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 4529 ('000 tonnes of CO_2 Eq.) whereas total removals from forest gain is -70 ('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 <u>the reduction of GHG emissions that occur due to</u> 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. Loss in forest plantations consists of timber harvesting after which the plantation is again planted. For this reason, 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.

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. Although 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 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.

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, its 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 prevaling 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 it's subsequent NCs and BUR with this new data ensuring consistency between the FRL and GHGI reporting.

10 INFORMATION USED FOR FRL CONSTRUCTION

10.1 Methodology of Activity Data Generation

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[1]. Sri Lanka's Forestry Department (FD) has 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 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.

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[1] 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.

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[2] to improve the quality of the change detection through visual interpretation of the samples. This script creates screenshots of the available satellite images for each plot and therefore it is useful when facing problems of internet connection.

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[2] 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.
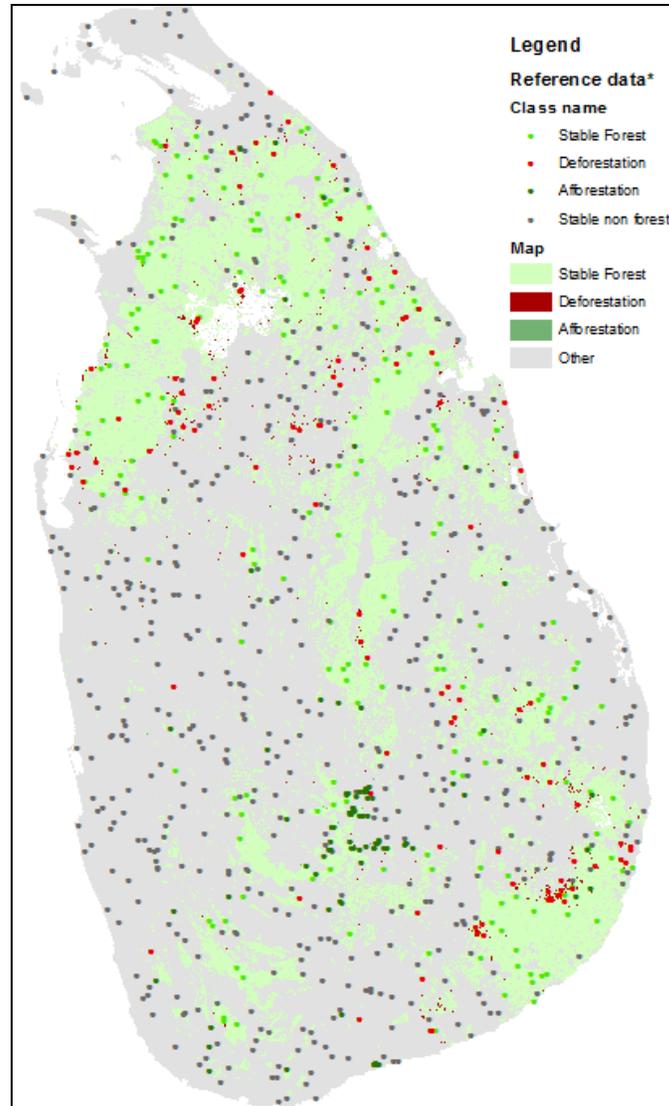
Figure 10-1 Forest change map with the sampling plots for reference data

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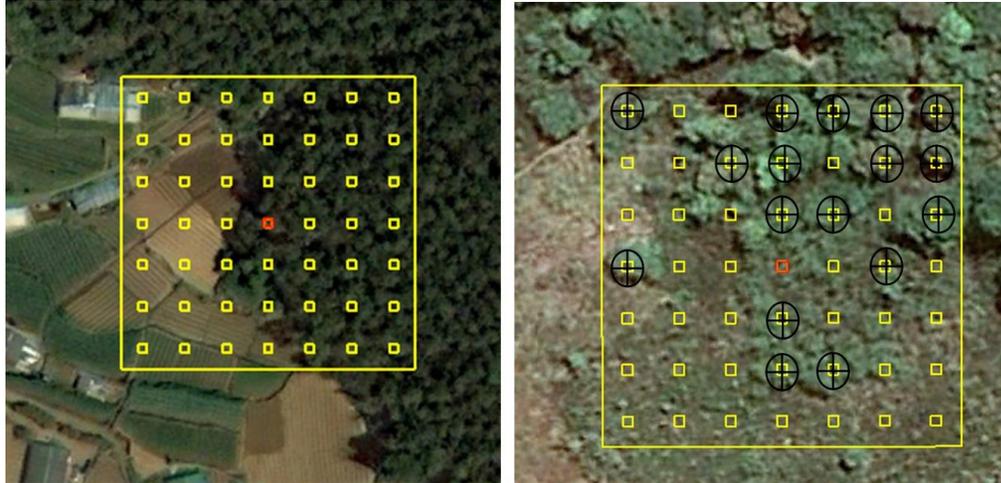
Figure 10-2 Rules applied during the assessment: on the left side (major Land Use is Forest, plot #837), on the right side, (plot # 783) the counting of the points gives an indication of the % tree cover.

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. 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 cover 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					
		Stable Forest	Forest loss	Forest gain	Stable Non Forest	Total samples in map class	User's accuracy
Map data	(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)	Usser's Accuracy (UA)	Map areas	Bias corrected areas in hectare	CI	CI (%)
(1) Stable Forest	64	95	1.767.579	2.619.454	173.838	7
(2) Forest loss	23	79	24.571	80.879	48.303	57
(3) Forest gain	2	9	1.764	9.454	18.219	193
(4) Stable Non Forest	98	79	4.749.965	3.834.092	175.442	5
Total			6.543.878	6.543.878		

As shown in the results, 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 weighed omission error is relatively large. Producer Accuracy of the Stable Forest class shows higher values (64%), because weighted by the area which covers almost 80% of the country. It also means that the map has correctly captured Stable Forest (most of the detected Stable Forest in the map are 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.

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 class3 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 2.04. It is important to underline that the corrected estimates are bias-corrected ('adjusted') considering the national forest definition which includes the Land use component, beside the tree cover.

[3] Divided by total samples in map class
[4] GFOI 2016, see section 5.1.5. of the MGD 2.0 available here: www.gfoi.org/reddcompass

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). The bias-corrected areas indicate around 2.6 million ha of Stable forest (Table 10-3), however the official forest cover in 2010 of 2.1 million ha is maintained. The bias-corrected area of annual deforestation is about 8088 ha/yr over the period 2000-2010, corresponding to an annual deforestation rate of aprox. 0.3 %. The forest area for the year 2010 reported to FRA 2015 was 2.1 million ha, and net forest loss between 2000-2010 was reported as 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 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. Taking into consideration the forest cover estimates declared for year 2010 of 2.1 million ha, the bias corrected estimate for stable forest have been altered to comply with the official forest statistics (see Table 10-4). This does not affect the bias-corrected areas for forest gain and forest loss and as such, this does not affect the FRL calculation.

Table 10-4: Adjusted Stable Forest area

Class	Areas considered (ha)
Stable forest	2,096,504

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[5], 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.

Considering the above explained situation it was decided to use bias corrected forest loss and gain estimate as activity data.

Table 10-5: Activity data

Activity Data Class	Biass Corrected Area (in ha) During Year 2000 to 2010
Forest Loss	80,879
Forest Gain	9,454

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 10.6).

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

Table 10-6: Forest cover loss in different forest classes

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

Considering deforestation associated to plantations are temporary phenomenon and this a rotational cycle (planting and harvesting) these areas can be considered as temporary loss and could not added in deforestation loss. This case has been considered as forest land remaining in forest land hence it was not considered as deforestation. Mangrove was also not considered because of negligible area (36 hectares in 10 years).

Table 10-7: Deforestation by forest types

Activity	Forest classes	Biass Corrected Area in ha	% of total forest cover loss
Deforestation	Dense forest	51,381	64
	Sparse forest	29,462	36
	Mangroves	36	0
	TOTAL	80,879	100

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 efforts 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 10-8: Above ground biomass in natural forests

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 10-9: Ratio of below ground biomass to above ground biomass (R) in natural forest

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 (0.09 -0.25)	Mokany et. al. 2006
	Tropical dry forest	AGB < 20 tonnes per ha	0.56 (0.28 -0.68)	Mokany et. al. 2006

Table 10-10: Default values for litter and dead wood carbon stocks

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 10-11: 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 10-12: Above ground net biomass growth in plantation

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 10-13: Below ground biomass in plantation

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 10-14: 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	References
Tropical	Tropical moist deciduous forest	0.1050	Teak	Fittkau and Klinge, 1973
	Tropical rain forest	0.1050	Eucalyptus	Mokany et. al. 2006
	Tropical rain forest	0.1050	Pinus Caribaea	Mokany et. al. 2006
	Tropical rain forest	0.1050	Other Plantation	Mokany et. al. 2006

Note: Growth in litter biomass of plantation is 2.1 tonnes per ha upto age of 20 years hence for getting per year rate 2.1 is divided by 20 which equals to 0.1050. Mokany et. al. 2006): 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, 85500 Ha of dense forests and 16875 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 4529 ('000 tonnes of CO_2 Eq.) whereas total removals from forest gain is -70 ('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)	CO2 Eq in 1000 tonnes	CO2 Eq in 1000 tonnes per year
LOSS	Above ground carbon	872,778	3200	4529
	Below ground carbon	345,535	1267	
	Litter	16,985	62	
Gain	Enhancement in Above Ground Biomass	14,566	-53	-70
	Enhancement in Below Ground Biomass	4326	-16	
	Enhancement in Litter	99	-0.36	
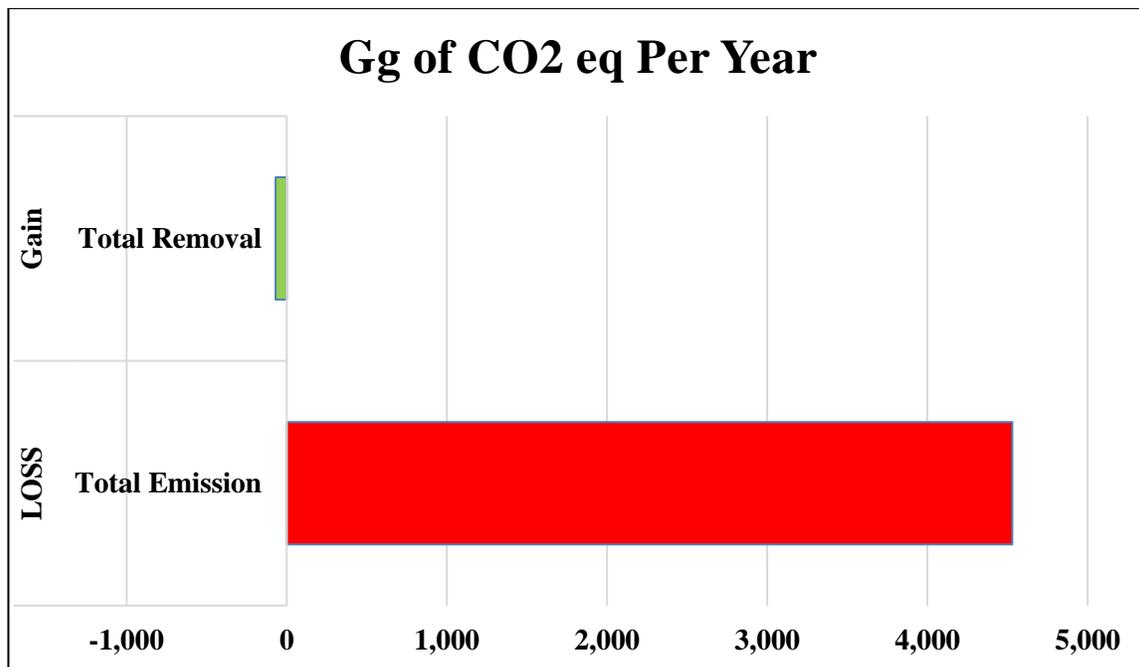
Figure 12-1: Graphical representation of emission and removals per year as part of FRL

Year 2000 and 2010 were considered as historical period for FRL construction. The validity period of the FRL will be 05 years after which Sri Lanka will re-calculate and submit a new FRL.

13 FUTURE IMPROVEMENTS

Below mentioned improvements can be made in future FRL in a stepwise manner.

- ➢ Replace EFs from national studies with EFs from NFI
- ➢ Include emissions from forest degradation
- ➢ Include enhancement of forest carbon stocks
- ➢ Include all five carbon pools

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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)
	• 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)
		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

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)
	  o Root-Shoot Ratio = 0.33
		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

	(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:

Emission from Deforestation:

Emission from Above Ground Biomass

Above ground carbon	Area in ha		EF (tonnes d.m. ha-1)	Total Biomass	CF	Tonnes of C per year
Total deforestation per year	8088					
Dense Forest	64%	5176.236	280	1449346.182	0.47	681193
Open Forest	36%	2911.633	140	407628.6136	0.47	191585
					TOTAL	872778

Emission from Below Ground Biomass

Below ground carbon	Area in ha		EF (tonnes d.m. ha-1)	Total Biomass	R to S ratio	CF	Tonnes of C per year
Total deforestation per year	8088						
Dense Forest	64%	5176.236363	280	1449346.182	0.37	0.47	252041
Open Forest	36%	2911.632954	140	407628.6136	0.488	0.47	93494
						TOTAL	345535

Note:

1) For dense forest "Tropical Rain Forest", volume -4, table 4.7 Emission factor, IPCC 2006 was used
2) 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.
3) 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

Litter Carbon	Area in ha		EF (tonnes C ha-1)	Tonnes of C per year
Total deforestation per year	8088			
Desnse Forest	64%	5176.236363	2.1	10870
Open Forest	36%	2911.632954	2.1	6114
			TOTAL	16985

Removal from Reforestation (plantation)

Plantation - enhancement in Above Ground Biomass

Ecological Zone	Total Gain per year 945 ha	Area in ha		Above ground net biomass Growth (tonnes of d.m. per ha per year)	Total Biomass	CF	Tonnes of C
		% Area	Area under each plantation				
TMD forest	Teak (Asia)	32%	303	8	133115	0.47	62564
T R forest	Eucklyptus (Asia Euck.)	35%	331	5	90996	0.47	42768
T R forest	Pinus Caribaea (Asia Other)	17%	156	5	42898	0.47	20162
T R forest	Other Plantation (Asia Other)	17%	156	5	42898	0.47	20162
Total enhancement in above ground biomass in 10 years (Tonnes of C)							145656
Per year enhancement in above ground biomass (tonnes of C per year)							14566

Plantation - enhancement in Below Ground Biomass

Plantation enhancement in Below Ground BiomassEcological Zone	Total Gain per year (945 ha)	Area in ha		Above ground net biomass Growth (tonnes of d.m. per ha per year)	Root to Shoot Ratio	Total Biomass	CF	Tonnes of C
		% Area	Area under each plantation					
TMD forest	Teak (Asia)	32%	303	8	0.2	133115	0.47	12513
T R forest	Eucklyptus (Asia Euck.)	35%	331	5	0.37	90996	0.47	15824
T R forest	Pinus Caribaea (Asia Other)	17%	156	5	0.37	42898	0.47	7460
T R forest	Other Plantation (Asia Other)	17%	156	5	0.37	42898	0.47	7460
Total enhancement in below ground biomass in 10 years (Tonnes of C)								43257
Per year enhancement in below ground biomass (tonnes of C per year)								4326

Plantation - enhancement in litter carbon

Enhancement in plantation litter					
Ecological Zone	Above ground carbon	Area in ha		Growth in Litter Carbon (tonnes of C per ha per year)	Total Carbon in Litter Tonnes of C per year
	Total Gain per year	945	Area		
TMD forest	Teak	32%	303	0.1050	32
T R forest	Eucklyptus	35%	331	0.1050	35
T R forest	Pinus Caribaea	17%	156	0.1050	16
T R forest	Other Plantation	17%	156	0.1050	16
				Tonnes of C Per year	99