)**		
Dense Forest	TRF (100%)	64%	5176.236363	2.1	10870
Open Forest	TMDF (20%), TDF (80%)	36%	2911.632954	2.1	6114
				TOTAL	**16985**

Removal from Reforestation (plantation)

Plantation - enhancement in Above Ground Biomass

Land converted to Forestland - increase in carbon stocks in Aboveground biomass							
Ecological Zone	**plantation type**	**Annual area converted to forestland (ha/yr)**		**Above ground net biomass Growth (tonnes of d.m. per ha per year) (ipcc 2006 table 4.10)**	**Total gain in aboveground biomass over the reference period (tonnes of d.m.)**	**Carbon fraction of dry matter (CF) [tonnes C (tonne dm)-1]**	**total gain in C over the reference period (tonnes C)**
		%	**Area**				
TMD forest	Teak (Asia)	32%	303	8	133,115	0.47	62,564
T R forest	Eucklyptus (Asia Euck.)	35%	331	5	90,996	0.47	42,768
T R forest	Pinus Caribaea (Asia Other)	17%	156	5	42,898	0.47	20,162
T R forest	Other Plantation (Asia Other)	17%	156	5	42,898	0.47	20,162
total							**145656**
			Mean annual increase in carbon stocks in Aboveground biomass (tonnes C/yr)				**14,566**

Plantation - enhancement in Below Ground Biomass

Land converted to Forestland - increase in carbon stocks in Below Ground Biomass								
Ecological Zone	plantation type	Annual area converted to forestland (ha/yr)		Above ground net biomass Growth (tonnes of d.m. per ha per year) (ipcc 2006 table 4.10)	Total gain in aboveground biomass over the reference period (tonnes of d.m.)	Root To Shoot Ratio [tonnes bg dm (tonne ag dm)-1] (ipcc 2006 table 4.4)	Carbon fraction of dry matter (CF) [tonnes C (tonne dm)-1]	total gain in C over the reference period (tonnes C)
		%	Area					
TMD forest	Teak (Asia)	32%	303	8	133,115	0.2	0.47	12,513
T R forest	Eucklyptus (Asia Euck.)	35%	331	5	90,996	0.37	0.47	15,824
T R forest	Pinus Caribaea (Asia Other)	17%	156	5	42,898	0.37	0.47	7,460
T R forest	Other Plantation (Asia Other)	17%	156	5	42,898	0.37	0.47	7,460
total								**43,257**
						Mean annual increase in carbon stocks in belowground biomass (tonnes C/yr)		**4,326**

Plantation - enhancement in litter carbon

Land converted to Forestland - increase in carbon stocks in Litter						
Ecological Zone	**plantation type**	**Annual area converted to forestland (ha/yr)**		**Litter carbon stocks of mature forests (tonnes C ha-1) (ipcc 2006 table 2.2)**	**Annual gain in Litter Carbon stocks (tonnes of C per ha per year)**	**total gain in carbon stocks in litter over the inventory period (tonnes C)**
		%	**Area**			
TMD forest	Teak (Asia)	32%	303	2.1	0.1050	1,747
T R forest	Eucklyptus (Asia Euck.)	35%	331	2.1	0.1050	1,911
T R forest	Pinus Caribaea (Asia Other)	17%	156	5.2	0.2600	2,231
T R forest	Other Plantation (Asia Other)	17%	156	2.1	0.1050	901
total						**6,790**
	Mean annual increase in carbon stocks in litter (tonnes C/yr)					**679**