

Approved VCS Methodology  
VM0010

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Sectoral Scope 14

Methodology for Improved Forest  
Management: Conversion from  
Logged to Protected Forest



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**About GCS**

GreenCollar Consulting Solutions (GCS) is an environmental markets and project services consultancy with extensive experience in the development of agriculture, forestry and other land use (AFOLU) methodologies, policy and projects throughout Asia-Pacific. Our goal is to provide the tools and support services that will help land managers realize the full commercial potential of their environmental assets.

Our diverse work experience extends from agriculture and forest management methodology development and project development, to domestic and international policy advice. Our project experience includes work on some of the world's largest carbon forestry and agricultural projects and initiatives. GCS is based in Sydney and has strong strategic partnerships with firms in Europe, North America and Asia.

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## 1 SOURCES

- *VCS Program Guidelines 2007.1*
- *VCS Tool for AFOLU Methodological Issues*
- *VCS Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*
- *VCS methodology VM0007 REDD Methodology Modules (Avoided Deforestation Partners)*
- *VCS methodology VM0003 Methodology for Improved Forest Management through Extension of Rotation Age (Ecotrust)*
- *VCS methodology VM0005 Methodology for Conversion of Low-Productive Forests to High-Productive Forests (Silvestrum for Face the Future)*
- *Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination*
- *Tool for Calculation of the Number of Sample Plots for Measurements within A/R CDM Project Activities<sup>1</sup>*
- *Tool for testing significance of GHG emissions in A/R CDM project activities<sup>2</sup>*

Note – All VCS program documents and approved VCS methodologies referenced in this methodology are available on the VCS website.

## 2 SUMMARY DESCRIPTION

This Logged to Protected Forest (LtPF) methodology is designed as a detailed procedure enabling conservative estimation of net GHG emission reductions/removals resulting from the implementation of IFM projects aimed at the protection of forests that would be logged in the absence of carbon finance.

The core methodological components are as follows:

- *Eligibility*, sets the criteria for eligibility of projects under the proposed LtPF methodology;
- *Project Boundaries and Scope*, provides guidelines for defining the geographical and temporal boundaries of the project and lists the GHG emissions sources and carbon pools to be included in the project accounts;
- *Baseline Selection, Additionality and Baseline Modelling*, provides guidelines to select the most conservative baseline scenario and to determine the additionality of the proposed project activities against the baseline selected;
- *Baseline Scenario Greenhouse Gas Emissions*, provides the detailed procedure to develop conservative estimates of net greenhouse gas emissions resulting from changes in carbon stocks as a result of planned timber harvest in the baseline scenario;
- *Project Scenario Net Greenhouse Gas Emissions*, provides the detailed, procedure to develop conservative estimates of net greenhouse gas emissions resulting from changes in carbon stocks in the project scenario;
- *Project Leakage*, describes the methodology approach to account for leakage mechanisms arising from the implementation of project activities;
- *Net Project Greenhouse Gas Emission Reductions*, provides the methodological approach to determine the amount of net greenhouse gas emission reductions/removals at the end of each year for both the baseline and project scenarios;

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<sup>1</sup> [http://cdm.unfccc.int/methodologies/ARmethodologies/approved\\_ar.html](http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html)

<sup>2</sup> [http://cdm.unfccc.int/methodologies/ARmethodologies/approved\\_ar.html](http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html)

- *Project Verified Carbon Units*, provides the methodological approach to determine, on the basis of the amount of net greenhouse gas emission reductions/removals, and deductions to account for risk and uncertainty, the amount of carbon units that should be credited to the project each year over the project crediting period; and
- *Project Monitoring*, provides guidelines for the implementation of a monitoring plan and identifies monitored parameters to assess carbon stock change and disturbance in the project case.

Additionality	Project Method
Crediting Baseline	Project Method

### 3 DEFINITIONS

Project proponents must refer to the definitions found in the most recent version of the *VCS Program Definitions* document.

The definitions in Table 1 are specific to this methodology.

**Table 1: IFM-LtPF Methodology: Definitions**

Term	Definition
Commercial timber harvest	Removal of merchantable trees from a forest to obtain income from the wood products.
Diameter at Breast Height (DBH)	A common dendrometric measurement to determine the diameter of the bole of a tree at 1.3 meters.
Degradation	Refer to definition found in the latest version of VCS document <i>Program Definitions</i> .
Forest inventory	A system for measuring the extent, quantity, and condition of a forest by sampling through; <ul style="list-style-type: none"> <li>a) a set of objective sampling methods designed to quantify the spatial distribution, composition, and rates of change of forest parameters within specified levels of precision for the purpose of management;</li> <li>b) the listing of data from such a survey.</li> </ul>
Land parcel	The area of land within a forest specified for annual logging and timber extraction operations as defined in a timber

	harvest plan.
Logging slash	A component of the dead wood pool, representing the woody debris left in the forest estate that is generated during a timber harvest event.
Planned timber harvest	Planned removal of merchantable trees from a forest to obtain income from the wood products under legal conditions for harvest and documented under a timber harvest plan.
Timber harvest plan	<p>Description of the methods and operations needed to harvest timber from a forest under a given set of legal conditions for harvest, that includes;</p> <ul style="list-style-type: none"> <li>a) demarcation of non-harvest areas within the forest;</li> <li>b) division of the harvestable forest into annual operating areas (land parcels) presented as descriptions and maps;</li> <li>c) the design and presentation of the transport system for the removal of harvested timber products; and</li> <li>d) a description of the harvest and transport machinery used for timber harvest.</li> </ul>

### 3.1 Symbols and Notations

#### 3.1.1 Physical quantities

This section presents the symbols that are used throughout the methodology to represent physical quantities used in the accounting equations.

##### Flows of greenhouse gas(es)

The symbol GHG is the common identifier used throughout this methodology to represent flows of greenhouse gas(es) to/from the atmosphere.

For these flows, the absolute value represents the intensity of the flow, in tCO<sub>2</sub>e year<sup>-1</sup>, or the total amounts exchanged with the atmosphere, in tCO<sub>2</sub>e.

##### Carbon stocks

The symbol **C** is the common identifier used throughout this methodology to represent carbon stocks. The values presented are either carbon stocks (in tC), or carbon stocks per unit area (in tC·ha<sup>-1</sup>) as indicated in the methodology described under Section 2.

### Carbon stock changes

The symbol  $\Delta C$  is the common identifier used throughout this methodology to represent changes in carbon stocks. The values presented could be either total changes in carbon stocks (in tC), annual changes in carbon stocks (in tC·year<sup>-1</sup>), or annual changes in carbon stocks per unit area (in tC·ha<sup>-1</sup>·year<sup>-1</sup>), as indicated in the methodology described under Section 2.

#### 3.1.2 Scenario qualifiers

This section presents the symbols that are used throughout the methodology as scenario qualifiers, for the physical quantities used in the accounting equations.

- Physical quantities referring to the **baseline scenario** feature the suffix */BSL*;
- Physical quantities referring to the **project scenario** feature the suffix, */PRJ*; and
- Physical quantities derived from baseline and project scenario accounting feature the suffix */LTPF*

## 4 APPLICABILITY CONDITIONS

Projects must fall within the AFOLU project category “IFM Logged to Protected Forest” as defined in the most recent version of the VCS *AFOLU Requirements* document. Specific conditions under which this methodology is applicable are:

- Forest management in the baseline scenario must be planned timber harvest;
- Under the project scenario, forest use is limited to activities that do not result in commercial timber harvest or forest degradation;
- Planned timber harvest must be estimated using forest inventory methods that determine allowable offtake as volume of timber (m<sup>3</sup> ha<sup>-1</sup>);
- The boundaries of the forest land must be clearly defined and documented;
- Baseline condition cannot include conversion to managed plantations;
- Baseline scenario, project scenario and project case cannot include wetland or peatland.

### 4.1 Eligibility

#### Legal Right to Harvest

Legal right to harvest must pre-exist the implementation of the project.

The legal right to harvest must be issued by a relevant government body, define a legal allocation of rights to a forest timber resource, and include a plan for forest management that includes a definition of the spatial extent of the forest, the volume of the timber resource to be extracted and a description of harvesting practices.

Rights to forest management must be demonstrated by documentary proof of legal permissibility for timber harvest, intent to harvest and a description of the timber resource. This proof must be issued by the relevant (governmental) regulatory body that has designated, sanctioned or approved the project area (or areas) for forest management.



## Intent to Harvest

Project proponents must demonstrate intent to harvest through the following forms of evidence originating prior to the date of all evidence in pursuit of carbon finance/consideration of IFM.

Projects must provide either:

- Documented evidence demonstrating that:
  - The project site is representative of other forestlands harvested in the country within the past two years; and
  - The project site is within commercially viable distance to existing transport networks and a port for timber export or a mill for timber processing; or
- A valid and verifiable Government-approved timber management plan for harvesting the project area.

## **5 PROJECT BOUNDARY**

### **5.1 Geographical Boundaries**

Project proponents must clearly define the spatial boundaries of a project so as to facilitate accurate measuring, monitoring, accounting, and verifying of the project's emissions reductions and removals.

The IFM project activity may contain more than one discrete area of land.

When describing physical project boundaries, the following information must be provided per discrete area;

- name of the project area (including compartment number, allotment number, local name);
- unique identifier for each discrete land parcel used in the timber harvest plan;
- map(s) of the area (preferably in digital format);
- geographic coordinates of each polygon vertex (preferably obtained from a geodetic coordinate or from a geo-referenced digital map);
- total land area; and
- details of forest land rights holder and user rights.

The geographic boundaries of an IFM project are fixed and thus do not change over the project lifetime.

Following the VCS definition of market leakage the geographic boundaries for leakage from market effects are those of the country in which the project area occurs.

### **5.2 Temporal Boundaries**

The following temporal boundaries must be defined:

#### Start date and length of the project crediting period

The project crediting period is the period of time for which the net GHG emissions reductions or removals will be verified.

The project crediting period must be set in accordance with the VCS rules for IFM LTPF projects. The duration of the project crediting period must be reported in the VCS Project Description (VCS-PD).

### Duration of the monitoring periods

Issuance of Verified Carbon Units (VCUs) is subject to monitoring and verification. The minimum duration of a monitoring period is one year and the maximum duration is 10 years.

Project proponents are free to decide the periodicity of verifications, however, in accordance with the VCS rules, if verification does not occur within 5 years, 50% of the buffer account credits are placed on hold.

Baseline projections are calculated ex-ante and are not adjusted through-out the project lifetime.

### 5.3 Carbon Pools

The carbon pools included or excluded from the project boundary are shown in Table 2.

**Table 2: Carbon pools**

Carbon pools	Included/Optional/Excluded	Justification / Explanation of choice
Aboveground trees	Included	The stock change in the aboveground tree biomass must be estimated
Aboveground non-tree	Excluded	Exclusion is always conservative when forests remains as forest
Belowground	Excluded	Unlikely to change significantly in forests remaining as forests and is difficult to measure - omission is conservative
Dead wood (logging slash)	Included in the baseline	The dead wood (logging slash) carbon pool is expected to be larger in the baseline than in the project scenario, and therefore this pool must be included
Dead wood (naturally accumulated)	Excluded	Following IPCC guidelines <sup>3</sup> , it is assumed that carbon stocks in the naturally occurring dead wood pool (both standing and lying) are equivalent in both the project and baseline scenario, and therefore this pool is conservatively excluded. It is not conservative to account for this pool in the baseline scenario only.

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<sup>3</sup> IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 4 AFOLU, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

Harvested wood products	Included	Will be greater in baseline than project scenario and significant
Litter	Excluded	Insignificant and exclusion is conservative
Soil organic carbon	Excluded	Exclusion is always conservative when forests remains as forest

## 5.4 Greenhouse Gases

The emissions sources included in or excluded from the project boundary are shown in Table 3.

Any one of these sources must be neglected (ie, accounted as zero) if the application of the most recent version of the *CDM Tool for testing significance of GHG emissions in A/R CDM project activities* leads to the conclusion that the emission source is insignificant<sup>4</sup>. In addition, the sum of decreases in carbon pools and increases in emissions that may be neglected must be less than 5% of the total project GHG benefits .

**Table 3: Emission sources other than resulting from changes in stocks in carbon pools**

Gas	Sources	Included/Excluded	Justification/explanation of choice
Carbon dioxide (CO <sub>2</sub> )	Combustion of fossil fuels (in vehicles, machinery and equipment)	Excluded	Conservative as emissions will be greater in the baseline scenario than in the project case.
	Removal of herbaceous vegetation	Excluded	Based on CDM EB decision reflected in paragraph 11 of the report of the 23rd session of the board: <a href="http://cdm.unfccc.int/Panels/ar/023/ar_023_rep.pdf">cdm.unfccc.int/Panels/ar/023/ar_023_rep.pdf</a>
Methane (CH <sub>4</sub> )	Combustion of fossil fuels (in vehicles, machinery and equipment)	Excluded	Conservative as emissions will be greater in the baseline scenario than in the project case.
	Burning of Biomass	Included	Included as CO <sub>2</sub> equivalent emission

<sup>4</sup> [http://cdm.unfccc.int/methodologies/ARmethodologies/approved\\_ar.html](http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html)

Nitrous oxide (N <sub>2</sub> O)	Combustion of fossil fuels (in vehicles, machinery and equipment)	Excluded	Potential emissions are negligible
	Nitrogen based fertilizer	Excluded	Potential emissions are negligible.  Following the VCS update to the Tool for AFOLU Methodological Issues and Guidance for AFOLU Projects emissions through the use of fertilizer are considered insignificant and are not considered here.
	Burning of Biomass	Excluded	Potential emissions are negligible

## 6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

### 6.1 Selection of baseline

The project proponent must use the most current version of the VCS *Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities* to assess which of the baseline alternatives must be excluded from further consideration.

As per the applicability conditions, the project must demonstrate a baseline of planned timber harvest. If such a baseline cannot be demonstrated then this methodology cannot be applied.

Planned timber harvest events in the baseline scenario can occur in any year of the project activity, not just year 0.

### 6.2 Modelling the baseline scenario

Once the baseline scenario of planned timber harvest is demonstrated, project proponents must determine how to model the baseline management scenario. A Historical Baseline Scenario (Section 6.2.1) must be used where data is available, otherwise a Common Practice Baseline Scenario (Section 6.2.2) must be used.

#### 6.2.1 Historical Baseline Scenario

A baseline scenario and timber harvest plan (see Box 1) derived from the historical practices of the baseline agent of timber harvest must be modelled as the project baseline if the following documents exist for the project proponent as the baseline land manager for forests in the same region as the project area:

1. Historical records of forest management exist for a minimum of 5 or more years preceding the project start date.
2. Historical records indicate that the management practices have surpassed the legal requirements provided by conforming to all local and regional forest legislation.

3. Historical records that indicate that the historical management surpasses financial barriers by providing above average financial returns.

### 6.2.2 Common Practice Baseline Scenario

All other cases must model baseline harvest based on common practice.

Common practice will be timber harvest under the legal requirements for forest management and will be determined from a timber harvest plan (see Box 1) developed from:

1. The project area through scenario modelling as though the legal requirements were implemented in the project area; and
2. A reference area<sup>5</sup> (or multiple reference areas) already under timber harvest management that complies with legal requirements for forest management and selected to be representative of local common practice for timber harvest.

Common practice cannot contradict management of the baseline agent except where common practice represents a lower harvest intensity (in m<sup>3</sup>/ha) than management by the baseline agent.

Where there is limited capacity to generate the baseline scenario using a reference site in the region of the project area, multiple reference areas may be selected to cover a country so long as the reference area criteria regarding forest types, climate and elevation are met.

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<sup>5</sup> Reference areas must be in the same region as the project area and must match the project area in terms of forest types, climate and elevation (identical mix of forest types  $\pm 20\%$ ; identical annual precipitation  $\pm 20\%$ ; elevation classes (500m classes) in the reference region shall be in the same proportion as in the project area (+/- 20%))

<sup>6</sup> Species selected to be harvested in the forest management plan shall be subset of species commercially harvested in the region

### Box 1. Timber Harvest Plan

The description of harvesting in the form of a timber harvest plan forms the basis of the baseline scenario for greenhouse gas accounting.

The timber harvest plan describes the harvest of timber products and must:

- a) reference the forest volume inventory (see Section 8.1.1 – parameter  $V_{j,i|BSL}$ ) to identify the relative number of trees per hectare potentially available for harvest by species in each stratum;
- b) demarcate all non-harvest areas within the forest based on legally required exclusions for environmental features such as slope, swamp areas or conservation buffers;
- c) divide the harvestable forest into annual operating areas (referred to throughout this methodology as *land parcels*) using common practice;
- d) include a design and presentation of the transport system to move harvested timber products from the land parcels to downstream processing or market entry points; and
- e) list necessary harvest and transport machinery.

The timber harvest plan must follow local best practice for timber harvest and the timber resource volume and extraction quotas defined in the legal requirements.

For the purpose of estimating the net annual changes in carbon stocks resulting from planned timber harvest in the baseline scenario a detailed *planned timber harvesting schedule* will be developed from the timber harvest plan, spelling out details of harvest for each land parcel in the project area in terms of the following:

- a) the species to be harvested<sup>5</sup>;
- b) the year (1,2,3...) in which timber harvest of each land parcel is scheduled to occur;
- c) the number of years each land parcel is in a post-harvest state during the project crediting period;
- d) the maximum and minimum diameters at breast height (DBH), at stump and at top for tree harvesting;
- e) the planned harvesting regime (clearfelling, specie/stratum-selective logging, area-selective logging);
- f) technical specifications for the categories of wood products to be harvested; and
- g) the total volumes or fractions to be harvested, broken down by categories of wood products defined as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other.

The planned timber harvest schedule is determined *ex ante* to reflect the timber harvesting plan as stipulated in the legal right to harvest. The *planned timber harvesting schedule* will be developed for the Project Area to include all land parcels within the project boundary for the proposed IFM activity.

The output of the timber harvest plan shall be the mean extracted volume per unit area by species in each stratum in each year ( $VEX_{j,i|BSL}$ ).

The planned timber harvesting schedule will be submitted by project proponents as part of the VCS-PD.

### 6.3 Stratification

If the proposed project area contains different forest types or forests with different carbon density, stratification must be carried out in order to improve the accuracy and precision of carbon stock estimates.

For estimation of base year carbon stocks, strata must be defined on the basis of parameters that are key variables in any method used to estimate changes in managed forest carbon stocks. Strata will include either forest type, vegetation type and/or target timber species.

Based on the availability of data regarding the nature and composition of forest stocks in the project area, stratification will be developed on the basis of either:

- a) existing vegetation mapping or stratification, where these are documented in the legal right to harvest; or
- b) estimates developed from sampling the project area using standard forest assessment protocols specific to the forest region where the project area is located.

Baseline stratification is developed *ex ante*.

Project proponents must submit as part of the VCS-PD a detailed description of the stratification adopted for the project area.

## 7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

The project proponent must demonstrate the additionality of the project using the most recent version of the *VCS Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*.

## 8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

### 8.1 Baseline Emissions

Calculation of baseline scenario greenhouse gas emissions requires the application of the equations presented in this section to complete the greenhouse gas accounts for all land parcels in the baseline case.

The following table lists the baseline emissions modelled by this methodology:

<b>Included in modelling</b>
Emission from wood product conversion
Decomposition of dead wood from harvested trees
Emissions from wood product retirement
Stock change due to regrowth following timber harvest
<b>Conservatively excluded from modelling</b>
Decomposition of trees incidentally killed during tree felling
Decomposition of trees killed through skid trail creation
Decomposition of trees killed through road construction
Emissions through fossil fuels burned in baseline harvesting practices
Emissions through subsequent forest re-entry

Baseline projections are calculated ex-ante and are not adjusted throughout the project lifetime.

The baseline net greenhouse gas emissions are determined from calculation of dead wood (logging slash) generated in the process of timber harvest (Section 8.1.2), the emissions resulting from production and subsequent retirement of wood products derived from the timber harvesting (Section 8.1.3), minus the rates of forest regrowth post timber harvest (Section 8.1.4).

Baseline commercial timber volumes must be derived for development of the timber harvest plan and for ex-post accounting of emissions resulting from natural forest disturbance.

The equations calculate the total emissions across the project crediting period for each emission source. Total emissions are averaged across the project crediting period to give annual emissions and are multiplied by  $t^*$ , time elapsed since the start of project activity. Ex-post,  $t^*$  is updated so baseline projections are available for each proposed future verification date.

Data for input into these carbon stock change calculations for the baseline scenario must be established from the same data used to create the timber harvesting plan.

### **8.1.1 Calculation of carbon stocks in commercial timber volumes**

This section calculates  $C_{HB,j,i|BSL}$ , the mean carbon stock in total harvested biomass in  $tC \cdot ha^{-1}$  and  $C_{EX,j,i|BSL}$ , the mean carbon stock in extracted timber (merchantable timber that leaves the forest) in  $tC \cdot ha^{-1}$ .

The following calculation of merchantable volume of timber per unit area ( $V_{j,i|BSL}$ ) that is potentially available for harvest must be based on data from field measurements in sample plots.



It is acceptable to use pre-existing forest inventory data<sup>7</sup> for this purpose, provided that the pre-existing data;

- a) represents the project strata;
- b) is not more than 10 years old; and
- c) where forest inventory data is more than 10 years old, that the volume estimate derived from the pre-existing data has been validated with limited sampling within the project area.

Validation of pre-existing forest inventory data must be carried out by field surveys. For each strata, mean volume is estimated from sample plots/points measured within the project area using standard forest inventory assessment methods. The number of sample plots will be determined from application of the most recent version of the *Tool for Calculation of the Number of Sample Plots for Measurements within A/R CDM Project Activities*<sup>8</sup>.

If the validated estimate of volume is within the 90% confidence interval of the corresponding estimate or is greater than the estimate calculated from pre-existing forest inventory data, the pre-existing forest inventory data may be used. If the validation estimate is less than the corresponding estimate calculated from pre-existing forest inventory data, the estimate from pre-existing data cannot be used.

Estimation of the merchantable volume of trees must be based on locally derived allometric equations or yield tables. If locally derived equations or yield tables for each species are not available it is acceptable to use relevant regional, national or default data.

Yield tables or allometric equations must be used to convert field measurements of diameter (DBH, at typically 1.3 m [4.3 ft] aboveground level or above buttress where they exist), and total height H of each tree in the sample plots to merchantable volume,  $V_{l,j,i,sp}$ .

It is acceptable to combine DBH and allometric equations if field instruments (eg, a relascope) that measure the volume of each tree directly have been used.

The estimate of merchantable volume for each species  $j$  at the sample plot level will be calculated as:

$$V_{j,i,sp} = \sum_{l=1}^L V_{l,j,i,sp} \quad (1)$$

Where:

$V_{j,i,sp}$	merchantable volume for species $j$ in stratum $i$ in sample plot $sp$ , $m^3$ ;
$V_{l,j,i,sp}$	merchantable volume for tree $l$ of species $j$ in stratum $i$ in sample plot $sp$ ; $m^3$ <sup>9</sup>
$l$	1, 2, 3 ... $L$ sequence of individual trees in sample plot;

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<sup>7</sup> Standard quality control / quality assurance procedures for forest inventory including field data collection and data management shall have been applied to the forest inventory assessment. Sampling data and methods shall be available for verification. Sample sizes shall have been sufficient to ensure inventory estimates are within the 95% confidence intervals with the estimated variance within +/- 15 percent from the mean.

<sup>8</sup> [http://cdm.unfccc.int/methodologies/ARmethodologies/approved\\_ar.html](http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html)

<sup>9</sup> See Data and parameters not monitored (default or possibly measured one time) list for information on data selection (p 51).

$i$	1, 2, 3 ... $M$ strata;
$sp$	1, 2, 3 ... $SP$ sample plots; and
$j$	1, 2, 3 ... $J$ tree species.

Therefore, the merchantable volume per unit area of species  $j$  in stratum  $i$  will be calculated as the mean merchantable volume in all sample plots in stratum  $i$ :

$$V_{j,i|BSL} = \frac{1}{SP} * \sum_{sp=1}^{SP} \frac{V_{j,i,sp}}{A_{sp}} \quad (2)$$

Where:

$V_{j,i BSL}$	mean merchantable volume per unit area of species $j$ in stratum $i$ in the baseline scenario, $m^3 \cdot ha^{-1}$ ;
$V_{j,i,sp}$	merchantable volume for species $j$ in stratum $i$ in sample plot $sp$ ; $m^3$ ;
$A_{sp}$	area of sample plot $sp$ , ha; <sup>10</sup>
$i$	1, 2, 3 ... $M$ strata;
$sp$	1, 2, 3 ... $SP$ sample plots; and
$j$	1, 2, 3 ... $J$ tree species.

$V_{j,i|BSL}$  will be used to develop the timber harvest plan (Box 1). The timber harvest plan sets the allowable mean extracted volume ( $V_{EX,j,i|BSL}$ ) from this merchantable volume based on legal limits.

Once the timber harvest plan is complete and  $V_{EX,j,i|BSL}$  is calculated the Biomass Conversion and Expansion Factors (BCEF) method<sup>11,12</sup> must be used to determine the carbon stock in harvested biomass.

This method is appropriate as forest inventory data and allowable harvest must be based on volume estimates to which expansion factors can be readily applied. The selected BCEF must have a minimum DBH compatible with the minimum DBH defined in the timber harvest plan (Box 1).

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<sup>10</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

<sup>11</sup> Somogyi, Z., E. Cienciala, R. Mäkipää, P. Muukkonen, A. Lehtonen and P. Weiss. (2006) Indirect methods of large-scale forest biomass estimation, Eur. J. Forest Res. 126 (2) pp. 197–207. <http://dx.doi.org/10.1007/s10342-006-0125-7>.

<sup>12</sup> IPCC. (2006) IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. In: Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.). IGES, Japan. <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>.

Therefore, the carbon stock of timber harvested per unit area for species  $j$  in stratum  $i$  will be calculated from this mean volume of extracted timber:

$$C_{HB,j,i|BSL} = V_{EX,j,i|BSL} * BCEF_R * CF_j \quad (3)$$

Where:

$C_{HB,j,i BSL}$	mean carbon stock of harvested biomass per unit area for species $j$ in stratum $i$ , tC·ha <sup>-1</sup> ;
$V_{EX,j,i BSL}$	mean volume of extracted timber per unit area for species $j$ in stratum $i$ , m <sup>3</sup> ·ha <sup>-1</sup> ;
$BCEF_R$	biomass conversion and expansion factor applicable to wood removals in the project area, t.d.m m <sup>-3</sup> ; <sup>13</sup>
$CF_j$	carbon fraction of biomass for species $j$ , tC t d.m. <sup>-1</sup> ; <sup>14</sup>
$i$	1, 2, 3 ... $M$ strata; and
$j$	1, 2, 3 ... $J$ tree species.

Not all of the harvested biomass leaves the forest because the timber harvested has two components: 1) wood removed to market (extracted timber) and, 2) wood remaining in the forest as a result of harvest (see Section 8.1.2).

Therefore, the mean carbon stock of extracted timber per unit area for species  $j$  in stratum  $i$  will be calculated from the mean volume of extracted timber multiplied by density and carbon fractions:

$$C_{EX,j,i|BSL} = V_{EX,j,i|BSL} * D_j * CF_j \quad (4)$$

Where:

$C_{EX,j,i BSL}$	mean carbon stock of extracted timber per unit area for species $j$ in stratum $i$ ; tC·ha <sup>-1</sup> ;
$V_{EX,j,i BSL}$	mean volume of extracted timber per unit area for species $j$ in stratum $i$ ; in m <sup>3</sup> ·ha <sup>-1</sup> ;
$D_j$	basic wood density of species $j$ ; t d.m. m <sup>-3</sup> ; <sup>15</sup>

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<sup>13</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 47).

<sup>14</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 47).

$CF_j$	carbon fraction of biomass for species $j$ , tC t d.m. <sup>-1</sup> ;
$i$	1, 2, 3 ... $M$ strata; and
$j$	1, 2, 3 ... $J$ tree species.

### 8.1.2 Calculation of dead wood (logging slash) generated in the process of timber harvest

This section calculates  $\Delta C_{DWSLASH,i,p|BSL}$ , the change in carbon stock in dead wood (ie, logging slash) left on the forest floor following timber harvest in stratum  $i$  in land parcel  $p$ , using  $C_{EX,j,i|BSL}$  and  $C_{HB,j,i|BSL}$  as calculated in Section 8.1.1.

The simplifying assumption is made that dead wood left on the forest floor following timber harvest follows a ten year linear decay function, as permitted by the *VCS AFOLU Requirements*. This decay function is applied when the net greenhouse gas emissions/removals are calculated on an annual basis in equations 11 and 12.

Therefore, the change in carbon stock in the dead wood pool in stratum  $i$  in land parcel  $p$  is calculated as the difference between the total carbon stock of the harvested biomass and the carbon stock of the extracted timber:

$$\Delta C_{DWSLASH,i,p|BSL} = \left[ \sum_{j=1}^J (C_{HB,j,i|BSL} - C_{EX,j,i|BSL}) \right] \quad (5)$$

Where:

$\Delta C_{DWSLASH,i,p BSL}$	change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum $i$ in land parcel $p$ , in tC ha <sup>-1</sup> ;
$C_{HB,j,i BSL}$	mean carbon stock of harvested biomass per unit area for species $j$ in stratum $i$ , tC·ha <sup>-1</sup> ;
$C_{EX,j,i BSL}$	mean carbon stock of extracted timber per unit area for species $j$ in stratum $i$ , tC·ha <sup>-1</sup> ;
$i$	1, 2, 3 ... $M$ strata; and
$j$	1, 2, 3 ... $J$ tree species.
$P$	1, 2, 3 ... $P$ land parcels.

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<sup>15</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

### 8.1.3 Calculation of baseline carbon sequestered in wood products

This section calculates the net carbon stock change resulting from wood product conversion and retirement.

In all cases where wood is harvested for conversion to wood products, carbon stock in the wood products pool must be included in the baseline case.

Carbon stocks treated here are those stocks entering the wood products pool at the time of harvest.

All factors are derived from Winjum *et al* (1998).

The carbon stock of extracted timber across species is calculated as:

$$C_{EX,i|BSL} = \sum_{j=1}^J C_{EX,j,i|BSL} \quad (6)$$

Where:

$C_{EX,i BSL}$	change in carbon stock of extracted wood products resulting from timber harvest per unit area in stratum $i$ in land parcel $p$ , in tC ha <sup>-1</sup> ;
$C_{EX,j,i BSL}$	Mean carbon stock of extracted wood per hectare, tC/ha;
$i$	1, 2, 3 ... $M$ strata; and
$j$	1, 2, 3 ... $J$ tree species.

The wood product class(es),  $k$ , (sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other) that are the anticipated end use of the extracted timber must now be selected. It is acceptable practice to assign gross percentages of volume extracted to wood product classes on the basis of local expert knowledge of harvest activities and markets.

In accordance with the *VCS AFOLU Requirements*, the amount of carbon stored in wood products that would decay within 3 years after harvest (ie, the Wood Waste (WW) and the Short Lived Fraction (SLF)), are assumed to be emitted at the time of harvest.

Wood products that are retired between 3 and 100 years after harvest (ie, the Additional Oxidised Fraction, OF), must be accounted according to a 20 year linear decay function. This decay function is applied when the net greenhouse gas emissions/removals are calculated on an annual basis in equations 11 and 12.

All other wood product pools are considered to permanently store carbon.

Therefore, the carbon stock of extracted timber that is immediately emitted to the atmosphere at the time of harvest is calculated as:

$$C_{WPO,i|BSL} = \sum_k C_{EX,i,k|BSL} * (WW_k + SLF_k) \quad (7)$$

Where:

$C_{WPO,i BSL}$	carbon stock of extracted timber from stratum $i$ that is assumed to be emitted immediately at the time of harvest, in $tC \cdot ha^{-1}$ ;
$C_{EX,i BSL}$	mean carbon stock of extracted timber per unit area in stratum $i$ , for wood product type $k$ , $tC \cdot ha^{-1}$ ;
$WW_k$	fraction of biomass carbon from wood waste that is assumed to be emitted to the atmosphere immediately at the time of harvest for wood product $k$ , dimensionless; <sup>16</sup>
$SLF_k$	fraction of biomass carbon from the short lived wood product pool that is assumed to be emitted to the atmosphere immediately at the time of harvest for wood product $k$ , dimensionless
$i$	1, 2, 3 ... $M$ strata; and
$k$	Wood products (sawnwood, wood base products, etc)

The amount of extracted carbon stock that is assumed to enter the wood products pool that is not immediately emitted at harvest is calculated as per equation 8 below:

$$C_{WPI|BSL} = \sum_k C_{EX,i,k|BSL} - C_{WPO,i|BSL} \quad (8)$$

Where:

$C_{WP,i BSL}$	carbon stock of extracted timber from stratum $i$ that is assumed to enter the wood products pool that is not immediately emitted at the time of harvest, in $tC \cdot ha^{-1}$ ;
$C_{EX,i BSL}$	mean carbon stock of extracted timber per unit area in stratum $i$ , for wood product type $k$ , $tC \cdot ha^{-1}$ ;
$C_{WPO,i BSL}$	carbon stock of extracted timber from stratum $i$ that is assumed to be emitted immediately at the time of harvest, in $tC \cdot ha^{-1}$ ;
$i$	1, 2, 3 ... $M$ strata; and
$k$	Wood products (sawnwood, wood base products, etc)

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<sup>16</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

Therefore, the carbon stock of wood products assumed to be retired between 3-100 years following harvest is calculated as:

$$C_{WP100,i|BSL} = C_{WP,i|BSL} * OF_k \quad (9)$$

Where:

$C_{WP100,i,p BSL}$	Amount of carbon stored in wood products that are assumed to be retired between 3 - 100 years after harvest from stratum $i$ in land parcel $p$ , tC ha <sup>-1</sup> ;
$C_{WP,i BSL}$	carbon stock of extracted timber from stratum $i$ that is assumed to enter the wood products pool that is not immediately emitted at the time of harvest, in tC·ha <sup>-1</sup> ;
$OF_k$	fraction of biomass carbon for wood product type $k$ that is assumed to be emitted to the atmosphere between 3 and 100 years of timber harvest, dimensionless; <sup>17</sup> and
$i$	1, 2, 3 ... $M$ strata.

#### 8.1.4 Change in carbon stocks due to forest regrowth after harvest

This section calculates  $\Delta C_{RG,i,p|BSL}$ , the carbon sequestration resulting from forest regrowth after timber harvest in stratum  $i$  in land parcel  $p$ ; tC.

The carbon sequestration in the baseline resulting from forest regrowth after timber harvest up to year  $t$  is equal to the forest regrowth rate of each stratum.

Therefore, carbon sequestration resulting from forest regrowth after timber harvest is calculated as:

$$C_{RG,i,p|BSL} = \sum_i RGR_i \quad (10)$$

Where:

$C_{RG,i,p BSL}$	carbon sequestration resulting from forest regrowth after timber harvest in stratum $i$ in land parcel $p$ , tC□ha <sup>-1</sup> yr <sup>-1</sup> ;
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<sup>17</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

RGR <sub>i</sub>	regrowth rate of forest post timber harvest for stratum <i>i</i> , tC□ha <sup>-1</sup> yr <sup>-1</sup> ; <sup>18</sup>
<i>i</i>	1, 2, 3 ... <i>M</i> strata

### 8.1.5 Calculation of baseline scenario greenhouse gas emissions from change in carbon stocks

This section calculates  $GHG_{NET|BSL}$ , the net greenhouse gas emissions in the baseline scenario, in tCO<sub>2</sub>e.

The net carbon stock change to be converted to emissions is equal to the carbon stock change as a result of timber harvest plus the carbon stock change resulting from conversion and retirement of wood products minus carbon sequestration from forest regrowth after harvest.

In order to generate the annual carbon stock change in the baseline scenario, the total net change in carbon stocks for parcels within is multiplied by the area of forest in the particular age class (ie, years since harvest in the baseline).

The annualized calculations vary between years 1, 2-10; 11-20; and all years since the start of the project activity, depending on which decay functions apply.

Therefore, the net change in carbon stock from wood products and logging slash across all parcels within the **first year of harvest** in the baseline is calculated as:

$$\Delta C_{NET|BSL(1)} = \sum_{i,p} A_{1,i,p} * \sum_{i=1}^M (C_{DWSLASH,i,p\backslash BSL}/10) + C_{WP0,i,p\backslash BSL} + (C_{WP100,i,p\backslash BSL}/20) \quad (11)$$

Where:

$\Delta C_{NET BSL(1)}$	net change in carbon stock across all parcels in the baseline scenario in the first year since harvest in the baseline scenario, in tC;
$\Delta C_{DWSLASH,i,p\backslash BSL}$	change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum <i>i</i> in land parcel <i>p</i> , in tC ha <sup>-1</sup> ;
$\Delta C_{WP0,i,p\backslash BSL}$	change in carbon stock resulting from wood product conversion and retirement from stratum <i>i</i> in land parcel <i>p</i> , that is assumed to be emitted in the first year of harvest in the baseline tC ha <sup>-1</sup> ;
$\Delta C_{WP100,i,p\backslash BSL}$	Amount of carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum <i>i</i> in land parcel <i>p</i> , tC ha <sup>-1</sup> ;
$A_{1,i,p}$	the area of stratum <i>i</i> in land parcel <i>p</i> that was harvested 1 year ago, ha; <sup>19</sup>

<sup>18</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

<sup>19</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).



- $i$  1, 2, 3 ...  $M$  strata; and  
 $p$  1, 2, 3 ...  $P$  land parcels harvested within the project crediting period.

The net change in carbon stock from wood products and logging slash across all parcels the **years 2 – 10** since harvest in the baseline are calculated as:

$$\Delta C_{NET|BSL(2-10)} = \sum_{i,p} A_{2-10,i,p} * \sum_{i=1}^M ((\Delta C_{DWSLASH,i,p\backslash BSL}/10) + (\Delta C_{WP100,i,p\backslash BSL}/20)) \quad (12)$$

Where:

- $\Delta C_{NET|BSL(2-10)}$  net change in carbon stock across all parcels in the baseline scenario in years 2 - 10 since harvest in the baseline scenario, in tC;
- $\Delta C_{DWSLASH,i,p\backslash BSL}$  change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum  $i$  in land parcel  $p$ , in tC ha-1;
- $\Delta C_{WP100,i,p\backslash BSL}$  Amount of carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum  $i$  in land parcel  $p$ , tC ha-1;
- $A_{2-10,i,p}$  the area of stratum  $i$  in land parcel  $p$  that was harvested between 2 and 10 year ago, ha;<sup>20</sup>
- $i$  1, 2, 3 ...  $M$  strata; and  
 $p$  1, 2, 3 ...  $P$  land parcels harvested within the project crediting period.

The net change in carbon stock from wood products across all parcels the **years 11 – 20** since harvest in the baseline are calculated as per equation 13 below. Note that there will be no more emissions quantified from decay of logging slash in these parcels.

$$\Delta C_{NET|BSL(11-20)} = \sum_{i,p} A_{11-20,i,p} * \sum_{i=1}^M (\Delta C_{WP100,i,p\backslash BSL}/20) \quad (13)$$

Where:

- $\Delta C_{NET|BSL(11-20)}$  net change in carbon stock across all parcels in the baseline scenario in years 11 - 20 since the start of the project activity, in tC;

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<sup>20</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

$\Delta C_{WP100,i,p\backslash BSL}$	Amount of carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum $i$ in land parcel $p$ , tC ha <sup>-1</sup> ;
$A_{11-20,i,p}$	the area of stratum $i$ in land parcel $p$ that was harvested between 11 and 20 years ago, ha; <sup>21</sup>
$i$	1, 2, 3 ... $M$ strata; and
$p$	1, 2, 3 ... $P$ land parcels harvested within the project crediting period.

The net change (sequestration) in carbon stock due to forest regrowth across all parcels in all years since harvest in the baseline scenario are calculated according to equation 14 below. Note that there will be no more emissions quantified from decay of logging slash or wood products.

$$\Delta C_{NET|BSL(1+)} = \sum_{i,p} A_{t^*} * \sum_{i=1}^M (-\Delta C_{RG,i,p\backslash BSL}) \quad (14)$$

Where:

$\Delta C_{NET BSL(1+)}$	net change in carbon stock due to forest regrowth in all parcels that have been harvested in the baseline scenario, in tC;
$\Delta C_{RG,i,p\backslash BSL}$	carbon sequestration resulting from forest regrowth after timber harvest in stratum $i$ in land parcel $p$ , tC ha <sup>-1</sup> ;
$A_{t^*}$	Cumulative area harvested until time $t^*$ , ha; <sup>22</sup>
$t^*$	1, 2, ..., 10, time elapsed since the start of the project, in years;
$i$	1, 2, 3 ... $M$ strata; and
$p$	1, 2, 3 ... $P$ land parcels harvested within the project crediting period.

Therefore, net change in carbon stock across all parcels harvested over each year of the project crediting period in the baseline scenario since the start of the project activity is calculated as:

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<sup>21</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

<sup>22</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection.

$$\Delta C_{NET|BSL,t^*} = \sum_{p=1}^P \Delta C_{NET,p|BSL(1)} + \Delta C_{NET,p|BSL(2-10)} + \Delta C_{NET,p|BSL(11-20)} + \Delta C_{NET,p|BSL(1+)} \quad (15)$$

Where:

$\Delta C_{NET BSL,t^*}$	net change in carbon stock across all parcels in the baseline scenario in the year $t^*$ since the start of the project activity, in tC;
$\Delta C_{NET,p BSL(1)}$	net change in carbon stock in the baseline scenario for all parcels $p$ that are within 1 year of harvest in the baseline scenario, in tC;
$\Delta C_{NET,p BSL(2-10)}$	net change in carbon stock in the baseline scenario for all parcels $p$ , that were harvested between 2 – 10 years ago in the baseline scenario, in tC;
$\Delta C_{NET,p BSL(11-20)}$	net change in carbon stock in the baseline scenario in parcel $p$ , that were harvested between 11 – 20 years ago in the baseline scenario, in tC;
$\Delta C_{NET,p BSL(1+)}$	net change in carbon stock due to forest growth in the baseline scenario for all parcels $p$ that have been harvested in the baseline scenario, in tC;
$t^*$	time elapsed since the start of the project, in years; and
$p$	1, 2, 3 ... $P$ land parcels harvested within the project crediting period.

The net carbon stock change in the baseline scenario must be converted to net greenhouse gas emissions and is calculated as:

$$GHG_{NET|BSL,t^*} = \Delta C_{NET|BSL,t^*} * \frac{44}{12} \quad (16)$$

Where:

$GHG_{NET BSL,t^*}$	net greenhouse gas emissions in the baseline scenario in the year $t^*$ since the start of the project activity, tCO <sub>2</sub> e;
$\Delta C_{NET BSL}$	net change in carbon stock across all parcels in the baseline scenario in the year $t^*$ since the start of the project activity, tC; and
44/12	ratio of molecular weights of carbon dioxide and carbon, tCO <sub>2</sub> -e tC <sup>-1</sup> .

## 8.2 Project Emissions

This section calculates  $GHG_{NET|PRJ}$ , the net greenhouse gas emissions in the project scenario, in tCO<sub>2</sub>e.

Greenhouse gas emissions from Improved Forest Management (IFM) activities implemented in the project scenario must be accounted subject to application of the de minimis rule, as prescribed by the VCS *AFOLU Requirements*.

The type and extent of the activities implemented in the project scenario will be described by the project proponents as part of the documentation submitted with the VCS-PD.

In accordance with the applicability conditions, the project scenario does not allow commercial timber harvest. As a result, carbon stock changes due to vegetation management and fuel removal will be negligible.

Thus net greenhouse gas emissions in the project scenario will be equal to carbon sequestration through ongoing forest growth minus any emissions resulting from forest disturbance (both illegal logging and natural disturbances).

Ex-ante and ex-post estimations of natural disturbance for the project scenario must be estimated following Section 8.2.2.1.<sup>23</sup>

The potential for illegal extraction of trees from the project area must be assessed ex-ante and ex-post through a participatory rural appraisal (PRA) of the communities in and surrounding the project area following Section 8.2.2.2a.<sup>24</sup>

At all subsequent verifications, data collected for monitored parameters for natural disturbance and illegal logging must be included using the equations given at Sections 8.2.2 and 8.2.3 below.

It is not a requirement of this methodology for project proponents to estimate carbon stock change from forest growth in the project scenario of undisturbed forest.

However, where project proponents choose to determine stock change from forest growth in the project scenario a detailed sampling plan must be provided in the VCS-PD and follow the equations in Section 8.2.1 below.

### 8.2.1 Ongoing forest growth in the project scenario

This section calculates  $\Delta C_{AB,t|PRJ}$  annual carbon stock change in aboveground biomass of trees in the project scenario, in tCO<sub>2</sub>e.

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<sup>23</sup> *Ex ante* estimations of areas burned and naturally disturbed shall be based on historic incidence of fire and natural disturbance in the Project region.

<sup>24</sup> If the belief is that zero illegal logging will occur within the project boundaries then ex-ante this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.

### 8.2.1.1. Allometry

Select or develop an appropriate allometric equation for forest type/group of species  $j$  (eg, tropical humid forest or tropical dry forest) or for each species or family  $j$  (group of species) found in the inventory (hereafter referred to as species group) that converts tree dimensions from field timber inventories on sample plots to aboveground biomass of trees.

Equation selection or development must follow the criteria described for  $f_j(X, Y \dots)$ , the aboveground biomass of trees based on allometric equation for species group  $j$  based on measured tree variable(s), in the parameters section below.

### 8.2.1.2. Measurements

Only the individual trees, species and strata which were to be harvested in the baseline scenario are to be measured. The tree dimensions and minimum diameter at breast height (DBH) specified by the selected allometric equation in Section 8.2.1.1 must apply to these trees.

Any minimum values employed in inventories are held constant for the duration of the project.

### 8.2.1.3. Determining Sample Plot Carbon Stocks

The carbon stock in aboveground biomass for each individual tree of species group  $j$  in the sample plot located in stratum  $i$  will be estimated using the selected or developed allometric equation applied to the tree dimensions resulting from Section 8.2.1.2.

Therefore, the sum of the carbon stock in each sample plot will be calculated as:

$$C_{AB,j,i,t,sp|PRJ} = \sum_{l=1}^{L_{j,i,sp,t}} f_j(X, Y \dots) * CF \quad (17)$$

Where

$C_{AB,j,i,t,sp PRJ}$	carbon stock in aboveground biomass of trees of species $j$ in plot $sp$ in stratum $i$ at time $t$ in the project scenario, tC
$CF_j$	carbon fraction of biomass for tree group $j$ , tC t d.m. <sup>-1</sup> ; <sup>25</sup>
$f_j(X, Y \dots)$	aboveground biomass of trees based on allometric equation for species group $j$ based on measured tree variable(s), t. d.m. tree <sup>-1</sup> ; <sup>26</sup>
$i$	1, 2, 3, ...M strata;

<sup>25</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

<sup>26</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

$j$	$1, 2, 3 \dots J$ tree species;
$l$	$1, 2, 3, \dots L_{j,i,t,sp}$ sequence number of individual trees of species group $j$ in stratum $i$ at time $t$ in sample plot $sp$ ;
$t$	$0, 1, 2, 3, \dots t^*$ years elapsed since start of the project activity; and
$sp$	$1, 2, 3 \dots SP$ sample plots.

#### 8.2.1.4. Determining Stratum Carbon Stocks

The total carbon stock in the aboveground biomass of all trees present in sample plot  $sp$  in stratum  $i$  at time  $t$ , must be calculated as:

$$C_{AB,i,t,sp|PRJ} = \sum_{j=1}^J C_{AB,j,i,t,sp|PRJ} \quad (18)$$

Where:

$C_{AB,i,t,sp PRJ}$	aboveground biomass carbon stock of all trees of stratum $i$ at time $t$ in sample plot $sp$ in the project scenario, tC;
$C_{AB,j,i,t,sp PRJ}$	carbon stock in aboveground biomass of trees of species $j$ in stratum $i$ at time $t$ in plot $sp$ in the project scenario, tC;
$i$	$1, 2, 3, \dots M$ strata;
$j$	$1, 2, 3 \dots J$ tree species; and
$t$	$0, 1, 2, 3, \dots t^*$ years elapsed since start of the project activity.

#### 8.2.1.5. Determining Mean Carbon Stocks

Therefore, the mean carbon stock in aboveground biomass for each stratum per unit area is calculated as:

$$C_{AB,i,t|PRJ} = \frac{1}{SP} * \sum_{sp=1}^{SP} \left( \frac{C_{AB,i,t,sp|PRJ}}{A_{sp}} \right) \quad (19)$$

Where:

$C_{AB,i,t PRJ}$	mean aboveground biomass carbon stock of trees in stratum $i$ at time $t$ , tC□ha <sup>-1</sup> ;
$C_{AB,i,t,sp PRJ}$	aboveground biomass carbon stock of trees in stratum $i$ at time $t$ in sample plot $sp$ , tC;

Asp	area of sample plot $sp$ , ha; <sup>27</sup>
sp	1, 2, 3 ... $SP$ sample plots;
i	1, 2, 3 ... $M$ strata; and
t	0, 1, 2, 3 ... $t^*$ years elapsed since the start of the project activity.

### 8.2.1.6. Determining Carbon Stock Changes

The annual carbon stock change in aboveground biomass of trees in year  $t$  is the difference in mean carbon stock in aboveground biomass between sampling events and, when expressed in tCO<sub>2</sub>e, is calculated as:

$$\Delta C_{AB,t|PRJ} = \left( \sum_{i=1}^M \left( A_i * \frac{C_{AB,i,t2|PRJ} - C_{AB,i,t1|PRJ}}{T} \right) \right) * \frac{44}{12} \quad (20)$$

Where:

$\Delta C_{AB,t PRJ}$	annual carbon stock change in aboveground biomass of trees in year $t$ , tCO <sub>2</sub> e yr <sup>-1</sup> ;
$C_{AB,i,t PRJ}$	mean aboveground biomass carbon stock of trees in stratum $i$ at time $t$ , tC ha <sup>-1</sup> ;
$A_i$	area covered by stratum $i$ , ha;
sp	1, 2, 3 ... $SP$ sample plots;
T	number of years between monitoring time $t1$ and $t2$ ( $T = t2 - t1$ ); years;
i	1, 2, 3 ... $M$ strata;
t	1, 2, 3 ... $t^*$ years elapsed since the start of the project activity; and
44/12	ratio of molecular weights of carbon dioxide and carbon, tCO <sub>2</sub> e tC <sup>-1</sup> .

The carbon stock change in aboveground biomass of trees ( $\Delta C_{AB,t|PRJ}$ ) is the output of this section and is necessary to calculate net greenhouse gas emissions in the project scenario.

### 8.2.2 Forest disturbance in the project scenario

This section calculates  $\Delta C_{DIST\_FR,t|PRJ}$ , carbon stock change due to fire disturbance in the project scenario; tCO<sub>2</sub>-e,  $\Delta C_{DIST\_NFR,t|PRJ}$ , carbon stock change due to non-fire natural disturbance in the project scenario; tCO<sub>2</sub>-e

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<sup>27</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

### 8.2.2.1 Natural disturbance

It is a requirement that any greenhouse gas emissions from natural disturbance above de minimis that may occur in the project area are monitored.

Estimation of emissions from natural disturbance must be calculated depending on the type of disturbance event. Disturbance due to fire is calculated following Section 8.2.2.1a, and all non-fire natural disturbance (eg, wind, disease, pest events) is calculated following Section 8.2.2.1b.

#### 8.2.2.1a Natural Disturbance - Fire

For fire damage it is assumed that a fire burning in the project scenario would also have burned in the baseline. Project emissions are therefore equal to the fire damage to biomass absent in the baseline case (harvested and removed) but present in the project case.

Where fires occur ex post in the project area, the area burned must be delineated.

Therefore, based on the IPCC 2006 Inventory Guidelines, estimation of greenhouse gas emissions from biomass burning must be calculated as:

$$\Delta C_{DIST-FR,t|PRJ} = \sum_{i=1}^M A_{burn,i,t} * B_{i,t|PRJ} * COMF_i * G_{g,i} * 10^{-3} * GWP_{CH4} \quad (21)$$

Where:

$\Delta C_{DIST-FR,t PRJ}$	net greenhouse gas emissions resulting from fire disturbance in year $t$ , tCO <sub>2</sub> e ;
$A_{burn,i,t}$	area burnt for stratum $i$ at time $t$ , ha; <sup>28</sup>
$B_{i,t PRJ}$	average aboveground biomass stock present in the project scenario but absent in the baseline scenario before burning stratum $i$ , time $t$ ; t d. m. ha <sup>-1</sup> ;
$COMF_i$	combustion factor for stratum $i$ , dimensionless; <sup>29</sup>
$G_{g,i}$	emission factor for stratum $i$ for methane, g kg <sup>-1</sup> dry matter burnt; <sup>30</sup>
$GWP_{CH4}$	global warming potential for CH <sub>4</sub> (IPCC default: 21), tCO <sub>2</sub> e tCH <sub>4</sub> <sup>-1</sup> ;
$i$	1, 2, 3 ... $M$ strata; and

<sup>28</sup> See *Data and parameters used in monitoring* parameter list for information on data selection (p59).

<sup>29</sup> See *Data and parameters not monitored (default or possibly measured one time)* parameter list for information on data selection (p 51).

<sup>30</sup> See *Data and parameters not monitored (default or possibly measured one time)* parameter list for information on data selection (p 51).



$t$  1, 2, 3, ...  $t^*$  years elapsed since the start of the IFM project activity.

The average aboveground biomass stock present in the project scenario but absent in the baseline scenario before burning for a particular stratum must be calculated as:

$$B_{i,t|PRJ} = \sum_{j=1}^J \{V_{EX,i,j|BSL} * BCEF_R\} \quad (22)$$

Where:

$B_{i,t PRJ}$	average aboveground biomass stock present in the project scenario but absent in the baseline before burning for stratum $i$ , time $t$ , t d. m. ha <sup>-1</sup> ;
$V_{EX,j,i BSL}$	mean volume of extracted timber per unit area for species $j$ in stratum $i$ , m <sup>3</sup> ·ha <sup>-1</sup> ;
$BCEF_R$	biomass conversion and expansion factor applicable to wood removals in the project area, t.d.m m <sup>-3</sup> ; <sup>31</sup>
$i$	1, 2, 3 ... $M$ strata;
$j$	1, 2, 3 ... $J$ tree species; and
$t$	1, 2, 3, ... $t^*$ years elapsed since the start of the IFM project activity.

### 8.2.2.1b Natural Disturbance - Non-Fire

For non-fire natural disturbance it is assumed that a disturbance event in the project scenario would also have occurred in the baseline. Project emissions are therefore equal to the non-fire natural disturbance to biomass absent in the baseline case (harvested and removed) but present in the project case.

It is conservatively assumed that the natural disturbance is a stand-replacing disturbance, and that the biomass change as a result of the natural disturbance ( $\Delta C_{DIST,t|PRJ}$ ) is emitted in the year of disturbance.

Where non-fire natural disturbances occur ex post in the project area, the area disturbed must be delineated.

$$\Delta C_{DIST,t|PRJ} = \sum_{i=1}^M \left( A_{dist,i,t} * \sum_{j=1}^J \{C_{AB,j,i|BSL}\} \right) * \frac{44}{12} \quad (23)$$

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<sup>31</sup> See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p51).

Where:

$\Delta C_{DIST,t PRJ}$	net greenhouse gas emissions resulting from non-fire natural disturbance in year $t$ , tCO <sub>2</sub> e ;
$A_{dist,i,t}$	area disturbed for stratum $i$ at time $t$ , ha; <sup>32</sup>
$C_{AB,i BSL}$	carbon stock in aboveground biomass per unit area in stratum $i$ , tC·ha <sup>-1</sup> ;
44/12	ratio of molecular weights of carbon dioxide and carbon, tCO <sub>2</sub> e□tC <sup>-1</sup> ;
$i$	1, 2, 3 ... $M$ strata;
$j$	1, 2, 3 ... $J$ tree species; and
$t$	1, 2, 3, ... $t^*$ years elapsed since the start of the IFM project activity.

### 8.2.2.2. Illegal logging

It is a requirement that any greenhouse gas emissions from illegal logging above de minimis that may occur in the project area ( $\Delta C_{DIST\_IL,i,t|PRJ}$ ) are monitored.

At the time of methodology approval, remote sensing technology using optical sensors is not capable of direct measurements of biomass and changes thereof<sup>33</sup> but has some capability to identify forest strata that have undergone a change in biomass<sup>34</sup>.

As remote methods for monitoring illegal logging are not available at the time of methodology approval, the following ground-based methods must be used.

#### 8.2.2.2a PRA

A participatory rural appraisal (PRA) of the communities surrounding the project area must be completed to determine if there is the potential for illegal extraction of trees from the project area. If this assessment finds no potential pressure for these activities then illegal logging ( $\Delta C_{DIST\_IL,i,t|PRJ}$ ) can be assumed to be zero and no monitoring is needed.

The PRA must be repeated every 2 years.

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<sup>32</sup> See *Data and parameters used in monitoring* parameter list for information on data selection (p62).

<sup>33</sup> However, technology is developing rapidly, including techniques such as RADAR, SAR, or LiDAR.

<sup>34</sup> For example, a multi-temporal set of remotely sensed data can be used to detect changes in the structure of the forest canopy. A variety of techniques, such as Spectral Mixture Analysis (Souza et al. 2005), SAR or LiDAR, can be used under this approach but no specific technology is prescribed here. Some of the newer technologies can estimate carbon contents of forest types, if supported by field information such as sample plots to calibrate the technology and fieldwork leading to allometric equations of key species. Project proponents should use techniques that are suitable to their specific situation and that have been published in peer-reviewed papers.

### 8.2.2.2b Sampling

If the results of the PRA suggest that there is a potential for illegal logging activities, then limited field sampling must be undertaken.

The area that is potentially subject to degradation ( $A_{DIST\_IL,i}$ ) uses the distance of illegal logging penetration from all access points (access buffer), such as roads and rivers or previously cleared areas, to the project area determined from the PRA.

The area subject to illegal logging must be delineated ( $A_{DIST\_IL,i}$ ) based on an access buffer from all access points, such as roads and rivers or previously cleared areas, to the project area, with a width equal to the distance of degradation penetration.

$A_{DIST\_IL,i}$  must be sampled by surveying several transects of known length and width across the access-buffer area (equal in area to at least 1% of  $A_{DIST\_IL,i}$ ) to determine the presence or absence of new tree stumps. The CDM tool for significance<sup>35</sup> must be applied to determine significance where there is evidence that trees are being harvested.

Where application of the CDM tool demonstrates that illegal logging is insignificant then illegal logging can be assumed to be zero and no monitoring is needed.

This limited sampling must be repeated each time the PRA indicates a potential for illegal logging.

Where limited sampling provides evidence that trees are being removed in the buffer area, then systematic sampling must be implemented based on a detailed sampling plan. The sampling plan must be designed using plots systematically placed over the buffer zone so that they sample at least 3% of the area of the buffer zone ( $A_{DIST\_IL,i}$ ). The diameter of all tree stumps will be measured and conservatively assumed to be the same as the DBH. Where the stump is a large buttress, several individuals of the same species nearby must be located and a ratio of the diameter at DBH to the diameter of buttress at the same height above ground as the measured stumps must be determined. This ratio will be applied to the measured stumps to estimate the likely DBH of the cut tree.

The aboveground carbon stock of each harvested tree will be estimated using the allometric regression equations chosen for forest growth in the project scenario<sup>36</sup>. The mean aboveground carbon stock of the harvested trees ( $C_{DIST\_IL,i,t|PRJ}$ ) is conservatively estimated to be, the total emissions and, consequently all emissions enter the atmosphere.

This sampling procedure must be repeated every 5 years and the results annualised by dividing the total emissions by five.

Therefore, where the PRA or the limited sampling indicate no illegal logging occurring:

$$\Delta C_{DIST-IL,t|PRJ} = 0$$

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<sup>35</sup> [http://cdm.unfccc.int/EB/031/eb31\\_repan16.pdf](http://cdm.unfccc.int/EB/031/eb31_repan16.pdf)

<sup>36</sup> If species-specific equations are used and species cannot be identified from stumps then it shall be assumed that the harvested species is the species most commonly harvested. A PRA shall be used to determine the most commonly harvested species.

Where the PRA and the limited sampling indicate degradation is occurring, net carbon stock changes as a result of illegal logging must be calculated as:

$$\Delta C_{DIST-IL,t|PRJ} = \sum_{i=1}^M \left( A_{DIST-IL,i} * \frac{C_{DIST-IL,i,t|PRJ}}{AP_i} \right) \quad (24)$$

Where:

$\Delta C_{DIST-IL,t PRJ}$	net carbon stock changes as a result of illegal logging at time $t$ , tCO <sub>2</sub> e;
$A_{DIST-IL,i}$	area potentially impacted by illegal logging in stratum $i$ , ha; <sup>37</sup>
$C_{DIST-IL,i,t PRJ}$	biomass carbon of trees cut and removed through illegal logging in stratum $i$ at time $t$ , tCO <sub>2</sub> e;
$AP_i$	total area of illegal logging sample plots in stratum $i$ , ha, <sup>38</sup>
$i$	1, 2, 3 ... $M$ strata in the in the project case; and
$t$	1, 2, 3, ... $t$ years elapsed since the projected start of the project activity.

### 8.2.3 Net greenhouse gas emissions in the project scenario

This section calculates  $\Delta C_{NET,t|PRJ}$ , the net greenhouse gas emissions in the project scenario in year  $t$ , in tCO<sub>2</sub>e.

The net greenhouse gas emissions in the project scenario are the sum of net greenhouse gas emissions resulting from fire and non-fire forest disturbance, plus any carbon stock changes that occur as a result of illegal logging, minus the annual carbon stock change in the aboveground biomass of trees due to forest growth.

Therefore, net greenhouse gas emissions in the project scenario in year  $t$ , is calculated as:

$$\Delta C_{NET,t|PRJ} = (\Delta C_{DIST-FR,t|PRJ} + \Delta C_{DIST,t,PRJ} + \Delta C_{DIST-IL,t|PRJ}) - \Delta C_{AB,t|PRJ} \quad (25)$$

Where:

$\Delta C_{NET,t PRJ}$	net greenhouse gas emissions in the project scenario in year $t$ , tCO <sub>2</sub> -e;
$\Delta C_{DIST-FR,t PRJ}$	net greenhouse gas emissions resulting from fire disturbance in year $t$ , tCO <sub>2</sub> e ;
$\Delta C_{DIST,t,PRJ}$	net greenhouse gas emissions resulting from non-fire natural disturbance in

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<sup>37</sup> See *Data and parameters used in monitoring* parameter list for information on data selection (p62).

<sup>38</sup> See *Data and parameters used in monitoring* parameter list for information on data selection (p62).

	year $t$ , tCO <sub>2</sub> e ;
$\Delta C_{\text{DIST\_IL},t \text{PRJ}}$	Net carbon stock changes as a result of illegal logging at time $t$ , tCO <sub>2</sub> e;
$\Delta C_{\text{AB},t \text{PRJ}}$	annual carbon stock change in aboveground biomass of trees in year $t$ , tCO <sub>2</sub> e·yr <sup>-1</sup> ; and
$t$	1, 2, 3, ... $t^*$ years elapsed since start of the project activity.

The net greenhouse gas emissions across in the project scenario since the start of the project activity is calculated as:

$$GHG_{\text{NET}|\text{PRJ}} = \sum_{t=1}^{t^*} \Delta C_{\text{NET},t|\text{PRJ}} \quad (26)$$

Where:

$GHG_{\text{NET} \text{PRJ}}$	net greenhouse gas emissions in the project scenario since the start of the project activity, tCO <sub>2</sub> e;
$\Delta C_{\text{NET},t \text{PRJ}}$	net greenhouse gas emissions in the project scenario in year $t$ , tCO <sub>2</sub> e; and
$t$	1, 2, 3, ... $t^*$ years elapsed since start of the project activity.

## 8.3 Leakage

### 8.3.1 Activity shifting leakage

There may be no leakage due to activity shifting.

Where the project proponent controls multiple parcels of land within the country the project proponent must demonstrate that the management plans and/or land-use designations of other lands they control have not materially changed as a result of the planned project (designating new lands as timber concessions or increasing harvest rates in lands already managed for timber) because such changes could lead to reductions in carbon stocks or increases in GHG emissions.

This must be demonstrated through:

- historical records showing trends in harvest volumes paired with records from the with- project time period showing no deviation from historical trends;
- forest management plans prepared  $\geq 24$  months prior to the start of the project showing harvest plans on all owned/managed lands paired with records from the with-project time period showing no deviation from management plans.

At each verification, documentation must be provided covering the other lands controlled by the project proponent where leakage could occur, including, at a minimum, their location(s), area and type of existing land use(s), and management plans.

Where activity shifting occurs or a project proponent is unable to provide the necessary documentation at first and subsequent verification, the project must not meet the requirements for verification. Therefore, the project must be subject to the conditions described in the VCS AFOLU Guidance Document on projects which fail to submit periodic verification after the commencement of the project. Project proponents may optionally choose to submit a methodology deviation with their future verifications to address activity shifting leakage.

Where the project proponent has control only over resource use in the project area and has no access to other forest resource, then the only type of leakage emissions calculated is GHG emissions due to market effects that result from project activity.

### 8.3.2 Market leakage

Leakage due to market effects is equal to the net emissions from planned timber harvest activities in the baseline scenario multiplied by an appropriate leakage factor:

$$GHG_{LK|LTPF,t^*} = LF_{ME} * GHG_{NET|BSL,t^*} \quad (27)$$

Where:

$GHG_{LK LTPF,t^*}$	is total market leakage as a result of IFM LTPF activities, in the year $t^*$ since the start of the project activity, tCO <sub>2</sub> e;
$LF_{ME}$	is the dimensionless leakage factor for market-effects calculations;
$GHG_{NET BSL,t^*}$	net greenhouse gas emissions in the baseline scenario in the year $t^*$ since the start of the project activity, tCO <sub>2</sub> e.

The leakage factor (see Box 2) is determined by considering where in the country logging will be increased as a result of the decreased timber supply caused by the project.

If the ratio of merchantable biomass to total biomass is higher in the project area, it is likely that additional logging will be performed in these areas as a result of reduced logging in the project area in the project scenario.

The leakage factor is thus defined as a dimensionless number with values between 0 and 1 assigned *ex ante* on the basis of a comparison between the ratio of merchantable biomass to total biomass across all strata in the base year, and the ratio of merchantable biomass to total biomass of the country's forest estate where harvesting would likely be displaced to.

### Box 2. Leakage factor calculation

The leakage factor is determined by considering where in the country logging will be increased as a result of the decreased supply of the timber caused by the project. If the areas liable to be logged have a higher ratio of merchantable biomass to total biomass higher than the project area it is likely that the proportional leakage is higher and vice versa:

Therefore,

$$LF_{ME} = 0$$

if it can be demonstrated that no market-effects leakage will occur within national boundaries, that is if no new concessions are being assigned AND annual extracted volumes cannot be increased within existing national concessions AND illegal logging is absent (or *de minimis*) in the host country.

The amount of leakage is determined by where in the country's forest estate harvesting would likely be displaced. If harvesting is displaced to forests where a lower proportion of forest biomass is merchantable material from harvestable species than in the project area, then in order to extract a given volume higher emissions should be expected as more trees will need to be cut to supply the same volume.

In contrast if a higher proportion of the total biomass of commercial species is merchantable in the displacement forest than in the project forests, then a smaller area would have to be harvested and lower emissions would result.

Therefore, each project shall calculate within each stratum the ratio of merchantable biomass to total biomass ( $PMP_i$ ). This shall then be compared to the ratio of merchantable biomass to total biomass for each forest type ( $PML_{FT}$ ).

The following deduction factors ( $LF_{ME}$ ) shall be used:

$$PML_{FT} \text{ is equal } (\pm 15\%) \text{ to } PMP_i \qquad LF_{ME} = 0.4$$

$$PML_{FT} \text{ is } > 15\% \text{ less than } PMP_i \qquad LF_{ME} = 0.7$$

$PML_{FT}$  is > 15% greater than  $PMP_i$

$LF_{ME} = 0.2$

Where:

$PML_{FT}$  mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type, %;

$PMP_i$  merchantable biomass as a proportion of total aboveground tree biomass for stratum  $i$  within the project boundaries, %; and

$LF_{ME}$  Leakage factor for market-effects calculations; dimensionless.

Where sufficient variation exists in  $PMP_i$  relative to  $PML_{FT}$  that multiple values of  $LF_{ME}$  result, then an area weighted final value for  $LF_{ME}$  shall be calculated. The area of stratum  $i$  as a proportion of the total project area shall be multiplied by  $LF_{ME}$ . All values are then summed to arrive at the area weighted final value of  $LF_{ME}$ .



## 8.4 Summary of GHG Emission Reduction and/or Removals

Knowledge of the greenhouse gas emission level calculations for baseline scenario, project scenario and leakage allows an ex-ante estimation of the level of net GHG emission reductions resulting at the end of each year over the project crediting period from the implementation of the proposed Logged to Protected Forest (LtPF)-IFM project.

Therefore, the project GHG credits are calculated as:

$$GHG_{CREDITS|LtPF,t^*} = GHG_{NET|BSL,t^*} - GHG_{NET|PRJ,t^*} - GHG_{LK|LtPF,t^*} \quad (28)$$

Where:

$GHG_{CREDITS LtPF,t^*}$	project greenhouse gas credits associated with the implementation of improved forest management (IFM) activities in the year $t^*$ since the start of the project activity, in the project scenario, tCO <sub>2</sub> e;
$GHG_{NET BSL,t^*}$	net greenhouse gas emissions in the baseline scenario in the year $t^*$ since the start of the project activity, tCO <sub>2</sub> e;
$GHG_{NET PRJ,t^*}$	net greenhouse gas emissions in the project scenario in the year $t^*$ since the start of the project activity, tCO <sub>2</sub> e; and
$GHG_{LK LtPF,t^*}$	total greenhouse gas emissions due to leakage arising outside the project boundary as a result of the implementation of improved forest management (IFM) activities in the year $t^*$ since the start of the project activity, in the project scenario, tCO <sub>2</sub> e.

### 8.4.1 Project Verified Carbon Units

The number of Verified Carbon Units (VCUs) for each year  $t$  in the project crediting period is the greenhouse gas emission reductions and removals adjusted for uncertainty and risk.

#### 8.4.1.1. Adjustment for uncertainty

Estimated greenhouse gas emissions and emission reductions from IFM activities have uncertainties associated with parameters and coefficients including estimates of area, carbon stocks, regrowth and expansion factors. It is assumed that the uncertainties associated with input data are available, either as default uncertainty values given in most recent IPCC guidelines, or as statistical estimates based on sampling.

Uncertainty at all times is defined at the 95% confidence interval where the estimated variance exceeds +/- 15 percent from the mean. Procedures including stratification and the allocation of sufficient measurement plots will help ensure that low uncertainty results and ultimately full crediting can result.

It is good practice to consider uncertainty at an early stage to identify the data sources with the highest uncertainty to allow the opportunity to conduct further work to diminish uncertainty.

Uncertainties arising from the measurement and monitoring of carbon pools and greenhouse gases must always be quantified. Errors in each pool must be weighted by the size of the pool so that projects may reasonably target a lower precision level in pools that only form a small proportion of the total stock.

For both the baseline and the with-project case the total uncertainty is equal to the square root of the sum of the squares of each component uncertainty and is calculated at the time of reporting through propagating the error in the baseline stocks and the error in the project stocks.

Therefore, total uncertainty for LtPF project is calculated as:

$$U_{TOTAL|LtPF} = \sqrt{U^2_{|PRJ} + U^2_{|BSL}} \quad (29)$$

Where:

- $U_{total|LtPF}$  total uncertainty for LtPF Project, dimensionless;
- $U_{|PRJ}$  total uncertainty for the improved forest management activities in the project scenario, dimensionless; and
- $U_{|BSL}$  total uncertainty for the baseline scenario, dimensionless.

Project proponents must justify the selection of uncertainty propagation in the VCS-PD. If  $U_{total|LtPF} \leq 0.15$  then no deduction will result for uncertainty.

If  $U_{total|LtPF} > 0.15$  then the amount of greenhouse gas emission credits associated with IFM activities will be deducted as follows:

$$Credits_{total|LtPF} = GHG_{credits|LtPF} * (1 - U_{total|LtPF}) \quad (30)$$

Where:

- $Credits_{total|LtPF}$  total greenhouse gas credits adjusted for uncertainty for each year  $t$  in the project crediting period;
- $GHG_{credits|LtPF}$  project greenhouse gas credits associated with the implementation of improved forest management (IFM) activities in the project scenario,  $tCO_2e \cdot year^{-1}$ ; and
- $U_{total|LtPF}$  total uncertainty for LtPF Project, dimensionless.

### 8.4.1.2. Calculation of verified carbon units

The amount of greenhouse gas credits estimated at Section 8.4.1.1 above must be adjusted to account for risk.

They must be subject to deductions based on application of the most recent version of the VCS Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination.

Therefore, the amount of VCU's that can be issued at time  $t=t_2$  (the date of verification) for monitoring period  $T=t_2-t_1$ , is calculated as:

$$VCU_{net|LtPF} = (Credits_{total,t_2|LtPF} - Credits_{total,t_1|LtPF}) - Bu_{|IFM-VCS} \quad (31)$$

Where:

$VCU_{net LtPF}$	number of verified carbon units; dimensionless;
$Credits_{total,t_1 LtPF}$	net anthropogenic greenhouse gas removals by sinks, as estimated for $t^*=t_1$ in tCO <sub>2</sub> e;
$Credits_{total,t_2 LtPF}$	net anthropogenic greenhouse gas removals by sinks, as estimated for $t^*=t_2$ in tCO <sub>2</sub> e; and
$Bu_{ IFM-VCS}$	total number of credits withheld in VCS buffer account.

## 9 MONITORING

### 9.1 Data and Parameters Available at Validation

In addition to the parameters listed in the tables presented in the following pages, the provisions on data and parameters not monitored in the tools referred to in this methodology apply. In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of existing published data, project participants must retain a conservative approach; that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

Data / parameter:	$V_{l,j,i,sp}$
Data unit:	$m^3$
Used in equations:	(1)
Description:	Merchantable volume for tree <i>l</i> of species <i>j</i> in sample plot <i>sp</i> in stratum <i>i</i>
Source of data:	<p>Calculated from volume tables or equations linking diameter at breast height (DBH, at typically 1.3 m aboveground level), and/or merchantable height (MH), to commercial (merchantable) volume of trees in the sample plots above the minimum DBH set in the timber harvest plan.</p> <p>If locally derived equations or yield tables are not available use relevant regional, national or default equations from IPCC literature, national inventory reports or published peer-reviewed studies— such as those provided in Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC 2003).</p>
Measurement procedures (if any):	N/A
Any comment:	<p>It is necessary to verify the applicability of equations used. Allometric equations can be verified by both:</p> <ol style="list-style-type: none"> <li>1. Verification of equation conditions</li> </ol> <p>Justification should be provided for the applicability of the equation to the project locations. Such justification should include identification of climatic, edaphic, geographical and taxonomic similarities between the project location and the location in which the equation was derived. Any equation used should have an <math>r^2</math> value of greater than 0.5 (50%) and a <math>p</math> value that is significant (<math>&lt;0.05</math> at the 95% confidence level).</p> <ol style="list-style-type: none"> <li>2. Additional field verification</li> </ol> <p>The following limited measures method must be used for field verification:</p> <ul style="list-style-type: none"> <li>• select at least 10 trees per species distributed across the age range (but excluding trees less than 15 years old for which there is rarely a great relative inaccuracy in equations) ;</li> </ul>

	<ul style="list-style-type: none"> <li>• measure DBH, and height to a 10 cm diameter top or to the first branch;</li> <li>• calculate stem volume from measurements; and</li> <li>• plot the estimated volume of all the measured trees along with the curve of volume against diameter as predicted by the allometric equation.</li> </ul> <p>If the estimated volume of the measured trees are distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a volume consistently higher than predicted by the equation. The equation may not be used if &gt;75% of the measured trees have a volume lower than the predicted curve. In this instance another equation must be selected.</p>
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Data / parameter:	CF <sub>j</sub>
Data unit:	tC·t d.m. <sup>-1</sup>
Used in equations:	(3), (4), (17)
Description:	Carbon fraction of dry matter for species j
Source of data:	Either the default value 0.5 tC·t d.m. <sup>-1</sup> or species specific values from the literature must be used. The same value, however, must be used in all instances where this parameter is used.
Measurement procedures (if any):	N/A
Any comment:	

Data / parameter:	D <sub>j</sub>
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Data unit:	t d.m. m <sup>-3</sup>
Used in equations:	(4)
Description:	Basic wood density of species <i>j</i> in t d.m. m <sup>-3</sup>
Source of data:	<p>Must be chosen with priority from higher to lower preference as follows:</p> <ul style="list-style-type: none"> <li>a) National species-specific or group of species-specific values (eg, from National GHG inventory);</li> <li>b) Species-specific or group of species-specific values from neighbouring countries with similar conditions. When species-specific data from neighbouring countries is of higher quality, being more representative of the species in the project scenario, it may be preferable to use these values than lower quality national data;</li> <li>c) Global species-specific or group of species-specific (eg, IPCC 2006 INV GLs AFOLU Chapter 4 Tables 4.13 and 4.14).</li> </ul> <p>Species-specific wood densities may not always be available, and may be difficult to apply with certainty in the typically species rich forests of the humid tropics, hence it is acceptable practice to use wood densities developed for forest types or plant families or species groups.</p>
Measurement procedures (if any):	N/A
Any comment:	Default values must be updated whenever new guidelines are produced by the IPCC

Data / parameter:	$f_j(X, Y \dots)$
Data unit:	t d.m. tree <sup>-1</sup>
Used in equations:	(17)

Description:	Allometric equation(s) for species <i>j</i> linking measured tree variable(s) to aboveground biomass of living trees
Source of data:	<p>Equations must have been derived using a wide range of measured variables (eg, DBH, Height, etc.) based on datasets that comprise at least 30 trees. Equations must be based on statistically significant regressions and must have an <math>r^2</math> that is <math>\geq 0.8</math>.</p> <p>The source of equation(s) must be chosen with priority from higher to lower preference, as available, as follows:</p> <ol style="list-style-type: none"> <li>a) National species-, genus-, family-specific;</li> <li>b) Species-, genus-, family-specific from neighbouring countries with similar conditions (ie, broad continental regions);</li> <li>c) National forest-type specific;</li> <li>d) Forest-type specific from neighbouring countries with similar conditions (ie, broad continental regions);</li> <li>e) Forest type-specific such as those provided Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC 2003); or in Pearson, T., Walker, S. and Brown, S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and the World Bank Biocarbon Fund. 57pp.; or in Chave, J., C. Andalo, S. Brown, M. A. Cairns, J. Q. Chambers, D. Eamus, H. Folster, F. Fromard, N. Higuchi, T. Kira, J.-P. Lescure, B. W. Nelson, H. Ogawa, H. Puig, B. Riera, T. Yamakura. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. <i>Oecologia</i> 145: 87-99.</li> </ol> <p>Species-, genus- and family-specific allometric equations may not always be available, and may be difficult to apply with certainty in the typically species rich forests of the humid tropics. Hence it is acceptable practice to use equations developed for regional forest types, provided that their accuracy has been validated with direct site-specific data following guidance given below. If a forest-type specific equation is used, it should not be used in combination with species-specific equation(s) (ie, it must be used for all tree species<sup>39</sup>).</p>
Measurement procedures (if any):	N/A

<sup>39</sup> Note that forest type specific and pantropical equations will typically not include palm species or hollow-stem species (eg, *Cecropia*) and so specific equations for these growth forms will be needed

<p>Any comment:</p>	<p>It is necessary to validate the applicability of equations used. Source data from which equation(s) was derived should be reviewed and confirmed to be representative of the forest type/species and conditions in the project and covering the range of potential independent variable values.</p> <p>Allometric equations can be validated either by:</p> <p>1. Limited Measurements</p> <ul style="list-style-type: none"><li>• select at least 30 trees (if validating forest type-specific equation, selection should be representative of the species composition in the project area, ie, species representation in roughly in proportion to relative basal area). Minimum diameter of measured trees must be 20cm and maximum diameter must reflect the largest trees present or potentially present in the future in the project area (and/or leakage belt);</li><li>• measure DBH, and height to a 10 cm diameter top or to the first branch;</li><li>• calculate stem volume from measurements and multiplying by species-specific density to gain biomass of bole;</li><li>• apply a biomass expansion factor to estimate total aboveground biomass from stem biomass<sup>40</sup>; and</li><li>• plot the estimated biomass of all the measured trees along with the curve of biomass against diameter as predicted by the allometric equation.</li></ul> <p>If the estimated volume of the measured trees are distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a biomass consistently higher than predicted by the equation. If &gt;75% of the measured trees have a biomass lower than the predicted curve, destructive sampling must be undertaken or another equation must be selected.</p> <p>2. Destructive Sampling</p> <ul style="list-style-type: none"><li>• select at least 5 trees (if validating forest type-specific equation, selection should be representative of the species composition in the project area, ie, species representation in roughly in proportion to relative basal area) at the upper end of the range of independent variable values existing in the project area;</li><li>• measure DBH and commercial height and calculate volume using the same procedures/equations used to generate commercial volumes to which BCEFs will be applied;</li><li>• fell and weigh the aboveground biomass to determine the total (wet) mass</li></ul>
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<sup>40</sup> See IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.5



	<p>of the stem, branch, twig, leaves, etc. Extract and immediately weigh subsamples from each of the wet stem and branch components, followed by oven drying at 70 degrees C to determine dry biomass;</p> <ul style="list-style-type: none"> <li>• determine the total dry weight of each tree from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components; and</li> <li>• plot the estimated biomass of all the measured trees along with the curve of biomass against diameter as predicted by the allometric equation.</li> </ul> <p>If the estimated volume of the measured trees are distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a biomass consistently higher than predicted by the equation. If &gt;75% of the measured trees have a biomass lower than the predicted curve another equation must be selected.</p> <p>Details of destructive sampling measurements are given in:</p> <p>Brown, S. 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper 134, Rome, Italy.</p> <p>Available at <a href="http://www.fao.org/docrep/W4095E/W4095E00.htm">http://www.fao.org/docrep/W4095E/W4095E00.htm</a></p> <p>If using species-specific equations, and new species are encountered in the course of monitoring, new allometric equations must be sourced from the literature and validated, if necessary, as per requirements and procedures above.</p> <p>Default values must be updated whenever new guidelines are produced by the IPCC</p>
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Data / parameter:	BCEF <sub>R</sub>
Data unit:	t.d.m m <sup>-3</sup>
Used in equations:	(3) (22)
Description:	Biomass conversion and expansion factor applicable to wood removals in the project area
Source of data:	The source of data must be chosen with priority from higher to lower preference

	<p>as follows:</p> <ul style="list-style-type: none"> <li>a) Existing local forest type-specific;</li> <li>b) National forest type-specific or eco-region-specific (eg, from national GHG inventory);</li> <li>c) Forest type-specific or eco-region-specific from neighbouring countries with similar conditions. Sometimes (c) might be preferable to (b);</li> <li>d) Global forest type or eco-region-specific (eg, IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.5).</li> </ul> <p>Alternatively:</p> $\text{BCEFR} = \text{BEFR} * \text{D}$ <p>Where BCEF values are not directly available, they can be calculated as Biomass Expansion Factor (BEF)* basic wood density (D).</p> <p>Application of this equation requires caution because basic wood density and biomass expansion factors tend to be correlated. If the same sample of trees was used to determine D, BEF or BCEF, conversion will not introduce error, therefore, it is acceptable to use this equation. If, however, basic wood density is not known with certainty, transforming one into the other might introduce error, as BCEF implies a specific but unknown basic wood density, therefore, all conversion and expansion factors must be derived or their applicability checked locally.</p>
<p>Measurement procedures (if any):</p>	<p>N/A</p>
<p>Any comment:</p>	<p>The combustion factor is a measure of the proportion of the fuel that is actually combusted, which varies as a function of the size and architecture of the fuel load (ie, a smaller proportion of large, coarse fuel such as tree stems will be burnt compared to fine fuels, such as grass leaves), the moisture content of the fuel and the type of fire (ie, intensity and rate of spread).</p> <p>Default values must be updated whenever new guidelines are produced by the IPCC</p>

<p>Data / parameter:</p>	<p>G<sub>gi</sub></p>
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Data unit:	$\text{g kg}^{-1}$ dry matter burnt
Used in equations:	(21)
Description:	Emission factor for stratum <i>i</i> for gas <i>g</i>
Source of data:	Defaults can be found in Volume 4, Chapter 2, of the IPCC 2006 Inventory Guidelines in table 2.5
Measurement procedures (if any):	N/A
Any comment:	Default values must be updated whenever new guidelines are produced by the IPCC

Data / parameter:	OF,SLF,WW
Data unit:	$\text{kg kg}^{-1}$
Used in equations:	(7), (9)
Description:	<p><i>OF</i> = Fraction of wood products that will be emitted to the atmosphere between 3 and 100 years after production;</p> <p><i>SLF</i> = Fraction of wood products that will be emitted to the atmosphere within 3 years of production; and</p> <p><i>WW</i> = Fraction of extracted biomass effectively emitted to the atmosphere during production</p> <p>Wood waste fraction (WW):</p> <p>Winjum et al 1998 indicate that the proportion of extracted biomass that is oxidized (burning or decaying) from the production of commodities to be equal to 19% for developed countries, 24% for developing countries.</p>

	<p>Short-lived fraction (SLF)</p> <p>Winjum et al 1998 give decay rates for proportions of wood products, which were converted to with short-term (&lt;3 yr) uses (applicable internationally) as below:</p> <p>Sawnwood 0.12</p> <p>Woodbase panels 0.06</p> <p>Other industrial roundwood 0.18</p> <p>Paper and Paperboard 0.24</p> <p>Additional oxidized fraction (OF)</p> <p>Winjum et al 1998 gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate and tropical).</p> <p>This methodology projects these fractions over 95 years to give the additional proportion that is oxidized between the 3rd and 100<sup>th</sup> years after initial harvest:</p> <table border="1" data-bbox="488 1024 1422 1377"> <thead> <tr> <th rowspan="2">Wood Product Class</th> <th colspan="3">OF</th> </tr> <tr> <th>Boreal</th> <th>Temperate</th> <th>Tropical</th> </tr> </thead> <tbody> <tr> <td>Sawnwood</td> <td>0.39</td> <td>0.62</td> <td>0.86</td> </tr> <tr> <td>Woodbase panels</td> <td>0.62</td> <td>0.86</td> <td>0.98</td> </tr> <tr> <td>Other industrial roundwood</td> <td>0.86</td> <td>0.98</td> <td>0.99</td> </tr> <tr> <td>Paper and paperboard</td> <td>0.39</td> <td>0.62</td> <td>0.99</td> </tr> </tbody> </table>	Wood Product Class	OF			Boreal	Temperate	Tropical	Sawnwood	0.39	0.62	0.86	Woodbase panels	0.62	0.86	0.98	Other industrial roundwood	0.86	0.98	0.99	Paper and paperboard	0.39	0.62	0.99
Wood Product Class	OF																							
	Boreal	Temperate	Tropical																					
Sawnwood	0.39	0.62	0.86																					
Woodbase panels	0.62	0.86	0.98																					
Other industrial roundwood	0.86	0.98	0.99																					
Paper and paperboard	0.39	0.62	0.99																					
Source of data:	The source of data is the published paper of Winjum et al. 1998 <sup>41</sup>																							
Measurement procedures (if any):	N/A																							

<sup>41</sup> Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. Forest Science 44: 272-284 31

Any comment:	
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Data / parameter:	PML <sub>FT</sub>
Data unit:	%
Used in equations:	Section 8.3.2 - Leakage, Box 2.
Description:	Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type.
Source of data:	<p>The source of data must be chosen with priority from higher to lower preference as follows:</p> <ul style="list-style-type: none"> <li>a) peer-reviewed published sources (including carbon/biomass maps or growing stock volume<sup>42</sup> maps with a scale of at least 1km);</li> <li>b) official Government data and statistics ; or</li> <li>c) original field measurements.</li> </ul> <p>The forest types considered must be only those relevant for the specific market effects leakage, that is, only forest types with active timber production.</p> <p>An appropriate source of data will be Government records on annual allowable cuts for the areas of commercial forests.</p> <p>Where volumes are used the source of data wood density is required to convert to merchantable biomass. The source of data on wood densities must be chosen as per the species specific density parameter, <math>D_j</math>.</p>
Measurement	

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<sup>42</sup> Volumes shall be converted to merchantable biomass using wood densities/specific gravities. A weighted wood density shall be used to convert multi-species data on growing stock volume to merchantable biomass

procedures (if any):	
Any comment:	

Data / parameter:	RGR <sub>i</sub>
Data unit:	tC.ha <sup>-1</sup> .yr <sup>-1</sup>
Used in equations:	(10)
Description:	Forest regrowth rate post timber harvest for stratum <i>i</i>
Source of data:	Regrowth rate must be calculated from either <ul style="list-style-type: none"> <li>a) data generated in a reference area using measurements of timber volume in a chronosequence of replicated sample plots; or</li> <li>b) published data on forest growth after timber harvest of the same forest type within the same region as the project; or</li> <li>c) the IPCC default values for aboveground net biomass growth in natural forests<sup>43</sup>.</li> </ul>
Measurement procedures (if any):	
Any comment:	Default values must be updated whenever new guidelines are produced by the IPCC

Data / parameter:	V <sub>EX,j,i BSL</sub>
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<sup>43</sup> IPCC Guidelines for National Greenhouse Gas Inventories (2006), Table 4.9

Data unit:	$m^3 ha^{-1}$
Used in equations:	(3), (4), (22)
Description:	Mean volume of extracted timber per unit area for species $j$ in stratum $i$
Source of data:	The timber harvest plan sets the allowable mean extracted volume from the merchantable volume of timber in the forest inventory ( $V_{j,i BSL}$ ), based on legal limits.
Measurement procedures (if any):	N/A
Any comment:	

Data / parameter:	$TH_{i,p}$
Data unit:	Years
Used in equations:	
Description:	Number of years since timber harvest in stratum $i$ in land parcel $p$
Source of data:	The timber harvest schedule specifies the year (1,2,3...) timber harvest in each land parcel is scheduled to occur and the number of years each land parcel is in a post harvest state during the project crediting period.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{i,p}$
Data unit:	Ha
Used in equations:	(20)
Description:	Area covered by stratum $i$ over land parcel $p$
Source of data:	Geodetic coordinates and/or Remote Sensing data and/or legal parcel records
Measurement procedures (if any):	
Any comment:	It must be assumed ex-ante that land parcel boundaries and strata areas must not change through time

Data / parameter:	$A_{1,i,p}$
Data unit:	Ha
Used in equations:	(11)
Description:	The area of stratum $i$ in land parcel $p$ that was harvested 1 year ago
Source of data:	Geodetic coordinates, GIS Files or legal parcel records
Measurement procedures (if any):	



Any comment:	
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Data / parameter:	$A_{2-10,i,p}$
Data unit:	Ha
Used in equations:	(12)
Description:	The area of stratum $i$ in land parcel $p$ that was harvested between 2 and 10 year ago
Source of data:	Geodetic coordinates, GIS Files or legal parcel records
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{11-20,i,p}$
Data unit:	Ha
Used in equations:	(13)
Description:	The area of stratum $i$ in land parcel $p$ that was harvested between 11 and 20 years ago
Source of data:	Geodetic coordinates, GIS Files or legal parcel records

Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{t^*}$
Data unit:	Ha
Used in equations:	(14)
Description:	Cumulative area harvested until time $t^*$
Source of data:	Geodetic coordinates, GIS Files or legal parcel records
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{sp}$
Data unit:	Ha
Used in equations:	(2), (19)
Description:	Area of sample plot $sp$

Source of data:	Recording and archiving of size of sample plots
Measurement procedures (if any):	Standard procedures for plot delineation in forest timber inventory surveys must be used (see references in Box 3 for example procedures)
Any comment:	<i>Ex-ante</i> the size of the plots must be defined and recorded in the monitoring plan.

## 9.2 Data and Parameters Monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply. In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of existing published data, project participants must retain a conservative approach; that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

Data / parameter:	Illegal Logging PRA Results
Data unit:	
Used in equations:	Used in Section 8.2.2.2a
Description:	
Source of data:	PRA
Measurement procedures (if any):	<p>The PRA must evaluate whether timber harvest may be occurring in the project area and must consist of semi-structured interviews / questionnaires.</p> <p>If <math>\geq 10\%</math> of those interviewed/surveyed believe that illegal logging may be occurring within the project boundary then the limited on- the-ground illegal logging survey must be triggered.</p>

	An additional output of the PRA must be a depth of penetration of illegal logging pressure. A maximum distance must be recorded for penetration into the forest from access points (such as roads, rivers, already cleared areas) for the purpose of harvesting timber.
Measurement Frequency	Every two years
QA/QC Procedures	
Any comment:	Ex ante estimation must be made of illegal logging in the with-project case. If the belief is that zero illegal logging will occur within the project boundaries then this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.

Data / parameter:	Result of Limited Illegal Logging Survey
Data unit:	
Used in equations:	Section 8.2.2.2b
Description:	
Source of data:	Limited on-the-ground illegal logging survey
Measurement procedures (if any):	Sampled by surveying multiple transects of known length and width across the access-buffer area to check whether new tree stumps are evident or not. The access-buffer area must be equal in area to at least 1% of ADIST_IL,i
Measurement Frequency	Must to be repeated each time the PRA indicates a potential for illegal logging.
QA/QC Procedures	

Any comment:	Ex ante an estimation must be made of illegal logging in the with- project case. If the belief is that zero illegal logging will occur within the project boundaries then this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.
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Data / parameter:	Aburn,i,t
Data unit:	Ha
Used in equations:	(21)
Description:	Area burnt in stratum <i>i</i> at time <i>t</i>
Source of data:	Geodetic coordinates and/or Remote Sensing data
Measurement procedures (if any):	N/A
Measurement Frequency	Areas burnt must be monitored at least every five years
QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended.
Any comment:	Ex ante estimations of areas burned must be based on historic incidence of fire in the Project region

Data / parameter:	Adist,i,t
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Data unit:	Ha
Used in equations:	(23)
Description:	Area disturbed in stratum <i>i</i> at time <i>t</i>
Source of data:	Geodetic coordinates and/or Remote Sensing data
Measurement procedures (if any):	N/A
Measurement Frequency	Areas disturbed must be monitored at least every five years
QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended.
Any comment:	Ex ante estimations of areas disturbed must be based on historic incidence of natural disturbance in the Project region

Data / parameter:	$A_{\text{DIST\_IL},i}$
Data unit:	Ha
Used in equations:	(24)
Description:	Area potentially impacted by illegal logging in stratum <i>i</i>
Source of data:	GIS delineation and ground truthing

Measurement procedures (if any):	ADIST_IL,i must be composed of a buffer from all access points (access buffer), such as roads and rivers or previously cleared areas. The width of the buffer must be determined by the depth of degradation penetration as defined as a PRA output
Measurement Frequency	Repeated each time the PRA indicates a potential for degradation
QA/QC Procedures	
Any comment:	Ex ante a limited survey can be used to determine a likely depth of degradation penetration

Data / parameter:	$C_{DIST\_IL,i,t PRJ}$
Data unit:	tCO <sub>2</sub> -e
Used in equations:	(24), (25)
Description:	biomass carbon of trees cut and removed through illegal logging in stratum i at time t
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	<p>The sampling plan must be designed using plots systematically placed over the buffer zone so that they sample at least 3% of the area of the buffer zone (ADIST_IL,i). The diameter of all tree stumps will be measured and conservatively assumed to be the same as the DBH. Where the stump is a large buttress, several individuals of the same species nearby must be located and a ratio of the diameter at DBH to the diameter of buttress at the same height above ground as the measured stumps must be determined. This ratio will be applied to the measured stumps to estimate the likely DBH of the cut tree.</p> <p>The aboveground carbon stock of each harvested tree will be estimated using the</p>

	allometric regression equations chosen for forest growth in the project scenario. The mean aboveground carbon stock of the harvested trees is conservatively estimated to be the total emissions and to all enter the atmosphere
Measurement Frequency	Repeated each time limited sampling of ADIST_IL, indicates illegal logging
QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended.
Any comment:	If species-specific equations are used and species cannot be identified from stumps then it must be assumed that the harvested species is the species most commonly harvested. A PRA must be used to determine the most commonly harvested species.

Data / parameter:	$AP_i$
Data unit:	Ha
Used in equations:	(24)
Description:	Total area of illegal logging sample plots in stratum $i$
Source of data:	Ground measurement
Measurement procedures (if any):	A sampling plan must be designed using multiple sample plots systematically placed across the buffer zone so that they sample at least 3% of the area of the buffer zone.
Measurement Frequency	Not more than five years



QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended.
Any comment:	Ex ante estimation should be made of area of plots. This should be set to exactly 3% of the buffer zone ADIST_IL,i

Data / parameter:	$PMP_i$
Data unit:	%
Used in equations:	Section 8.3.2, Box 2: 'Leakage Factor Calculation'
Description:	Merchantable biomass as a proportion of total aboveground tree biomass for stratum <i>i</i> within the project boundaries
Source of data:	Within each stratum divide the summed merchantable biomass (defined as total gross biomass of a tree 15cm DBH or larger) by the summed total of aboveground tree biomass.
Measurement procedures (if any):	
Measurement Frequency	Not more than five years
QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , is recommended.

Any comment:	<p>Ex-ante a time zero measurement must be made of this factor.</p> <p>The timber harvest plan sets the allowable mean extracted volume from the merchantable volume of timber in the forest inventory (<math>V_{j,i} BSL</math>), based on legal limits.</p>
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Data / parameter:	$A_i$
Data unit:	Ha
Used in equations:	(20)
Description:	Area covered by stratum $i$
Source of data:	Geodetic coordinates and/or Remote Sensing data and/or legal parcel records
Measurement procedures (if any):	
Measurement Frequency	
QA/QC Procedures	
Any comment:	<p>In the baseline scenario strata areas must not change through time.</p> <p>In the project scenario it must be assumed <i>ex-ante</i> that stand boundaries and strata areas must not change through time. <i>Ex post</i> adjustments of the project scenario strata may be needed if unexpected disturbances occur during the project crediting period, severely affecting different parts of an originally homogenous stratum. This disturbance will be delineated as a separate stratum for the purpose of monitoring the carbon stock changes.</p>

### 9.3 Description of the Monitoring Plan

The following parameters must be monitored in this methodology:

- Illegal logging PRA
- Result of limited illegal logging survey
- Area burnt in stratum  $i$  at time  $t$  ( $A_{burn,i,t}$ )
- Area potentially impacted by illegal logging in stratum  $i$  ( $A_{DIST\_IL, i}$ )
- Total area of illegal logging sample plots in stratum  $i$  ( $AP_i$ )
- Merchantable biomass as a proportion of total aboveground tree biomass for stratum  $i$  ( $PMP_i$ )
- Area covered by stratum  $i$  ( $A_i$ )
- Diameter at breast height of tree ( $DBH$ )

These parameters will be required at each verification and are used in equations 20, 21 and 23.

#### 9.3.1 Scope of monitoring and the monitoring plan

Monitoring is required to:

- a) determine changes in forest carbon stocks and greenhouse gas emissions from project activity;
- b) confirm project activity; and
- c) determine changes in forest carbon stocks and greenhouse gas emissions from disturbance and illegal logging.

In some project cases monitoring may also be implemented to update stratification.

It is a requirement that the monitoring plan presented in the VCS-PD must address the monitoring of project implementation, the monitoring of actual carbon stock changes from project activity, and estimation of ex-post net carbon stock changes from disturbance and illegal logging.

The description of the monitoring plan in the VCS-PD will include the following for each of these monitoring tasks:

- a) technical description of the monitoring task;
- b) a list of data and parameters to be collected;
- c) overview of data collection procedures;
- d) quality control and quality assurance procedure;
- e) data archiving; and
- f) organisation and responsibilities of the parties involved in all the above.

#### 9.3.2 General requirements for monitoring

All data collected as part of monitoring will be archived electronically and be kept at least for 2 years after the end of the project crediting period. All measurements will be conducted according to relevant standards.

Data archiving must take both electronic and paper forms, and copies of all data must be provided to each project participant.

All electronic data and reports must also be copied on durable media such as CDs and copies of the CDs are to be stored in multiple locations.

The archives must include:

- copies of all original field measurement data, laboratory data, data analysis spreadsheets;
- estimates of the carbon stock changes in all pools and non-CO<sub>2</sub> GHG and corresponding calculation spreadsheets;
- GIS products; and
- copies of the measuring and monitoring reports.

### **9.3.3 Monitoring of project implementation**

Information must be provided, and recorded in the VCS-PD, to establish that:

- the geographic position of the project boundary is recorded for all areas of land;
- the geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This will be achieved by field survey (eg, using Geodetic coordinates) or by using georeferenced spatial data (eg, maps, GIS datasets, aerial photography, or georeferenced remote sensing images);
- commonly accepted principles of forest inventory and management are implemented;
- standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national forest monitoring or available from published handbooks or from the IPCC GPG LULUCF 2003 is recommended; and
- the project plan, together with a record of the plan as actually implemented during the project, must be available for validation or verification as appropriate.

### **9.3.4 Stratification**

This methodology requires that an ex ante stratification of the project area in the project scenario is described in the VCS-PD as documented in the timber harvest plan, or developed by project proponents through sampling in the project area.

The monitoring plan may include sampling to adjust the number and boundaries of the strata defined ex ante where an update is required because of:

- a) unexpected disturbances occurring during the project crediting period affecting differently various parts of an originally homogeneous stratum and/or
- b) forest management activities that are implemented in a way that affects the existing stratification in the project scenario.

Established strata may also be merged if the reasons for their establishment have disappeared.

### 9.3.5 Monitoring of actual carbon stock changes

Carbon stocks will be measured according to the stock assessment equations in this methodology with field sampling based on forest inventory methods. Various sources exist to assist with the design of a verifiable forest field inventory based on best practice for sampling, data management and analysis (Box 3).

In the project area (or areas) the inventory plan must be specified in the VCS-PD and include:

- a) adequate forest stratification, sample size estimation methods and consider uncertainty; and
- b) a sampling framework including sample size, plot size, plot shape and information to determine plot location.

To determine the sample size and allocation among strata, this methodology uses the most recent version of the tool for the “Calculation of the number of sample plots for measurements within A/R CDM project activities”<sup>44</sup> approved by the CDM Executive Board.

Carbon stock changes over time must be estimated by taking measurements in plots at each monitoring event. Monitoring events must take place at intervals of 5, or preferably 3 years. For intermittent years it is good practice to use extrapolations of trends as they have occurred up till that moment. Monitoring reports can use such extrapolated parameter values for the determination of net emissions by sources and removals resulting from the project.

The design of the sampling regime will be determined by the number of strata and timber harvest the baseline case.

### 9.3.6 Conservative approach and uncertainty

Project proponents will also apply all relevant equations for the ex-ante calculation of net anthropogenic GHG removals by sinks with care and provide transparent estimations for the parameters that are monitored during the project crediting period. These estimates must be based on measured or existing published data where possible and project proponents should retain a conservative approach; that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

An uncertainty analysis is required for all estimates from monitoring related to change in area, change in carbon stocks and emissions for both the baseline and project case.

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<sup>44</sup> [http://cdm.unfccc.int/methodologies/ARmethodologies/approved\\_ar.html](http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html)

**Box 3. Resource material for the design of forest field inventories**

IPCC Good Practice Guidance on Land Use, Land Use Change and Forestry (IPCC 2003)

<http://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf.html>

The Sourcebook for Land Use Change and Forestry Projects (Pearson et al. 2005)

[http://www.winrock.org/feature\\_ecosystem\\_200802.asp](http://www.winrock.org/feature_ecosystem_200802.asp)

Measurement guidelines for the sequestration of forest carbon (Pearson et al. 2007)

<http://www.nrs.fs.fed.us/pubs/3292>

Field Measurements for Forest Carbon Monitoring A Landscape-Scale Approach (Hoover. 2008)

The Winrock sampling calculator <http://www.winrock.org/Ecosystems/tools.asp?BU=9086>

The CDM A/R Methodological Tool “Calculation of the number of sample plots for measurements within A/R CDM project activities” (Version 02)

[http://cdm.unfccc.int/methodologies/ARmethodologies/approved\\_ar.html](http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html)

The California Climate Action Reserve Registry Forest Project Protocol (Version 2) 2009

<http://www.climateactionreserve.org/how-it-works/protocols/adopted-protocols/forest/forest-project-protocol-update/>

Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States (Smith et al. 2006)<http://nrs.fs.fed.us/pubs/8192>

A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects (MacDicken. 1997)

<http://www.winrock.org/fnrm/publications.asp?BU=9058>

## 10 REFERENCES AND OTHER INFORMATION

None.

## DOCUMENT HISTORY

Version	Date	Comment
v1.0	11 Feb 2011	Initial version released.
v1.1	10 Nov 2011	<p>Updates:</p> <ol style="list-style-type: none"> <li>1) In Equation 7 parameter <math>CEX_{i,k BSL}</math> was clarified to be the mean carbon stock of extracted timber per unit area in stratum <math>I</math>, for wood product type <math>k</math>.</li> <li>2) Section 4.1.2, was clarified that only individual trees, species and strata which were to be harvested in the baseline scenario may be modeled for on-going forest growth in the project scenario.</li> <li>3) Equation 21 was modified to clarify that net greenhouse gas emissions in the project scenario are a result of the sum of emission from disturbance minus the annual carbon stock change in the aboveground biomass of trees due to forest growth.</li> <li>4) Parameter BECFR was clarified to have the unit <math>t.d.m\ m^{-3}</math>.</li> </ol>
v1.2	27 Mar 2013	<p>Updates:</p> <p>The methodology was updated in order to comply with Section 4.5.3 of the <i>VCS AFOLU Requirements, v3.2</i>, which requires methodologies to set out criteria and procedures to reliably establish the pattern of carbon loss in the baseline scenario. Specifically, the methodology has been updated to account for a 10-year linear decay of the dead wood pool, an immediate release of the wood waste and short-term wood product pools and a 20-year linear decay of the medium-term wood product pool.</p>