VCS | VERIFIED CARBON STANDARD
A Global Benchmark for Carbon

Approved VCS Methodology VM0005

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Sectoral Scope 14

Methodology for Improved Forest Management: Conversion of Low Productive to High Productive Forest

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1 SOURCES

This methodology is written to conform with the VCS rules that apply to Improved Forest Management projects (conversion of low-productive forests to high-productive forests (LtHP)) and has been prepared by Silvestrum on behalf of Face the Future, both based in the Netherlands. The methodology draws on elements from VCS methodologies VM0007 and VM0011, and CDM methodology AR-ACM0002.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology facilitates the quantification of the net GHG benefits of Improved Forest Management projects in natural Evergreen Tropical Rainforests that achieve carbon benefits in one of, or a combination of, two activities:

- Avoiding emissions from re-logging of already logged-over forest; and,
- Rehabilitation of previously logged-over forest by cutting climbers and vines, or liberation thinning, or enrichment planting, or a combination of these activities.

The baseline scenario therefore consists of a logged-over natural Evergreen Tropical Rainforest, normally with no or insignificant regrowth, that may or may not be relogged. To determine the emissions in the baseline, the following components are quantified: volume of timber removed during relogging (expanded to include emissions from total associated biomass losses); the amount of dead wood left after relogging; the carbon stored in harvested wood products; if absence of regrowth cannot be substantiated, regrowth of the residual stand; and, emissions associated with the establishment of infrastructure and fuel consumption.

Because baselines often become counter factual once the project gets implemented, this methodology facilitates the quantification of the above components in two ways:

- On the basis of a-spatial data in a pre-relogging situation in the project area, in combination with, for instance, logging information in a management plan; or,
- By the determination of the carbon stock components after relogging has occurred in a reference area for which similarity to the project area is demonstrated.

The relationship between the two baseline options and the project area is then established by analyzing the logging rates in the various strata in the baseline, determining the same strata in the project area, and applying the stratum-specific logging rates to the strata in the project area.

The methodology allows for the use of both approaches together, if either of the two cannot be supported with a complete set of information, with the following examples: (1) While obtaining spatially explicit post-relogging carbon stock data from a reference area through direct measurements, spatially explicit pre-relogging data based on direct measurements may be lacking. Once the similarity of the reference area and the project area has been ensured, pre-relogging carbon stock data may also be obtained from the project area. (2) If spatially explicit pre-relogging carbon stock data based on direct measurements is lacking, similarity between the reference area and the project area may be justified by reconstructing pre-relogging carbon stocks from the post-relogging data of the reference area and harvesting volumes from management files of the forest management unit, and comparing these with pre-relogging carbon stock data from the project area. The validity of reconstructed pre-relogging carbon stocks may be supported by other inventory data of the reference area (eg, inventories of commercial timber prior to relogging), the supporting data being subject to the scrutiny of the validator. (3) While using a-spatial data for assessing baseline carbon stock changes, carbon stocks in dead wood may be derived from a reference area.

While ensuring conservative results for net GHG project benefits, these options support the implementation of FM project activities in areas where data collection has not been organized in such a way that it facilitates compliance *a priori* with international carbon standards, which is very often the case.

The with-project scenario constitutes the avoidance of relogging, or rehabilitation of previously logged-over forest, or both. Rehabilitation, if any, is achieved by cutting climbers and vines, or liberation thinning, or enrichment planting, or a combination of these activities. To determine the emissions and removals in the with-project scenario, the following components are quantified: carbon stocks before the intervention; increases in carbon stocks over time; and emissions due to site preparation and project implementation.

An additional feature of this methodology is the determination of the regrowth of the residual forest in both the baseline and the with-project scenario. If regrowth occurs in the baseline scenario this is assumed to be small compared to regrowth in the with-project scenario.

The removal of herbaceous vegetation (including climbers and vines) is deemed an insignificant emissions source and therefore is not accounted for in the with-project scenario.

The methodology also provides for the quantification of leakage.

Finally, the methodology provides for the determination of the project's net GHG benefits and the resulting Verified Carbon Units (VCUs) that are generated. The methodology details the steps necessary to come to the final calculation of the project's net GHG benefits, represented by ΔC_{IFM}.

$$\Delta C_{IFM} = \Delta C_{BSL} - \Delta C_{WPS} - \Delta C_{LK} \quad (1)$$

Where:

Parameter	Description
ΔC_{IFM}	Total net GHG emission reductions from the IFM project activity
ΔC_{BSL}	Sum of the carbon stock changes and greenhouse gas emissions under the baseline scenario
ΔC_{WPS}	Sum of the carbon stock changes and greenhouse gas emissions under the with-project scenario

ΔC_{LK}	Sum of the carbon stock changes and greenhouse gas emissions due to leakage

Thus, the basis of the methodology is the estimation of total carbon benefits from the IFM project activity as the result of the total carbon loss in the baseline scenario (ΔC_{BSL}) avoided due to the project activity and the net removals through the enhancement of forest growth due to liberation thinning and enrichment planting (ΔC_{WPS}), minus any leakage (ΔC_{LK}) that might occur.

Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS

This methodology does not use any methodology-specific definitions.

4 APPLICABILITY CONDITIONS

This methodology is applicable to Improved Forest Management (IFM) activities, as defined by the VCS rules.

Only areas that have been designated, sanctioned or approved for such activities (eg, as logging concessions) by the national or local regulatory bodies are eligible for crediting under this VCS Improved Forest Management (IFM) category.

In particular, this methodology is applicable to improved forest management practices that achieve the conversion of low-productive forest to high-productive forest (LtHP) through the protection of logged-over, degraded forest from further logging or the adoption of silvicultural techniques increasing the density of tree vegetation, or a combination of these activities.

This methodology is applicable to situations whereby the original forest is natural *Evergreen Tropical Rainforest*, using the FAO definition where the term “Evergreen Tropical Rainforest” is defined as follows: “Evergreen Tropical Rainforests occur where the annual rainfall is greater than 2,500 mm, where forests grow mostly at low elevations, are evergreen, luxuriant, predominantly of hardwood species, have a complex structure and are rich in both plants and animals. Soils tend to be mustow and poor in nutrients, features having a marked effect on forest management practices.”[1]

The applicability conditions for this methodology are the following:

- Project activities aim at the avoidance of relogging of logged-over, degraded natural Evergreen

[1] Source: http://www.fao.org/docrep/W8212E/w8212e03.htm#a definition of tropical forests

Tropical Rainforest, or the rehabilitation of logged-over natural Evergreen Tropical Rainforest through direct human intervention such as cutting of climbers and vines, liberation thinning and/or enrichment planting, or a combination of these activities;

- Land within the project area must have qualified as forest;
- In the baseline, the logged-over forest in the project area is unlikely to revert to normal regrowth patterns due to vines and climbers, which may include climbing bamboos, resulting from high-intensity logging operations in the past. In such cases, and subject to appropriate substantiation, regrowth of tree biomass before and following relogging in the baseline can be assumed to be zero. Where this is not the case, ex-ante estimates of regrowth must be made and monitoring of the baseline for ex-post confirmation of regrowth rates must be conducted;
- The soil carbon pool within the project boundary is either in a steady state at project commencement, or, if not, the soil carbon pool is only expected to increase more or decrease less in the with-project scenario in comparison to the baseline, and may therefore, conservatively be omitted;[2]
- Site preparation is carried out so as to avoid levels of soil disturbance or soil erosion sufficient to significantly reduce the soil carbon pool over the project lifetime;
- The use of nitrogen fertilizer in the project activities is prohibited;
- During the project crediting period, harvesting must not occur in the with-project scenario[3].
- Biomass burning, fuel gathering, removal of litter, or removal of dead wood do not occur in the baseline scenario and in the with-project scenario within the project boundary;
- A reference area may be used to derive relevant parameter values for the baseline scenario. This area must be of similar size as the project area, or larger (ie, 75% of the project area or more), for which similarity with the project area can be demonstrated using criteria outlined in this methodology, and for which it can be demonstrated that the management is not affected by its selection as a reference area; and,
- Flood irrigation or drainage of primarily saturated soils are not permitted as part of the project activity, so associated non-CO2 greenhouse gas emissions can be neglected.
- There is no peatland[4] within the project area or emissions associated with peatland are not significant.
- The methodology is not applicable to grouped projects.

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[2] Project proponents must use the A/R CDM approved tool 6 to demonstrate insignificance.

[3] If harvesting is planned or expected to occur after the project crediting period, the associated carbon sink reversal will be addressed in the non-permanence risk assessment.

[4] See VCS definition.

5 PROJECT BOUNDARY

5.1 Land eligibility and Geographic boundaries

No land use change is occurring in the project area: it is forest land remaining forest land. Where the activity takes place in a country that has adopted a forest definition under the Kyoto Protocol, those thresholds must be adhered to. Otherwise, the definition used in the national GHG Inventory must be used.

Only areas that have been designated, sanctioned or approved for such activities (eg, as logging concessions or plantations) by the national or local regulatory bodies are eligible for crediting under the VCS Improved Forest Management (IFM) category. This will be determined according to the legally sanctioned logging laws, regulations and codes of practice of the relevant national or sub-national regulatory authority. These laws may be defined in absolute terms (hectares) or via prescription (relative per cent). Areas within the project area, where logging has been prohibited due to environmental, cultural or other reasons, must be determined through maps and spatial analysis and be excluded from the estimations of emission reductions or removals.

The boundary of the IFM activity must be clearly delineated and defined and include only land qualifying as "forest".

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. Each discrete area of land must have a unique geographical identification.

When describing physical project boundaries (for both the project areas and, if any, the reference area), the following information must be provided per discrete area:

- Name of the project area (including compartment numbers, local name (if any)
- Unique identifier for each discrete parcel of land
- Map(s) of the area in digital format)
- Geographic coordinates obtained from a GPS or from a geo-referenced digital map)
- Total land area
- Details of forest land rights holder and user rights

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.

In this methodology, the project area (the geographic area in which the project activity is implemented) may exceed the area eligible for carbon accounting, ie, the forest area protected against relogging, rehabilited, or both. This may exclude areas that do not contain merchantable timber and/or that are inaccessible for legislative, technical or economic reasons. A justification for the in- or exclusion of areas within the project area must be provided in the project description of the actual project applying this methodology.

A reference area is an area that is representative of the project area in the baseline scenario and thus meets the criteria set out by the applicability conditions (minimum size) and those elaborated below (similarity to project area), where the volume of biomass that would have been removed from the project area over the lifetime of the project can be assessed.

5.2 Temporal boundaries

The temporal boundary for projects applying this methodology is equal to the project crediting period.

Project proponents must determine the project crediting period, the project crediting period start date and the project start date and provide verifiable evidence when the 1st monitoring period started and when the project begins to reduce or avoid GHG emissions.

5.3 Carbon pools

The carbon pools that must be included and that may be excluded from the project boundary are shown in Table 1.

Carbon pools and emissions sources may be neglected, ie, accounted as zero, if the application of the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities"[5] leads to the conclusion that the pool or emission source (see Table 2) is insignificant.

Table 1: Selection and justification of carbon pools

Carbon pools	Selected	Justification/Explanation of choice
Above-ground tree biomass	Yes	Major carbon pool assumed to significantly decrease in the baseline, or increase in the project, or both.
Above-ground non-tree biomass	No	Pool need not to be measured because it is not subject to significant changes or potential changes are transient in nature.
Below-ground biomass	Optional	Major carbon pool assumed to significantly decrease in the baseline, or increase in the project, or both. Not accounting for below-ground biomass is conservative.
Dead wood	Yes	Carbon pool likely to decrease as a result of the project

[5] Available at: http://cdm.unfccc.int/methodologies/ARmethodologies/tools/

		activity. Accounting for dead wood as zero in the with-project scenario is conservative. Accounting for dead wood occurring prior to re-logging as zero is conservative.
Litter	No	Conservative approach - unlikely to decrease as a result of the project activity, or increase in the baseline
Soil organic carbon	No	Conservative approach - unlikely to decrease as a result of the project activity, or increase in the baseline
Wood products	Yes	Carbon pool likely to decrease as a result of the project activity. Accounting for wood products as zero in the with-project scenario is conservative.

5.4 Greenhouse gases

The emissions sources included in or excluded from the project boundary are shown in Table 2. In addition, insignificance of sources can be determined by the tool referred to above.

Table 2: Gases considered from emissions by sources other than resulting from changes in stocks in carbon pools

Gas	Sources	Selected	Justification/explanation of choice
Carbon dioxide (CO_2)	Combustion of fossil fuel in vehicles / machinery	Yes or No	Included subject to materiality if relogging is the baseline activity
	Removal of herbaceous vegetation	No	Excluded based on VCS guidance
Methane (CH_4)	Combustion of fossil fuel in vehicles / machinery	Yes or No	Included as CO_2 equivalent emission if relogging is the baseline activity
	Burning of biomass	No	Not included – no burning allowed; not accounting for methane emissions in the baseline scenario is conservative
Nitrous oxide (N_2O)	Combustion of fossil fuel in vehicles / machinery	Yes or No	Included as CO_2 equivalent emission if relogging is the baseline activity
	Nitrogen based fertilizer	No	Not included – no use of fertilizer allowed

	Burning of biomass	No	Not included – no burning allowed; not accounting for N_2O emissions in the baseline scenario is conservative

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario must reflect what most likely would have occurred in the absence of the project. It consists of a logged-over natural Evergreen Tropical Rainforest, normally with no or insignificant regrowth that may or may not be relogged.

The following information must be provided to prove that the project proponent meets the minimum acceptable standards outlined for this baseline scenario:

- A documented history of the operator (operator must have at least 5 years of management records to show logging intensities and normal historical practices). Common records would include data on timber cruise volumes, inventory levels, harvest levels, etc. on the property that demonstrate what the normal practice in the area is. The documented history must also indicate the periodicity in logging operations in the area and in management planning (eg, interval between two subsequent logging coupes according to management plans (past or current) and in reality); and

- The legal requirements for forest management and land use in the area; however if these are not enforced then this requirement does not have to be met; and

- Proof that their environmental practices equal or exceed those commonly considered a minimum standard among similar landowners in the area.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

The project proponent must demonstrate that the project is additional through the use of the latest version of the VCS Tool for the Demonstration and Assessment of Additionality in IFM Project Activities*.*

8 STRATIFICATION

If the project activity area at the start of the project is not homogeneous, stratification may be carried out to improve the accuracy and the precision of carbon stock estimates. Different stratifications may be required for the baseline and with-project scenarios in order to achieve optimal accuracy of the estimates of net GHG emissions or removal.

Strata must be spatially discrete and defined on the basis of forest carbon stocks or expected changes in forest carbon stocks. Stratum sizes must be known. Areas of individual strata must sum to the total project area. Strata must be identified with spatial data (eg, maps, GIS coverage, classified imagery, or sampling grids) from which the area can be determined accurately. Land use/land cover maps in particular must be ground-truthed and current, less than 10 years old. Strata must be discernible taking into account good practice in terms of the accuracy requirements for the definition of strata limits / boundaries. This must be indicated in the project description and the choice must be justified.

For estimation of baseline net GHG emissions or removals, or estimation of project net GHG emissions or removals, strata must be defined on the basis of parameters that are key entry variables used to estimate changes in biomass stocks.

The project area may be stratified *ex ante*, and this stratification may be revised *ex post* for monitoring purposes. Strata need only reflect consistent differences in biomass stocks and not for example species composition or ecological variables. Established strata may be merged if reasons for their establishment have disappeared or have proven irrelevant to key variables for estimating forest carbon stocks or changes in forest carbon stocks.

For baseline net GHG emissions or removals: Stratification is carried out according to pre-project carbon stocks. This stratification must be determined prior to the project activity. For each stratum, assumptions must be made as to how the carbon stocks would be affected in the business as usual scenario. In case of relogging, this must be based on the relogging that has taken place in an appropriately selected reference area or on the basis of reliable management or logging plans for the project area indicating anticipated logging intensities. The remaining carbon stocks per stratum must be determined.

For project net GHG emissions and removals. The *ex-ante* estimations must be based on the project plan, which must include a timetable for and scheduling of the silvicultural interventions, such as for example liberation thinning and enrichment planting. The *ex-post* stratification must be based on the actual implementation of the projected activities. The *ex-post* stratification may be affected by natural or anthropogenic impacts if they add variability to growth pattern in the treated project area.

Baseline stratification must occur only once and remain fixed for the lifetime of the project, unless baseline monitoring occurs in a reference area.

Stratification in the with-project scenario must be updated at the time of each and every monitoring campaign prior to verification based on recent developments.

For *ex-ante* and *ex-post* stratification, project proponents may optionally make use of remote sensing data and analysis platforms acquired close to the time the project commences.

9 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

9.1 Baseline Emissions

9.1.1 General Approach

The baseline scenario is characterized by emissions from relogging, which in the with-project scenario are avoided, or an absent or limited regrowth of the residual forest, which in the with-project scenario may be enhanced, or a combination of these two.

If relogging occurs in the baseline scenario, the volume of biomass that would have been removed from the project area over the lifetime of the project can either be determined by:

1. Harvesting levels, defined in terms of cubic meters, as determined in advance and reflected for example in management plans for the project area; or

2. Post-relogging carbon stocks in a reference area.

In the first case above, the baseline net GHG emissions are estimated based on available information on the volume of timber removed and damage to the residual stand due to relogging, carbon storage in dead wood and harvested wood products, regrowth and project emissions.

'Harvested volume' or 'volume of timber removed' ($V_{harvest,i,j}$:) is measured as cubic meters removed from the forest and as reported in available information mostly based on for instance truck loads of timber that have been transported off-site. Most often timber is measured at the landing / yard before loading and freight bills accompany the timber to the place where it is transported to. Volumes are normally measured by authorities such as the Forest Department, or as a minimum inspected by such authorities, after which volumes of timber are reported. Volumes are normally calculated on the basis of diameter measurement on both sides of the log at the landing / yard with calipers and the length of the log, and specified per species.

In the second case, net emissions are estimated as the pre-relogging carbon stock minus the post-relogging carbon stock in biomass, dead wood and harvested wood products, taking also into account regrowth and project emissions.

Regrowth, if any, of the residual stand may be estimated on the basis of existing, peer-reviewed literature, quantifying regrowth in comparable areas, or in a reference area.

If a reference area is used for the estimation of baseline net GHG emissions or removals, this area is selected through the identification of areas where degradation and loss of biomass from relogging is expected to be similar to what would occur in the project area. Justification must be provided in the project description that the selected reference area is representative for the project area in the baseline scenario, and that the management of the reference area is not affected by its selection as such. The latter can be based on documented evidence that the planning of relogging occurred prior to the assignment as reference area by the IFM project proponent.

Alternatively, a sample of reference areas can be taken. The reference areas together must meet the criteria set out by the applicability conditions (minimum size) and those elaborated in this section (similarity to project area).

If emissions due to avoided timber harvesting in the baseline are determined based on activity levels in a reference area, project proponents must demonstrate that the quantification of avoided emissions in the with-project scenario is taking into account:

a. Similarity of strata and timber quantities:

Similar strata in the project area and in the reference area will have similar quantities of timber, and therefore, it can reasonably be assumed that logging intensities in those strata in the project area are the same as the logging intensity that took place in the reference area;

b. Areas for infrastructure establishment:

The same percentages of land are likely to be liberated for roads and log landings in the project area compared with the reference area; and,

c. Areas that do not contain merchantable timber and/or, are inaccessible for legislative, technical or economic reasons:

Such areas must be excluded from the area for which the changes in carbon stocks are estimated because they would have remained untouched in the baseline in any case.

Similarity of the reference area(s) to the project area can be demonstrated through meeting the following conditions, based on own measurements, literature recourses, datasets or a combination of these:

- Supporting comparable quantities of pre-relogging carbon stocks in above-ground woody biomass, or tree biomass with *DBH* ≥ 5 cm, and dead wood before relogging and comparable predicted yields of commercial timber (all ±20%). If project proponents conservatively choose not to account for dead wood in the with-project scenario, similarity for the dead wood carbon pools between the reference area and the project area does not need to be demonstrated. In case of a larger difference than 20%, the project proponent must demonstrate that due to a larger or smaller carbon stock in above-ground tree biomass and/or dead wood in the reference area compared to the project area the value for relogging carbon stock losses is at least underestimated and thus a conservative result for the net GHG benefits of the project is obtained (eg, if biomass in forest in the reference area is greater than in the project area and relogging rates will be the same). Supporting documentation may include geo-referenced data in one or more of the following: management and/or logging plans, measurement data, peer-reviewed literature, maps and/or remotely sensed footage; and

- Having been subjected to the same management regime for first-round logging, as evidenced in management and/or logging plans; and

- Having comparable legal rights and harvesting rights.

This methodology accounts for carbon stock in above-ground tree biomass (AGB), below-ground biomass (BGB – optional), dead wood (DW) and carbon stored in wood products (WP). However, $C_{BSLpre,i}$ and $C_{BSLpost,i}$ below refer only to the AGB and DW carbon pools. These stocks are estimated through fieldwork, possibly combined with carbon stock determination methods using aerial photography or remote sensing, or the use of peer-reviewed default factors for the project area. Below-ground biomass is not included in the calculation of $\Delta C_{REL,i,t}$ because that would result into an overestimation of CO_2 emissions due to relogging in the baseline scenario.

The net baseline GHG emissions and removals can be estimated through one of the two following approaches:

1. Using Pre-relogging A-spatial Data; and,

2. Using Post-relogging Mid to High Resolution Spatial Data.

In both cases, the net CO_2 equivalent emissions in the baseline will be determined as:

$$\Delta C_{BSL} = \sum_{t=1}^{t*} \sum_{i=1}^{M_{BSL}} \left(\Delta C_{REL,i,t} + \Delta C_{tree-exist,i,t} \right) + GHG_{BSL-E,t} \qquad (2)$$

Where:

Parameter	Description	Unit
ΔC_{BSL}	Net CO_2 equivalent emissions in the baseline scenario up to year *t**	t CO_2-e
$\Delta C_{REL,i,t}$	Net carbon stock change due to relogging in the baseline scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$\Delta C_{tree-exist,i,t}$	Net carbon stock change in existing tree vegetation[6] in the baseline scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$GHG_{BSL-E,t}$	Greenhouse gas emissions as a result of relogging within the project boundary in stratum *i* at year *t*	t CO_2-e yr^{-1}
i	1, 2, 3 …M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

9.1.2 Pre-relogging A-spatial Data for $\Delta C_{REL,i,t}$

Estimates of the levels of forest degradation and therefore biomass loss can be obtained based on a-spatial information contained in either management or logging plans, harvesting records, or in legal documentation for the concession. Preferably this information relates to the project area, but if such information is not available it can be obtained from a reference area, provided that similarity requirements as described above are met or that it results in an underestimated value of relogging carbon stocks losses and thus a conservative result for the net GHG benefits for the project. Loss of biomass is estimated through predicted volumes of timber removals per hectare combined with

6 With *DBH* ≥ 5 cm.

estimates of damage to the residual stand and carbon storage in wood products. The estimated post-relogging carbon stock in dead wood at year *t* is quantified as being emitted over 10 years with a linear decay function, following the procedure described in the VCS AFOLU Requirements v3.3, section 4.5.3.

$$\Delta C_{REL,i,t} = \left(\begin{array}{l} A_{REL,i,t} \times \left(C_{harvest,i} + \left(C_{damage,i} - C_{DW,i,t} \right) - \left(\mathrm{C}_{\mathrm{WP100,i}} + C_{WP20,i,t} \right) \right) \\ + \sum_{t-20}^{t} \left(A_{REL,i,t} \times C_{WP20,i,t} \times \frac{1}{20} \right) + \sum_{t-10}^{t} \left(A_{REL,i,t} \times C_{DW,i,t} \times \frac{1}{10} \right) \end{array} \right) \times \frac{44}{12} \quad (3)$$

Where:

Parameter	Description	Unit
$\Delta C_{REL,i,t}$	Net carbon stock change due to relogging in the baseline scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$A_{REL,i,t}$	Area relogged in baseline stratum *i* at year *t*	ha yr^{-1}
$C_{harvest,i}$	Carbon stock in harvested timber in stratum *i*	t C ha^{-1}
$C_{damage,i}$	Carbon loss due to damage to the residual stand in stratum *i*	t C ha^{-1}
$C_{DW,I,t}$	Post-relogging carbon stock in dead wood in the baseline scenario (stock emitted is quantified over 10 years with a linear decay function) in stratum *i* at year *t*	t C ha^{-1}
$C_{WP100,i}$	Post-relogging carbon stock stored in long-term wood products (stock remaining in wood products after 100 years) in the baseline scenario in stratum *i*	t C ha^{-1}
$C_{WP20,i,t}$	Post-relogging carbon stock stored in short-term and medium-term wood products (stock emitted is quantified over 20 years with a linear decay function) in the baseline scenario in stratum *i* at year *t*	t C ha^{-1}
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
44/12	The ratio of molecular weight of carbon dioxide to carbon	t CO_2-e t C^{-1}

If no relogging occurs, $\Delta C_{REL,i,t}$ is equal to zero and Equation 3 does not need to be used.

The actual or predicted volume of timber to be harvested from each stratum, is estimated via the below equations.

Carbon Stock in Harvested and Damaged Wood

$$C_{harvest,i} = \sum_{j=1}^{S}(V_{harvest,i,j} \times D_j \times CF) \quad (4)$$

Where:

Parameter	Description	Unit
$C_{harvest,i}$	Carbon stocks in harvested timber in the baseline scenario in stratum *i*	t C ha^{-1}
$V_{harvest,i,j}$	Volume of timber harvested in the baseline scenario of species *j* in stratum *i*	m^3 ha^{-1} yr^{-1}
D_j	Basic density of the harvested wood of species *j*	t d.m. m^{-3}
CF	Carbon fraction of dry matter[7]	t d.m.$^{-1}$
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
j	1, 2, 3 … *S* tree species	

$$C_{damage,i} = C_{harvest,i} \times f_{damage} \quad (5)$$

Where:

Parameter	Description	Unit
$C_{damage,i}$	Loss of carbon due to damage to the residual stand in the baseline scenario, in stratum *i*	t C ha^{-1}
$C_{harvest,i}$	Carbon stocks in harvested timber in the baseline scenario in stratum *i*	t C ha^{-1}
f_{damage}	Factor for damage to the residual stand caused by relogging	

7 IPCC default value = 0.50

i	1, 2, 3 … M_{BSL} strata in the baseline scenario	

C_{damage} represents all carbon in damaged biomass, including dead wood, resulting from logging. Accounting for C_{damage} as zero in the baseline scenario is therefore conservative and in this case accounting for C_{DW} can be omitted as well. If project proponents want to account for C_{damage}, both C_{damage} and C_{DW} must be estimated.

f_{damage} must be determined using appropriate measurement techniques such as those described in the project description of the Noel Kempff Mercado Climate Action Project (NKM-CAP), version 02.02, dated 7/11/2005, or other similar established emission quantification approaches. Alternatively, peer reviewed literature may be used to derive f_{damage} from areas for which it can be shown that they are representative for the project area or general f_{damage} proxies for natural Evergreen Tropical Rainforests for conventional and/or Reduced Impact Logging (eg, Pulkki (1997)).

If C_{DW} for the project area cannot be derived from peer-reviewed literature, data can be obtained using appropriate measurement techniques applied in areas for which it can be shown that they are representative for the project area. The method for estimating the carbon stock in dead wood from field measurements is outlined below.

Harvested Wood Products

In line with the VCS guidelines on wood products, long-term storage in this pool is accounted for using the below equations. In case no reliable assumptions can be made as to the timber classes of the harvested wood and its end use, general information from Forest Departments from that area reflecting breakdown of timber classes as they are normally harvested from this forest type and area may be used (eg, plywood, round logs, sawn timber, etc.).

This methodology follows the conceptual framework detailed in Winjum *et al.* (1998).[8]

Step 1: Estimate the biomass carbon of the volume extracted by wood product type *ty* at year *t* from within the project boundary:

$$C_{XB,ty,i,t} = \frac{1}{A_i} \times \sum_{j=1}^{S} \left(V_{ex,ty,j,i,t} \times D_j \times CF \right) \quad (6)$$

8 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

Where:

Parameter	Description	Unit
$C_{XB,ty,i,t}$	Mean stock of extracted biomass carbon by class of wood product *ty* from stratum *i* at year *t*	t C ha^{-1}
A_i	Total area of stratum *i*	ha
$V_{ex,ty,j,i,t}$	Volume of timber extracted from within stratum *i* (does not include slash left onsite) by species *j* and wood product class *ty* at year *t*	m^3
D_j	Mean wood density of species *j*	t d.m.m^{-3}
CF	Carbon fraction of biomass	t C t^{-1} d.m.
t	1, 2, 3, … t^* years elapsed since the project start	
j	1, 2, 3 … *S* tree species	
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other	

<u>Mean wood density of species (Dj)</u>

Values for *Dj* can be taken from tables generally used in the local or regional timber and forest industry, or from peer-reviewed literature applicable to the region. If no species-specific values for *Dj* are available, the average value across all species can be used, increased by 20% to ensure a conservative (higher) estimate of $C_{WP100,i,t}$ and $C_{WP20,i,t}$ below.

Step 2: Estimate the proportion of biomass carbon extracted at year *t* that remains sequestered in long-term wood products after 100 years, and estimate the proportion of biomass carbon extracted at year *t* that is expected to be emitted from short-term and medium-term wood products over 20 years with a linear decay function.

$$C_{WP100,i,t} = \sum_{s,w,oir,p,o}^{ty} C_{XB,ty,i,t} \times (1 - ww_{ty}) - C_{WP20,i,t} \qquad (7a)$$

$$C_{WP20,i,t} = \sum_{s,w,oir,p,o}^{ty} \left(\left(C_{XB,ty,i,t} \times slp_{ty} \right) + \left(C_{XB,ty,i,t} \times \left(1 - slp_{ty} \right) \times fo_{ty} \right) \right) \qquad (7b)$$

Where:

Parameter	Description	Unit
$C_{WP100,i,t}$	Carbon stock in long-term wood products pool (stock remaining in wood products after 100 years) in stratum *i* at year *t*	t C ha^{-1}
$C_{WP20,i,t}$	Post-relogging carbon stock in short-term and medium-term wood products pool (stock emitted is quantified over 20 years with a linear decay function) in the baseline scenario in stratum *i* at year *t*	t C ha^{-1}
$C_{XB,ty,i,t}$	Mean stock of extracted biomass carbon by class of wood product *ty* from stratum *i* at year *t*	t C ha^{-1}
ww_{ty}	Wood waste fraction. The fraction immediately emitted through mill inefficiency	
slp_{ty}	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest	
fo_{ty}	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest	
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other	
i	*1, 2, 3, …* M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

Wood waste fraction (ww_{ty}):

Winjum *et al*. (1998) indicate that the proportion of extracted biomass ($C_{XB,ty}$) that is oxidized (burning or decaying) from the production of commodities to be equal to 19% for developed countries and 24% for developing countries. The fraction ww_{ty} is therefore equal to 0.19 for developed countries and 0.24 for developing countries.

Short-lived proportion (slp)

Winjum *et al.* (1998) give the following proportions for wood products with short-term (<5 yr) uses (*slp*) after which they are retired and oxidized (applicable internationally):

Wood Product Class	slp
Sawnwood	0.2
Woodbase panels	0.1
Other industrial roundwood	0.3
Paper and Paperboard	0.4

The methodology makes the assumption that all other classes of wood products are 100% oxidized within 5 years.

Additional oxidized fraction (fo)

Winjum *et al*. (1998) gives annual oxidation fractions for each class of wood products split by forest region. This methodology uses the fractions for tropical wood products, projected over 95 years to give the additional proportion that is oxidized between the 5th and 100th years after initial harvest:

Wood Product Class	*fo* (tropical)
Sawnwood	0.84
Woodbase panels	0.97
Other industrial roundwood	0.99
Paper and paperboard	0.99

9.1.3 Post-relogging Mid to High Resolution Spatial Data for $\Delta C_{REL,i,t}$

Where available, spatial data from a reference area that has undergone relogging can be combined with field sampling to produce post-relogging values of remaining biomass and dead wood. In case a sample of various reference areas is taken, the equation below provides for the calculations to be performed for each stratum *i* in these reference areas. The outcome of the equation must be the weighted average across similar strata in all reference areas, where the weighing factor is the total area of stratum *i* in each of the reference areas.

$$\Delta C_{REL,i,t} = \begin{pmatrix} A_{REL,i,t} \times \left(C_{BSLpre,i} - \left(C_{BSLpost,i} + \left(C_{DW,i,t} - C_{DWpre,i,t}\right) + \mathrm{C}_{\mathrm{WP100,i}} + C_{WP20,i,t}\right)\right) \\ + \sum_{t-20}^{t}\left(A_{REL,i,t} \times C_{WP20,i,t} \times \frac{1}{20}\right) + \sum_{t-10}^{t}\left(A_{REL,i,t} \times \left(C_{DW,i,t} - C_{DWpre,i,t}\right) \times \frac{1}{10}\right) \end{pmatrix} \times \frac{44}{12} \qquad (8)$$

Where:

Parameter	Description	Unit
$\Delta C_{REL,i,t}$	Net carbon stock change due to relogging in the baseline scenario in stratum *i* at year *t*	$t\ CO_2\text{-}e\ yr^{-1}$
$A_{REL,i,t}$	Area relogged in baseline stratum *i* at year *t*	$ha\ yr^{-1}$
$C_{BSLpre,i}$	Pre-relogging carbon stock in above-ground biomass in the baseline scenario in stratum *i*	$t\ C\ ha^{-1}$
$C_{DWpre,I,t}$	Pre-relogging carbon stock in dead wood (stock emitted is quantified over 10 years with a linear decay function) in stratum *i* at year *t*	$t\ C\ ha^{-1}$
$C_{BSLpost,i}$	Post-relogging carbon stock in above-ground biomass in the baseline scenario in stratum *i*	$t\ C\ ha^{-1}$
$C_{DW,i,t}$	Post-relogging carbon stock in dead wood in the baseline scenario (stock emitted is quantified over 10 years with a linear decay function in stratum *i* at year *t*	$t\ C\ ha^{-1}$
$C_{WP100,i}$	Carbon stock in long-term wood products pool (stock remaining in wood products after 100 years) in stratum *i* at year *t*	$t\ C\ ha^{-1}$
$C_{WP20,i,t}$	Post-relogging carbon stock in short-term and medium-term wood products pool (stock emitted over 20 years with a linear decay function) in the baseline scenario in stratum *i* at year *t*	$t\ C\ ha^{-1}$
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
44/12	The ratio of molecular weight of carbon dioxide to carbon	$t\ CO_2\text{-}e\ t\ C^{-1}$

If no relogging occurs, $\Delta C_{REL,i,t}$ is equal to zero and Equation 8 does not need to be used.

<u>Pre-relogging Carbon Stocks in Above-ground Tree Biomass</u>

Above-ground tree biomass carbon stocks prior to relogging ($C_{BSLpre,i}$) can be determined on the basis of previously conducted fieldwork or surveys or peer-reviewed proxies in the reference area. They can be estimated using the method outlined in Estimation of $\Delta C_{AGB,i,t}$.

In case data for $C_{BSLpre,i}$ cannot be obtained from the reference area (eg, because relogging has already occurred throughout the reference area), such information may also be obtained from parts of the project area that have not been treated with silvicultural techniques. Or, in case for the reference area data on $C_{BSLpost,i}$ and harvesting levels are available, $C_{BSLpre,i}$ can be approximated by the following equation:

$$C_{BSLpre,i} = C_{BSLpost,i} + C_{harvest,i} + C_{damage,i} \quad (9)$$

Values for $C_{harvest,i}$ and $C_{damage,i}$ must be obtained from management or logging plans, harvesting records and peer-reviewed literature as described previously.

Post-relogging Carbon Stocks in Above-ground Tree Biomass

$C_{BSLpost,i}$ can be estimated using the method outlined in Estimation of $\Delta C_{AGB,i,t}$ below.

Carbon Stock in Dead Wood

Estimating the baseline carbon stocks in dead wood as a result of relogging comprises of two components – *standing dead wood* and *lying dead wood*, both of which are estimated through field measurements within permanent sample plots. The methods for each of these two components are detailed below. Accounting for dead wood occurring prior to relogging as zero is conservative.

Standing Dead Wood

Step 1: Standing dead trees must be measured using the same techniques and criteria (eg, minimum *DBH*) used for measuring living trees, taking account of equations provided in Step 3. Stumps must be inventoried as if they are very short standing dead trees.

Step 2: The decomposition class (not to be confused with dead wood density class) of the dead tree must be recorded and the standing dead wood is categorized under two decomposition classes:

1. Tree with branches and twigs that resembles a live tree (except for leaves);
2. Tree with signs of decomposition (other than loss of leaves) including loss of twigs, branches, or crown.

Step 3: Biomass is estimated using an allometric equation or BEF calculation for live trees in the decomposition class 1; with no outward signs of decomposition (ie, twigs remaining) wood density is assumed to be comparable to live tree. Calculations for dealing with above-ground tree biomass are described above. In decomposition class 2, the estimate of biomass should be limited to the main trunk (bole) of the tree, in which case the biomass is calculated converting volume to biomass using the appropriate dead wood density class. Volume is estimated as either the volume of a cone if the top diameter cannot be measured (and is assumed to be zero), or a cylinder if the top diameter can be measured directly or by using an instrument such as a relascope or laser inventory instrument. Height/length is determined as either the total height in case of a standing bole or the height at the base of the crown if the crown is persistent[9].

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[9] It is conservative and, therefore, acceptable to take the normal species' wood densities in case dead wood

For decomposition class 2, the biomass of standing dead trees is estimated as:

$$B_{SDW,l,sp,i,t} = \frac{1}{3} \times \pi \times \left(\frac{BDia_{SDW,l,sp,i,t}}{200} \right)^2 \times H_{SDW,l,sp,i,t} \times D_{DW,dc} \quad (10)$$

Where:

Parameter	Description	Unit
$B_{SDW,l,sp,i,t}$	Biomass of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*;	t d.m.
$BDia_{SDW,l,sp,i,t}$	Basal diameter of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*;	cm
$H_{SDW,l,sp,i,t}$	Height of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*	m
$D_{DW,dc}$	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3);	t d.m. m^{-3}
sp	1, 2, 3 … P_i sample plots in stratum *i*	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … years elapsed since the start of the project activity	
l	1, 2, 3 … $N_{i,sp,t}$ standing dead trees in sample plot *sp* of stratum *i* at year *t*	

or (where top diameter is measured):

$$B_{SDW,l,sp,i,t} = \frac{BDia_{SDW,l,sp,i,t} + TD_{SDW,l,sp,i,t}}{200} \times H_{SDW,l,sp,i,t} \times D_{DW,dc} \quad (11)$$

Where:

Parameter	Description	Unit
$B_{SDW,l,sp,i,t}$	Biomass of standing dead tree *l* from sample plot *sp* in stratum	t d.m.

density classes are not known.

	i at year *t*;	
$BDia_{SDW,l,sp,i,t}$	Basal diameter of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*;	cm
$TD_{SDW,l,sp,i,t}$	Top diameter of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*	cm
$H_{SDW,l,sp,i,t}$	Height of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*	m
$D_{DW,dc}$	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3);	t d.m. m^{-3}
sp	1, 2, 3 … P_i sample plots in stratum *i*	
I	1, 2, 3 … M_{BSL} strata in the baseline scenario	
T	1, 2, 3 … years elapsed since the start of the project activity	
I	1, 2, 3 … $N_{i,sp,t}$ standing dead trees in sample plot *sp* of stratum *i* at year *t*	

In selecting one of the 2 approaches provided above, project proponents must ensure that in the baseline scenario conservative estimates for dead wood are obtained.

Step 4: Estimate total carbon stock in standing dead trees present in the sample plot *sp* in stratum *i* at year *t*.

$$B_{SDW,sp,i,t} = \sum_{l=1}^{N_{sp,i,t}} B_{SDW,l,sp,i,t} \qquad (12)$$

Where:

Parameter	Description	Unit
$B_{SDW,sp,i,t}$	Biomass of standing dead wood in sample plot *sp* in stratum *i* at year *t*;	t d.m
$B_{SDW,l,sp,i,t}$	Biomass of standing dead tree *l* in sample plot *sp* in stratum *i* at year *t*;	t d.m
sp	1, 2, 3 … P_i sample plots in stratum *i*	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	

t	1, 2, 3 … *t** years elapsed since the start of the project activity	
$N_{sp,i,t}$	Number of standing dead trees in sample plot *sp* of stratum *i* at year *t*	
l	1, 2, 3 … $N_{i,sp,t}$ standing dead trees in sample plot *sp* of stratum *i* at year *t*	

Step 5: Estimate the mean biomass stock per unit area in standing dead wood for each stratum at year *t*:

$$B_{SDW,i,t} = \frac{1}{A_{sp,i,t}} \times \sum_{sp=1}^{P_i} B_{SDW,sp,i,t} \quad (13)$$

Where:

Parameter	Description	Unit
$B_{SDW,i,t}$	Biomass of standing dead wood in stratum *i* at year *t*	t d.m. ha^{-1}
$B_{SDW,sp,i,t}$	Biomass of standing dead wood in sample plot *sp* in stratum *i* at year *t*	t d.m
$A_{sp,I,t}$	Total area of all sample plots in stratum *i* in year *t*	ha
sp	1, 2, 3 … P_i sample plots in stratum *i*	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Lying Dead Wood

Step 1: Lying dead wood can be sampled using the line intersect method of Harmon and Sexton (1996)[10] or other peer reviewed and published methods. Harmon and Sexton prescribe two 50-meter lines to be established bisecting each sample plot and the diameters of the lying dead wood (≥ 10 cm diameter) intersecting the lines are measured.

[10] Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of wood detritus in forest ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

Step 2: The dead wood is assigned to one of the three density states (sound, intermediate and rotten) using the 'machete test', as recommended by *IPCC Good Practice Guidance for LULUCF* (2003), Section 4.3.3.5.3.

Step 3: The volume of lying dead wood per unit area is estimated using the equation (Warren and Olsen 1964)[11] as modified by Van Wagner (1968)[12] separately for each density state:

$$V_{LDW,i,t} = \frac{\pi^2 \times \left(\sum_{n=1}^{N} Dia_{n,i,t}{}^2 \right)}{8 \times L} \quad (14)$$

Where:

Parameter	Description	Unit
$V_{LDW,i,t}$	Volume of lying dead wood per unit area in stratum *i* at year *t*	$m^3\ ha^{-1}$
$Dia_{n,i,t}$	Diameter of piece *n* of dead wood along the transect in stratum *i* at year *t*	cm
n	1, 2, 3 … *N* wood pieces intersecting the transect	
L	Length of the transect	m
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

To convert this to a mass per unit area multiply the volumes of each density state by their respective wood densities as outlined below:

Step 4: Volume of lying dead wood must be converted into biomass using the following relationship:

$$B_{LDW,i,t} = \sum_{dc=1}^{3} V_{LDW,i,t} \times D_{DW,dc} \quad (15)$$

11 Warren, W.G. and Olsen, P.F. (1964) A line intersect technique for assessing logging waste. *Forest Science* 10: 267-276.

12 Van Wagner, C.E. (1968). The line intersect method in forest fuel sampling. *Forest Science* 14: 20-26.

Where:

Parameter	Description	Unit
$B_{LDW,i,t}$	Biomass of lying dead wood per unit area in stratum *i* at year *t*	t d.m. ha^{-1}
$V_{LDW,i,t,}$	Volume of lying dead wood per unit area in stratum *i* at year *t*	m^3 ha^{-1}
$D_{DW,dc}$	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3)	t d.m. m^{-3}
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Total carbon stock in dead wood for each stratum is then calculated as the sum of standing and lying dead wood components.

$$C_{DW,i,t} = \left(\left(B_{SDW,i,t} + B_{LDW,i,t}\right) \times CF_{DW}\right) \quad (16)$$

Where:

Parameter	Description	Unit
$C_{DW,i,t}$	Carbon stock of dead wood in stratum *i* at year *t*	t C ha^{-1}
$B_{SDW,i,t}$	Biomass of standing dead wood in stratum *i* at year *t*	t d.m. ha^{-1}
$B_{LDW,i,t}$	Biomass of lying dead wood in stratum *i* at year *t*	t d.m. ha^{-1}
CF_{DW}	0.5 Default carbon fraction of dry matter in dead wood	t C t d.m.$^{-1}$
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

<u>Carbon stocks in Wood Products</u>

The procedure to determine the carbon stocks stored in wood products in the baseline scenario is provided in the previous section.

9.1.4 Logging rate

To estimate the baseline net carbon loss for the entire project area, the total net loss of carbon in the baseline scenario for relogged strata as estimated using one of the above methods, must be multiplied with the rate at which logging would have occurred across the project area. Where a management plan exists outlining the phasing of logging activities for either the project area, or the reference area, that management plan may be used.

$$A_{i,t} = D\%_{i,t} \times A_{TOT,i} \quad (17)$$

Where:

Parameter	Description	Unit
$A_{i,t}$	Area logged in stratum *i* at year *t*	ha
$D\%_{i,t}$	Projected annual proportion of land that will be logged in stratum *i* at year *t*. If actual annual proportion is known and documented (eg, 25% per year for 4 years), set to proportion	% yr^{-1}
$A_{TOT,i}$	Total area logged in stratum *i*	ha
i	1, 2, 3 …M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

Where no rate is available, it can be established through an examination of a reference area. This is done using the below equation:

$$D\%_{planned,i,t} = \sum_{pn=1}^{pn^*} \left(\left(D\%_{pn,i} \big/ Yrs_{pn} \right) \big/ n \right) \quad (18)$$

Where:

Parameter	Description	Unit
$D\%_{planned,i,t}$	Projected annual proportion of land that will be logged in stratum *i* at year *t*. If the actual annual proportion is known and documented (eg, 25% per year for 4 years), set to proportion	% yr^{-1}
$D\%_{pn,i}$	Percent of logged area in land parcel *pn* in stratum *i* of the	%

	reference area	
Yrs_{pn}	Number of years over which relogging occurred in land parcel *pn* in the reference area	yr
pn	1, 2, 3 … pn^* land parcels in the reference area	
n	Total number of land parcels examined	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	

9.1.5 Forest Regrowth

If no or insignificant regrowth occurs following first and subsequent logging, eg, due to the complete colonization by climbers and vines, this must be demonstrated by sampling above-ground carbon stocks in woody biomass in a time series of logging coupes (eg, in tranversal studies). The length of the time series must not be shorter than 75% of the length of the project crediting period.

When accounting for regrowth, *ex-ante* estimates of tree biomass regrowth in the baseline can be based on peer-reviewed literature providing values for regrowth from comparable residual forest types in comparable areas.

If regrowth occurs in the baseline scenario this is assumed to be small compared to regrowth in the with-project scenario. Furthermore, regrowth in the relogged residual stand is assumed to be smaller than regrowth in the pre-relogged residual stand. Therefore, as a conservative approach, the regrowth in the baseline case is estimated as the regrowth of the pre-relogged residual forest applied to the entire area of the stratum, despite any relogging in that stratum.

Estimates of changes in carbon stocks due to regrowth of tree biomass in the baseline, can be obtained from a (part of a) reference area that has not been relogged, or from parts of the project area that have not been treated with silvicultural techniques, as follows:

$$\Delta C_{tree-exist,i,t} = A_{i,t} \times \sum_{j=1}^{S} \Delta C_{tree-exist,j,i,t} \quad (19)$$

Where:

Parameter	Description	Unit
$\Delta C_{tree\text{-}exist,i,t}$	Change in carbon stock in existing tree vegetation[13] in the	$t\ CO_2\text{-}e\ yr^{-1}$

[13] With *DBH* ≥ 5 cm.

	baseline in stratum *i* at year *t*	
$A_{i,t}$	Area of baseline stratum *i* at year *t*	ha
$\Delta C_{tree\text{-}exist,j,i,t}$	Change in carbon stock in existing tree vegetation in the baseline in species *j* in stratum *i* at year *t*	t CO_2-e ha^{-1} yr^{-1}
j	1, 2, 3 … *S* tree species	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

$\Delta C_{tree\text{-}exist,j,i,t}$ is estimated as follows:

$$\Delta C_{tree-exist,j,i,t} = \Delta C_{tree-exist-AB,j,i,t} + \Delta C_{tree-exist-BB,j,i,t} \quad (20)$$

Where:

Parameter	Description	Unit
$\Delta C_{tree\text{-}exist,j,i,t}$	Change in carbon stock in existing tree vegetation in the baseline in species *j* in stratum *i* at year *t*	t CO_2-e ha^{-1} yr^{-1}
$\Delta C_{tree\text{-}exist\text{-}AB,j,i,t}$	Change in above-ground carbon stock in trees in the baseline in species *j* in stratum *i* at year *t*	t CO_2-e ha^{-1} yr^{-1}
$\Delta C_{tree\text{-}exist\text{-}BB,j,i,t}$	Change in below-ground carbon stock in trees in the baseline in species *j* in stratum *i* at year *t*	t CO_2-e ha^{-1} yr^{-1}
j	1, 2, 3 … *S* tree species	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

To estimate $\Delta C_{tree\text{-}exist\text{-}AB,j,i,t}$ see subsection: “Changes in C Stock in Above-ground Tree Biomass”. The inclusion of below-ground biomass is optional. If below-ground biomass is included, $\Delta C_{tree\text{-}exist\text{-}BB,j,i,t}$ can be estimated as in subsection: “Changes in C Stock in Below-ground Tree Biomass”.

9.1.6 Estimation of the Carbon Stock in Trees at t0

The carbon stock in tree biomass at t0 is defined as $C_{AGB,i,t}$ (plus optionally below-ground biomass by using a root:shoot ratio as defined above) at t0 and can be estimated as follows.

1. As $C_{BSL,pre,i}$
2. Based on an inventory of above-ground tree carbon stocks from Parts of the project area that have not been treated with silvicultural techniques.

9.1.7 Baseline Activity Emissions

A number of emission sources can arise from the implementation of baseline activities. Project proponents may choose to omit accounting for those sources as that leads to conservative estimates of the overall carbon benefits of the project.

Possible emission sources include, but may not be limited to: timber harvesting/logging operations, emissions due to infrastructure establishment, log extraction and transport of logs to the wharf for export or to the local sawmill or to the local depot for onwards sale.

This methodology does not foresee in the quantification of emissions due to timber procession, whether it is grid or generator powered.

Therefore, the emissions associated with activities in the baseline are estimated as:

$$GHG_{BSL\text{-}E,t} = E_{clearing,t} + E_{harvesting,t} + E_{extraction,t} + E_{transport,t} \quad (21)$$

Where:

Parameter	Description	Unit
$GHG_{BSL\text{-}E,t}$	Baseline emissions from sources in the baseline scenario at year *t*	t CO_2-e yr^{-1}
$E_{clearing,t}$	Emissions due to the new establishment of infrastructure such as the construction of roads or log landings for baseline logging at year *t*	t CO_2-e yr^{-1}
$E_{harvesting,t}$	Emissions due to the harvesting operations such as felling and debranching, etc. at year *t*	t CO_2-e yr^{-1}
$E_{extraction,t}$	Extraction of logs from the tree stump to the log landing at year *t*	t CO_2-e yr^{-1}
$E_{transport,t}$	Emissions due to transport of the logs from the log landing to the wharf for export, the sawmill, or to the depot for onward sale at year *t*	t CO_2-e yr^{-1}
t	1, 2, 3, … t^* years elapsed since the project start	

$E_{clearing,t}$: Emissions due to clearing of the area for infrastructure establishment

Emissions due to the establishment of infrastructure such as the construction of roads and log landings is estimated by considering the emissions due to the removal of biomass, the emissions from the equipment used to remove the biomass and the emissions from the equipment used to grade the roads (fuel emissions).

$$E_{clearing,t} = E_{biomass,t} + E_{felling,t} + E_{grading,t} \quad (22)$$

Where:

Parameter	Description	Unit
$E_{clearing,t}$	Emissions due to the establishment of infrastructure at year *t*	t CO_2-e yr^{-1}
$E_{biomass,t}$	Emissions due to the removal of the biomass itself at year *t*	t CO_2-e yr^{-1}
$E_{felling,t}$	Emissions due to the equipment use for felling the biomass (fuel emissions) at year *t*	t CO_2-e yr^{-1}
$E_{grading,t}$	Emissions due to the equipment used for the grading of the roads (fuel emissions) at year *t*	t CO_2-e yr^{-1}

To determine the emissions due to the removal of the biomass present at locations where infrastructure is being established, the area used for such purposes needs to be determined. This can be done on the basis of remote imagery (photographs or satellite) or by using a reported percentage that is typical for the area. Such a percentage has to be derived from peer-reviewed literature applicable to the area, or from Pulkki (1997) who reported for conventional logging in Evergreen Tropical Rainforests, a conservative percent of area cleared for infrastructure of 12%.[14]

To estimate the emissions from the removal of the biomass the area can be multiplied by an average carbon stock value per hectare that is representative of the project area.

Emissions due to the loss of biomass from felling is quantified as follows:

$$E_{biomass,t} = C_{biomass} \times A_{infrastructure,t} \times (44/12) \quad (23)$$

[14] Pulkki, R.E. (1997). Literature synthesis on logging impacts in moist tropical forests. FAO Working Paper GFSS/WP/06. Here a range of 12-17% is reported and hence for the baseline scenario a value of 12% is considered conservative.

Where:

Parameter	Description	Unit
$E_{biomass,t}$	Emissions due to the removal of the biomass on the area dedicated to infrastructure at year *t*	t CO_2-e yr^{-1}
$C_{biomass}$	Carbon in biomass lost due to the clearing for infrastructure	t C ha^{-1}
$A_{infrastructure,t}$	Area designated for infrastructure at year *t*	ha yr^{-1}
44/12	The ratio of molecular weight of carbon dioxide to carbon	t CO_2-e t C^{-1}

$C_{biomass}$ equals the area-weighed C_{BSLpre}, see Equation 45.

$E_{felling,t}$: emissions due to the use of equipment for the removal of the biomass

Emissions due to the use of equipment for the removal of biomass are quantified as follows:

$$E_{felling,t} = FC_{equip} \times EF_{fuel} \times V_{infrastructure,t} \quad (24)$$

Where:

Parameter	Description	Unit
$E_{felling,t}$	Emissions due to the use of equipment for removal of the biomass on the area dedicated to infrastructure at year *t*	t CO_2-e yr^{-1}
FC_{equip}	Fuel consumption of equipment employed for felling	kL m^{-3}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$V_{infrastructure,t}$	Volume of trees felled to clear the area designated for infrastructure at year *t*	m^3 yr^{-1}

$E_{grading,t}$: emissions due to the use of equipment for the grading of the roads

Emissions due to the use of equipment for grading roads are quantified as follows:

$$E_{grading,t} = FC_{grader} \times EF_{fuel} \times A_{infrastructure,t} \quad (25)$$

Where:

Parameter	Description	Unit
$E_{grading,t}$	Emissions due to road grading at year *t*	t CO_2-e yr^{-1}
FC_{grader}	Fuel consumption of equipment employed for road grading	kL ha^{-1}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$A_{infrastructure,t}$	Area designated for infrastructure at year *t*	ha yr^{-1}

$E_{harvesting,t}$: emissions due to the extraction of logs from the forest

Emissions are estimated as:

$$E_{harvesting,t} = FC_{equip} \times EF_{fuel} \times V_{harvested,t} \quad (26)$$

Where:

Parameter	Description	Unit
$E_{harvesting,t}$	Emissions due to harvesting at year *t*	t CO_2-e yr^{-1}
FC_{equip}	Fuel consumption of the equipment employed for harvesting	kL m^{-3}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$V_{harvested,t}$	Volume harvested at year *t*	m^{-3} yr^{-1}

Volume harvested in the baseline is determined through Section 9.1.

This methodology in Section 9.1 facilitates the quantification of the volume harvested in two ways:

- On the basis of a-spatial data in a pre-relogging situation in the project area (for instance on the basis of information in a management plan); or,
- By the determination of the four components after relogging has occurred in a reference area for which similarity to the project area is demonstrated.

This quantification exercise determines amongst other the relationship between cubic meters of timber removed/harvested in the baseline. The correlation between the two baseline options and the project area is established by analyzing the logging rates in the various strata in the baseline, determination of the same strata in the project area, and the application of the stratum specific logging rates to the strata in the project area. This is a valid approach because the reference area is subjected to strict selection criteria that ascertain similarity to the project area. That parameter value determined by this approach is also used in this section as the harvested volume.

Alternatively, $E_{harvesting,t}$ can be determined on the basis of fuel consumed by the company for the purpose of its felling and debranching activities.

As default fuel consumption (FC) 1.28 – 1.73 liter per m^3 can be used. For new and efficient machinery the parameter value of 1.28 can be applied. For old and inefficient machinery 1.73 must be used.

$E_{extraction,t}$: emissions due to the extraction of the timber

Timber extraction from the forest to the log landing can be conducted with various types of machines. This methodology provides a quantification approach for extraction with medium sized bulldozers for transport to road side and trucks or trailers for transport to the log landings.

Emissions from log extraction and transport to log landing are estimated as:

$$E_{extraction,t} = (D_{extr\_total} / Eff_{fuel}) \times EF_{fuel} \quad (27)$$

$$D_{extr\_total} = D_{aver\ extrac} \times N_{trucks} \times 2 \quad (28)$$

$$N_{trucks} = V_{extr} / Cap_{truck} \quad (29)$$

Where:

Parameter	Description	Unit
$E_{extraction,t}$	Emissions due to extraction of timber from the forest to the log landings at year *t*	t CO_2-e yr^{-1}
D_{extr_total}	Total timber extraction distance	km
Eff_{fuel}	Fuel efficiency for medium-sized bulldozers/trucks/trailers	km kL^{-1}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$D_{aver\ extrac}$	Average extraction distance of logs from stump to log landing	km
N_{trucks}	Number of trucks	
V_{extr}	Volume of timber extracted from the forest	m^{-3}
Cap_{truck}	Capacity of the truck	m^3 $truck^{-1}$

Default parameter values for medium sized bulldozers are estimated to be similar to those of truck and trailers. The defaults, including those for associated emission factors and fuel efficiency are derived from Kinjo et al. (2005) as cited in Carbon Planet (2009) and are: truck / trailer load capacity (10 m^3 $truck^{-1}$); EF_{fuel} (2.9 t CO_2-e kL^{-1}); and, Eff_{fuel} (3000 km kL^{-1}).

$E_{transport,t}$: emissions due to the transport of the logs from the log landing to the point of onward transport (eg, to a wharf in case of export) or point of (local) sale

Emissions from log extraction and transport to log landing are estimated as:

$$E_{transport,t} = (D_{trans\_total} / Eff_{fuel}) \times EF_{fuel} \quad (30)$$

$$D_{trans\_total} = D_{aver\ trans} \times N_{trucks} \times 2 \quad (31)$$

$$N_{trucks} = V_{trans} / Cap_{truck} \quad (32)$$

Where:

Parameter	Description	Unit
$E_{transport,t}$	Emissions due to the transport of the timber from the log landings to point of onward sale/transport at year *t*	t CO_2-e yr^{-1}
D_{trans_total}	Total timber transport distance	km
Eff_{fuel}	Fuel efficiency for medium-sized bulldozers/trucks/trailer	km kL^{-1}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$D_{aver\ trans}$	Average transport distance of logs log landing to point of onward sale/transport	km
N_{trucks}	Number of trucks	
V_{trans}	Volume of timber transported	m^{-3}
Cap_{truck}	Capacity of the truck	m^3 $truck^{-1}$

9.2 Project Emissions

The net greenhouse gas emission reduction and removals in the with-project scenario must be estimated using the equations in this section. When applying these equations for the *ex-ante* estimation of total net GHG emission reduction by the IFM project activity, project proponents must provide estimates of the values of those parameters that are not available before the start of the project crediting period and commencement of monitoring activities. Project proponents must retain a conservative approach in making these estimates.

GHG emissions and removals in the with-project scenario are related to regrowth of the residual forest, silvicultural interventions such as climber cutting, liberation thinning, enrichment planting and/or harvesting, or a combination of these activities, and project implementation activities, such as the ones listed in Section 9.1.7.

Net CO_2 equivalent emissions in the with-project scenario (WPS) are estimated as:

$$\Delta C_{WPS} = \sum_{t=1}^{t*} \sum_{i=1}^{M_{WPS}} \Delta C_{P,i,t} + GHG_{WPS-E,t} \qquad (33)$$

Where:

Parameter	Description	Unit
ΔC_{WPS}	Net CO_2 equivalent emissions in the with-project scenario up to year *t**	t CO_2-e yr^{-1}
$\Delta C_{P,i,t}$	Net carbon stock change due to forest regrowth and silvicultural interventions in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$GHG_{WPS-E,t}$	Greenhouse gas emissions related to project implementation at year *t*	t CO_2-e yr^{-1}

9.2.1 Net carbon stock changes due to forest regrowth and silvicultural interventions

Estimation of $\Delta C_{P,i,t}$

Net carbon stock changes due to forest regrowth and silvicultural interventions in the with-project scenario are estimated as follows:

$$\Delta C_{P,i,t} = \Delta C_{AGB,i,t} + \Delta C_{BGB,i,t} + \Delta C_{DW,i,t} + \Delta C_{WP,i,t} - E_{biomassloss,i,t} \qquad (34)$$

Where:

Parameter	Description	Unit
$\Delta C_{P,i,t}$	Net carbon stock change due to forest regrowth and silvicultural interventions in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$\Delta C_{AGB,i,t}$	Net carbon stock change in above-ground tree biomass[15] in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}

[15] With *DBH* ≥ 5 cm.

$\Delta C_{BGB,i,t}$	Net carbon stock change in below-ground tree biomass in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$\Delta C_{DW,i,t}$	Net carbon stock change in dead wood in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$\Delta C_{WP,i,t}$	Net carbon stock change in wood products in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$E_{biomassloss,i,t}$	Emissions due to site preparation for project activities in stratum *i* at year *t*	t CO_2-e yr^{-1}
t	1, 2, 3 … *t** years elapsed since the start of the project activity	
i	1, 2, 3 … M_{WPS} strata in the with-project scenario	

Accounting for dead wood in the with-project scenario as zero is conservative. Accounting for wood products in the with-project scenario as zero is conservative.

Estimation of $\Delta C_{AGB,i,t}$

The changes in the carbon stock in above-ground tree biomass within the project boundary are estimated using the following approach:

$$\Delta C_{AGB,i,t} = A_{i,t} \times (C_{AGB,i,t} - C_{AGB,i,t-T}) \times 44/12 / T \quad (35)$$

Where:

Parameter	Description	Unit
$\Delta C_{AGB,i,t}$	Net carbon stock change in above-ground tree biomass in stratum *i* at year *t*	t CO_2-e
$C_{AGB,i,t}$	Carbon stock in above-ground tree biomass in stratum *i* at year *t*	t C ha^{-1}
t	1, 2, 3 … ***t**** years elapsed since the start of the project activity	
i	1, 2, 3 … M_{WPS} strata in the with-project scenario	
44/12	Ratio of molecular weights of CO_2 and carbon	t CO_2-e t C^{-1}

$A_{i,t}$	Area of stratum *i* at year *t*	ha
T	Number of years between monitoring times t_m *and* t_{m-1}	

Changes in C Stock in Above-ground Tree Biomass[16]

The mean carbon stock in above-ground tree biomass per unit area is estimated for each stratum on the basis of field measurements in permanent sample plots. Two methods are available: the Biomass Expansion Factors (*BEF*) method and the Allometric Equations method.

BEF method

Step 1: Determine on the basis of available data, eg, volume tables (*ex ante*) and measurements (*ex post*) the diameter at breast height (*DBH,* at typically 1.3 m above-ground level), and also preferably height (*H*), of all the trees above some minimum *DBH* in the permanent sample plots. The exact tree dimensions to be measured will be specified by the information obtained in Step 2.

Step 2: Estimate the stem volume of trees based on available equations or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate).

It is possible to combine Steps 1 and 2 if volume tables allow for deriving average volume of trees, or field instruments (eg, a relascope) that measure the volume of each tree directly are applied.

Step 3: Choose *BEF*

Step 4: Convert the stem volume of trees into carbon stock in above-ground tree biomass via basic wood density, the *BEF* and the carbon fraction:

$$C_{AGB,l,j,i,sp,t} = V_{l,j,i,sp,t} \times D_j \times BEF_j \times CF_j \quad (36)$$

[16] This section, with the Biomass Expansion Factors (*BEF*) method and the Allometric Equations method, including a number of additional steps to expand AGB to include below-ground biomass, etc., are part of several CDM EB approved methodologies, including for instance AR-ACM0002.

Where:

Parameter	Description	Unit
$C_{AGB,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at year *t*	t C $tree^{-1}$
$V_{l,j,sp,t}$	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i* at year *t*	m^3 $tree^{-1}$
D_j	Basic wood density of species *j*	t d.m. m^{-3}
BEF_j	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*	
CF_j	Carbon fraction[17] of biomass for tree species *j*	t C t $d.m.^{-1}$
l	1, 2, 3 … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* at year *t*	
i	1, 2, 3 … M_{WPS} strata in the with-project scenario	
j	1, 2, 3 … S_{WPS} tree species in the with-project scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Step 5: Calculate carbon stock in above-ground biomass of all trees present in plot *sp* in stratum *i* at time *t* (ie, summation over all trees *l* by species *j* followed by summation over all species *j* present in plot *sp*).

$$C_{AGB,i,sp,t} = \sum_{j=1}^{S_{WPS}} \sum_{l=1}^{N_{j,i,sp,t}} C_{AGB,l,j,i,sp,t} \tag{37}$$

[17] IPCC default = 0.5

Where:

Parameter	Description	Unit
$C_{AGB,i,sp,t}$	Carbon stock in above-ground biomass of trees on plot *sp* of stratum *i* at time *t*	t C
$C_{AGB,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*	t C tree^{-1}
l	1, 2, 3 … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* at year *t*	
i	1, 2, 3 … M_{WPS} strata in the with-project scenario	
j	1, 2, 3 … S_{WPS} tree species in the with-project scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Step 6: Estimate the mean carbon stock in above-ground tree biomass for each stratum:

$$C_{AGB,i,t} = \frac{1}{A_{sp_i}} \sum_{sp=1}^{P_i} C_{AGB,i,sp,t} \tag{38}$$

Where:

Parameter	Description	Unit
$C_{AGB,i,t}$	Above-ground carbon stock in trees in stratum *i* at year *t*	t C ha^{-1}
$C_{AGB,i,sp,t}$	Above-ground carbon stock in trees on plot *sp* of stratum *i* at year *t*	t C
$A_{sp,i}$	Total area in all sample plots in stratum *i*	ha
sp	1, 2, 3 … *Pi* sample plots in stratum *i* in the with-project scenario	
i	1, 2, 3 … M_{WPS} strata in the project scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Allometric Equations Method

Step 1: Proceed as in Step 1 of the *BEF* Method. The exact tree dimensions to be measured will be specified by the equation selected in Step 2.

Step 2: Select or develop an appropriate allometric equation (if possible species-specific, or if not, from a similar species).

If default allometric equations are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then the equation may be used and considered conservative. Otherwise, it is necessary either to use conservatively assessed values, or to verify the applicability of the equation if mean predicted values are to be used.

When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1and 4.A.2 of GPG LULUCF, or updated in IPCC 2006 Guidelines for AFOLU, are used, allometric equations can be verified by:

- Selecting at least 5 trees covering the range of *DBH* existing in the project area, and felling and weighing the above-ground tree biomass to determine the total (wet) weight of the stem and branch components;
- Determining 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.

If the biomass of the harvested trees is within about ±10% of the mean values predicted by the selected default allometric equation, and is not biased—or if biased is wrong on the conservative side (ie, use of the equation results in an under- rather than over-estimate of project net anthropogenic removals by sinks)—then mean values from the default equation may be used. (IPCC Good Practice Guidance for LULUCF, 2003, Section 4.3.3.5.1, under direct approach Step 3).

When allometric equations are used that are not developed from a biome-wide database as mentioned above, a one-sided t-test (with alpha = 0.05) should be applied to determine whether the biomass predicted by the allometric equation does not exceed the biomass from the harvested trees. To obtain biomass from the harvested trees, the same procedure as described above should be used.

Step 3: Estimate carbon stock in above-ground biomass for each individual tree *l* of species *j* in the sample plot located in stratum *i* using the selected or developed allometric equation applied to the tree dimensions determined in Step 1, and sum the carbon stocks in the sample plot:

$$C_{AGB,j,i,sp,t} = \sum_{l=1}^{N_{j,sp}} f_j(X,Y,...) \times CF_j \tag{39}$$

Where:

Parameter	Description	Unit
$C_{AGB,j,i,sp,t}$	Carbon stock in above-ground biomass of trees of species *j* on sample plot *sp* of stratum *i* at year *t*;	t C
CF_j	Carbon fraction of dry matter for species or type *j*	t C t^{-1} d.m.

$f_j(X, Y, …)$	Allometric equation for species *j* linking measured tree dimension variables (eg, diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees	t d.m. $tree^{-1}$
i	1, 2, 3 … M_P strata in the with-project scenario	
j	1, 2, 3 … S_{WPS} tree species in the with-project scenario	
l	1, 2, 3 … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* at year *t*	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Step 4: Estimate the mean carbon stock in above-ground tree biomass for each stratum, as per the *BEF* method.

Estimation of $\Delta C_{BGB,i,t}$

The annual changes in below-ground tree biomass are estimated for each stratum on the basis of above-ground tree biomass. By using a root:shoot ratio, below-ground biomass is calculated from above-ground biomass, following Equation (40) below. Calculation of the parameter $\Delta C_{AGB,i,t}$ is described in “Estimation of $\Delta C_{AGB,i,t}$”.

$$\Delta C_{BGB,i,t} = \Delta C_{AGB,i,t} \times R_j \tag{40}$$

Where:

Parameter	Description	Unit
$\Delta C_{BGB,i,t}$	Net carbon stock change in below-ground tree biomass in the with-project scenario in stratum *i* at year *t*	t CO_2 yr^{-1}
$\Delta C_{AGB,i,t}$	Net carbon stock change in above-ground tree biomass in the with-project scenario in stratum *i* at year *t*	t CO_2 yr^{-1}
R_j	Root:shoot ratio for tree species *j*	t root d.m. t^{-1} shoot d.m.
t	1, 2, 3 … ***t**** years elapsed since the start of the project activity	

i	1, 2, 3 … M_{WPS} strata in the with-project scenario	

9.2.2 Changes in carbon stocks in dead wood

Carbon stock changes in the project are monitored using the stock change method:

$$\Delta C_{DW,i,t} = (C_{DW,i,t} - C_{DW,i,t-T}) / T \tag{41}$$

Where:

Parameter	Description	Unit
$\Delta C_{DW,i,t}$	Annual net carbon stock change in dead wood for stratum *i*, at year *t*;	t CO_2-e ha^{-1} yr^{-1}
$C_{DW,i,t}$	Carbon stock in dead wood for stratum *i,* at year *t*;	t CO_2-e ha^{-1}
i	1, 2, 3 … M_P strata in the with-project scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	
T	Number of years between monitoring times t_m and t_{m-1}	

9.2.3 Changes in carbon stocks in wood products

Carbon stock changes in the project are monitored using the stock change method:

$$\Delta C_{WP,i,t} = (C_{WP,i,t} - C_{WP,i,t-T}) / T \tag{42}$$

Where:

Parameter	Description	Unit
$\Delta C_{WP,i,t}$	Annual net carbon stock change in wood products for stratum *i* at year *t*;	t CO_2-e ha^{-1} yr^{-1}
$C_{WP,i,t}$	Carbon stock in wood products for stratum *i* at year *t*;	t CO_2-e ha^{-1}
i	1, 2, 3 … M_P strata in the with-project scenario	

t	1, 2, 3 … t^* years elapsed since the start of the project activity	
T	Number of years between monitoring times t_m and t_{m-1}	

9.2.4 Emissions due to site preparation for project activities

If any site preparation occurs for liberation thinning and enrichment planting, then $E_{biomassloss}$ must be estimated when significant, using the most recent version of the CDM approved methodological tool "Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of an A/R CDM project activity"[18].

If however, the emissions due to changes in carbon stock in tree vegetation due to site preparation are insignificant they may be ignored. The removal of herbaceous vegetation (including climbers and vines) is deemed an insignificant emissions source and therefore is not accounted for in the with-project scenario.

9.2.5 GHG emissions as a result of the implementation of the project activity

There are various sources of emissions resulting from the general project implementation. These can include, but may not be limited to:

- Emissions due to administration, data-processing, and/or operating field station(s): grid or generator powered electricity;
- Emissions due to travel of project staff (ground transport, flights, etc.);
- Emissions due to travel and transport of external visitors (eg, auditing companies, consultants, etc.)

This will require information on kL fuel combusted, energy consumption or efficiency rates, km travelled, emission factors for various types of fuels, emissions associated with electricity generation, etc.

Approaches for estimating GHG_{WPS-E} are similar to those for GHG_{BSL-E}.

9.3 Leakage

9.3.1 Identification of sources of leakage

Leakage is defined as any increase in greenhouse gas emissions that occurs outside a project's boundary (but within the same country), that is measurable and attributable to the project activity. Its

18 Available at: <http://cdm.unfccc.int/>

effects on all carbon pools must be assessed and significant effects taken into account when estimating net emission reductions.

The applicability conditions determine that: “biomass burning, fuel gathering, removal of litter, or removal of dead wood do not occur in the baseline scenario and in the with-project scenario within the project boundary”. Therefore, this methodology only provides for the determination of leakage due to market effects.

$$\Delta C_{LK} = \Delta C_{LK\text{-}ME} \quad (43)$$

9.3.2 Quantification of leakage due to market effects

Option 1: This methodology applies to project activities, which reduce harvest levels in comparison with the baseline and possible reference areas. Therefore, the following leakage credit adjustment can be applied.

Project Action	Leakage Risk	Leakage credit adjustment (discount)
Substantially reduce harvest levels permanently (eg, RIL activity that reduces timber harvest by 25% or more across the project area; or, a forest protection/no logging project)	Moderate to High Depends on where timber harvest is likely to be shifted	Depends on where timber harvest is likely to be shifted to: • Similar carbon dense forests within the country: 40% • Less carbon dense forests within the country: 20% • More carbon dense forests within country: 70% • Out of country: 0% (according to stated VCS and CDM policy of not accounting for international leakage)

$$\Delta C_{LK\text{-}ME} = LF_{ME} \times \Delta C_{REL} \quad (44)$$

Where:

Parameter	Description	Unit
$\Delta C_{LK\text{-}ME}$	Total GHG emissions due to market-effects leakage	t CO_2-e
LF_{ME}	Leakage factor for market-effects calculations	

ΔC_{REL}	Emissions from relogging displaced through implementation of the project activities across strata	t CO_2-e

LF_{ME}, the leakage factor, depends upon where in the country logging might be increased, as a result of a decrease in timber supply from the project area.

$LF_{ME} = 0$ if it can be demonstrated to the verifier that no market-effects leakage will occur within national boundaries, eg, if no new concessions are being assigned AND annual extracted volumes per hectare in existing concessions have not increased in comparison to previously documented and projected and authorised extraction levels within existing concessions in the host country.

$LF_{ME} = 0.4$ if $C_{BSLpre} = NCS$

(if $C_{BSLpre} \leq NCS \times 1.15$ and $\geq NCS \times 0.85$)

$LF_{ME} = 0.7$ if $C_{BSLpre} < NCS \times 0.85$

$LF_{ME} = 0.2$ if $C_{BSLpre} > NCS \times 1.15$

Where:

Parameter	Description	Unit
LF_{ME}	Leakage factor for market-effects calculations	
NCS	The mean national forest carbon stock	t C ha^{-1}
C_{BSLpre}	Pre-relogging mean carbon stock in above-ground tree biomass across strata in the baseline scenario	t C ha^{-1}

Estimating C_{BSLpre} involves area-weighting the stocks across the strata:

$$C_{BSLpre} = \frac{\sum_{i=1}^{M_{BSL}} \left(C_{BSLpre,i} \times A_{REL,i} \right)}{\sum_{i=1}^{M_{BSL}} A_{REL,i}} \qquad (45)$$

Where:

Parameter	Description	Unit
C_{BSLpre}	Mean carbon stock across strata in all pools selected in the	t C ha^{-1}

	baseline	
$C_{BSLpre,i}$	Carbon stock in all pools selected in the baseline in stratum *i*	t C ha^{-1}
$A_{REL,i}$	Area relogged in baseline stratum *i*	ha
I	1, 2, 3 …M_{BSL} strata in the baseline scenario	
M_{BSL}	The total number of strata in the baseline scenario	

ΔC_{REL} equals emissions from harvests displaced through implementation of the project activities as quantified in Sections 9.1.3 or 9.1.4, summed across strata.

Option 2: Instead of applying the default market leakage effect discount above, project proponents may opt to estimate the project's market leakage effect across the entire country and/or use analysis(es) from other similar projects to justify a different market leakage value.

9.4 Summary of GHG Emission Reduction and/or Removals

The total net GHG benefits from the IFM project activity (ΔC_{IFM}) are calculated as the result of the total carbon loss in the baseline scenario (ΔC_{BSL}) and the net removals through the enhancement of forest growth due to liberation thinning and enrichment planting (ΔC_{WPS}), minus any potential leakage (ΔC_{LK}) that might occur.

$$\Delta C_{IFM} = \Delta C_{BSL} - \Delta C_{WPS} - \Delta C_{LK} \quad (46)$$

Where:

Parameter	Description	Unit
ΔC_{IFM}	Total net GHG emission reductions from the IFM project activity up to year *t*	t CO_2-e
ΔC_{BSL}	Sum of the carbon stock changes and greenhouse gas emissions under the baseline scenario up to year *t*	t CO_2-e
ΔC_{WPS}	Sum of the carbon stock changes and greenhouse gas emissions under the with-project scenario up to year *t*	t CO_2-e
ΔC_{LK}	Sum of the carbon stock changes and greenhouse gas emissions due to leakage up to year *t*	t CO_2-e

ΔC_{IFM} must be corrected for uncertainty, as follows:

$$C_{IFM\_ERROR} = \sqrt{Uncertainty_{BSL}{}^{2} + Uncertainty_{WPS}{}^{2}} \quad (47)$$

Where:

Parameter	Description	Unit
C_{IFM_ERROR}	Total uncertainty for IFM project activity	%
$Uncertainty_{BSL}$	Total uncertainty in baseline scenario	%
$Uncertainty_{WPS}$	Sum of the carbon stock changes and greenhouse gas emissions under the with-project scenario up to year *t*	%

The procedure for estimating C_{IFM_ERROR} must be in accordance with the most recent version of the *Tool for Estimating Uncertainty in IFM Project Activities.*

If C_{IFM_ERROR} ≤ 10% of $\Delta C_{IFM,t}$ then no deduction must result for uncertainty.

If C_{IFM_ERROR} > 10% of $\Delta C_{IFM,t}$ then the modified value for $\Delta C_{IFM,t}$ to account for uncertainty must be:

$$= \frac{100 - C_{IFM\_ERROR}}{100} \times C_{IFM,t} \quad (48)$$

Where:

Parameter	Description	Unit
$\Delta C_{IFM,t}$	Total net GHG emission reductions from the IFM project activity up to year *t*	t CO_2-e
C_{IFM_ERROR}	Total uncertainty for IFM project activity	%

<u>Calculation of Verified Carbon Units</u>

The number of Verified Carbon Units is calculated as follows:

$$VCU_{t2} = \left(\Delta C_{IFM,t2} - \Delta C_{IFM,t1}\right) \times \left(\frac{100 - C_{IFM\_ERROR}}{100}\right) - Bufferwithholding_{t2} \tag{49}$$

Where:

Parameter	Description	Unit
$VCU_{,t2}$	Number of Verified Carbon Units at year *t2*	
$\Delta C_{IFM,\ t1}$	Total net GHG emission reductions from the IFM project activity up to year *t1*	t CO_2-e
$\Delta C_{IFM,\ t2}$	Total net GHG emission reductions from the IFM project activity up to year *t2*	t CO_2-e
C_{IFM_ERROR}	Total uncertainty for IFM project activity	%
$Bufferwithholding_{t2}$	The number of VCU's to be withheld in the VCS AFOLU Pooled Buffer Account at year *t2*	

The percentage to be withheld in the VCS AFOLU Pooled Buffer Account is to be determined using the VCS Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination. This percentage is to be multiplied with the carbon stock changes within the project boundary at year *t2* in order to obtain the parameter $Bufferwithholding_{t2}$.

10 MONITORING

10.1 General

The monitoring plan must contain at least the following sections:

- Monitoring of stock changes and greenhouse gas emissions in the baseline (only under certain conditions)
- Monitoring of project carbon stock changes and greenhouse gas emissions
- Monitoring of leakage carbon stock changes and greenhouse gas emissions
- Estimation of ex-post total net carbon stock changes and greenhouse gas emissions.

This must include the following elements:

- A description of each monitoring task to be undertaken, and the technical requirements
- Parameters to be measured
- Data to be collected and data collection techniques
- Frequency of monitoring
- Quality Assurance and Quality Control (QA/QC) procedures
- Data archiving procedures
- Roles, responsibilities and capacity of monitoring team and management

All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last project crediting period. One hundred percent of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted according to relevant standards. In addition, the monitoring provisions in the tools referred to in the most recent version of the CDM methodology AR-ACM0002, Version 1 or its replacement must apply.

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 stored in multiple locations. The archives must include:

- Copies of all original field measurement data, laboratory data, data analysis spreadsheet;
- Estimates of the carbon stock changes in all pools and non-CO2 GHG and corresponding calculation spreadsheets;

- GIS products;
- Copies of the measuring and monitoring reports

When applying all relevant equations provided in this methodology for the *ex-ante* estimation of net anthropogenic GHG removals by sinks, project proponents must 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.[19]

10.2 Monitoring of Regrowth in the Baseline Scenario

When monitoring regrowth in the baseline scenario using a reference area, the monitoring plan must provide specific monitoring procedures. These procedures must follow the same approach as provided below for the monitoring of the with-project scenario. Thus, the monitoring plan is to provide (justifications for) sampling frequency, sample size and field procedures for monitoring regrowth of residual forest in the baseline scenario.

Data and Parameters Not Monitored in the Baseline

Data / parameter:	A_i
Data unit:	Ha
Description:	Area of stratum *i*
Source of data:	Equation (2)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	GHG_{BSL-E}
Data unit:	t CO_2-e yr^{-1}
Description:	Greenhouse gas emissions as a result of relogging within the project boundary

[19] AR-ACM0002, Version 1

	in stratum *i*
Source of data:	Equation (2)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{REL,i}$
Data unit:	Ha
Description:	Area relogged in baseline stratum *i*
Source of data:	Equation (3)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{harvest,i}$
Data unit:	t C ha^{-1}
Description:	Carbon stock in harvested timber in stratum *i*
Source of data:	Equation (3)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{damage,i}$
Data unit:	t C ha^{-1}
Description:	Carbon loss due to damage to the residual stand in stratum *i*
Source of data:	Equation (3)

Measurement procedures (if any):	
Any comment:	Accounting for C_{damage} as zero in the baseline scenario is conservative

Data / parameter:	$C_{WP100,i,t}$
Data unit:	t C ha^{-1}
Description:	Post-relogging carbon stock stored in long-term wood products (stock remaining in wood products after 100 years) in the baseline scenario in stratum i
Source of data:	Equation (3),(7a) and (8)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{WP20,i,t}$
Data unit:	t C ha^{-1}
Description:	Post-relogging carbon stock stored in short-term and medium-term wood products (stock is expected to be emitted over 20 years with a linear decay function) in the baseline scenario in stratum i at year t
Source of data:	Equation (3),(7b) and (8)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{DW,I,t}$
Data unit:	t C ha^{-1}

Description:	Post-relogging carbon stock in dead wood in the baseline scenario (stock emitted is quantified over 10 years with a linear decay function) in stratum *i* at year *t*
Source of data:	Equation (3) and (8)
Measurement procedures (if any):	
Any comment:	If C_{DW} for the project area cannot be derived from peer-reviewed literature, data can be obtained using appropriate measurement techniques applied in areas for which it can be shown that they are representative for the project area.

Data / parameter:	$V_{harvest,j,i}$
Data unit:	m^3 ha^{-1} yr^{-1}
Description:	Volume of timber harvested in the baseline scenario of species *j* in stratum *i*
Source of data:	Equation (4)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	D_j
Data unit:	t d.m. m^{-3}
Description:	Basic wood density for species *j*
Source of data:	Equation (4) Values for *Dj* can be taken from tables generally used in the local or regional timber and forest industry, or from peer-reviewed literature applicable to the region. If no species-specific values for *Dj* are available, the average value across all species can be used, increased by 20% to ensure a conservative (higher) estimate of $C_{WPi,t}$. The source of data must be chosen with priority from higher to lower

	preference as follows: (a) National and species-specific or group of species-specific (eg, from national GHG inventory); (b) (Group of) Species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (eg, IPCC GPG-LULUCF 2003).
Measurement procedures (if any):	NA
Any comment:	

Data / parameter:	CF
Data unit:	t d.m.$^{-1}$
Description:	Carbon fraction of dry matter
Source of data:	IPCC default value 0.5
Measurement procedures (if any):	NA
Any comment:	

Data / parameter:	f_{damage}
Data unit:	Dimensionless
Description:	Factor for damage to the residual stand caused by relogging
Source of data:	Equation (5) Determined using appropriate measurement techniques such as those described in the project description of the Noel Kempff Mercado Climate Action Project (NKM-CAP), version 02.02, dated 7/11/2005, or other similar established emission quantification approaches. Alternatively, peer reviewed

	literature may be used to derive f_{damage} from areas for which it can be shown that they are representative for the project area or general f_{damage} proxies for natural Evergreen Tropical Rainforests for conventional and/or Reduced Impact Logging (eg, Pulkki (1997)).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{XB,ty,i}$
Data unit:	t CO_2-e ha^{-1}
Description:	Mean stock of extracted biomass carbon by class of wood product *ty* from stratum *i*
Source of data:	Equation (6)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$V_{ex,ty,j,i}$
Data unit:	m^3
Description:	Volume of timber extracted from within stratum *i* (does not include slash left onsite) by species *j* and wood product class *ty*
Source of data:	Equation (6)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	ty
Data unit:	No dimension

Description:	Wood product class (eg, sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other)
Source of data:	Equation (6)
Measurement procedures (if any):	
Any comment:	Wood product classes are used to account for long-term storage of carbon in wood products. The share of timber ending up in the various wood product classes needs to be determined. In case no reliable assumptions can be made as to the timber classes of the harvested wood and its end use, general information from Forest Departments from that area reflecting breakdown of timber classes as they are normally harvested from this forest type and area may be used (eg, plywood, round logs, sawn timber, etc.).

Data / parameter:	ww_{ty}
Data unit:	No dimension
Description:	The fraction immediately emitted through mill inefficiency
Source of data:	Published paper of Winjum *et al*. 1998[20] (used in Equation (7a))
Measurement procedures (if any):	
Any comment:	

Data / parameter:	slp_{ty}
Data unit:	No dimension
Description:	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest

[20] 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

Source of data:	Published paper of Winjum *et al*. 1998[24] (used in Equation (7b))
Measurement procedures (if any):	
Any comment:	

Data / parameter:	fo_{ty}
Data unit:	No dimension
Description:	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest
Source of data:	Published paper of Winjum *et al*. 1998[24] (used in Equation (7b))
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{BSLpre,i}$
Data unit:	t C ha^{-1}
Description:	Pre-relogging carbon stock in above-ground tree biomass in the baseline scenario in stratum *i*
Source of data:	Equation (8)
Measurement procedures (if any):	$C_{BSLpre,i}$ can be determined on the basis of previously conducted fieldwork or surveys or peer-reviewed proxies in the reference area or can be approximated in case of a reference area as follows: $C_{BSLpre,i} = C_{BSLpost,i} + C_{harvest,i} + C_{damage,I}$
Any comment:	

Data / parameter:	$C_{BSLpost,i}$
Data unit:	t C ha^{-1}

Description:	Post-relogging carbon stock in above-ground tree biomass in the baseline scenario in stratum *i*
Source of data:	Equation (8)
Measurement procedures (if any):	$C_{BSLpost,i}$ can be estimated using the method outlined in (Estimation of $\Delta C_{P,i,t}$).
Any comment:	

Data / parameter:	$B_{SDW,l,sp,i}$
Data unit:	t d.m.
Description:	Biomass of standing dead tree *l* from sample plot *sp* in stratum *i*
Source of data:	Equation (10) and (11)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	BDia
Data unit:	cm
Description:	Basal diameter of standing dead tree
Source of data:	Field measurements in sample plots. Used in Equation (10) and (11)
Measurement procedures (if any):	Measured at ground level. Measure all trees above some minimum *BDia* in the sample plots, typically $\geq$ 10 cm.
Any comment:	

Data / parameter:	TD_{SDW}
Data unit:	cm
Description:	Top diameter of standing dead tree / from sample plot *sp* in stratum *i*

Source of data:	Field measurements in sample plots. Used in Equation (10) and (11)
Measurement procedures (if any):	Height measured from ground level to either the top of a standing bole or to the base of crown if crown is persistent. Height is measured either directly or by using an instrument such as a clinometers, relascope or laser inventory instrument.
Any comment:	

Data / parameter:	H_{SDW}
Data unit:	cm
Description:	Height of standing dead tree
Source of data:	Field measurements in sample plots. Used in Equation (10) and (11)
Measurement procedures (if any):	Height measured from ground level to either the top of a standing bole or to the base of crown if crown is persistent. Height is measured either directly or by using an instrument such as a clinometers, relascope or laser inventory instrument.
Any comment:	

Data / parameter:	$D_{DW,dc}$
Data unit:	t d.m. m^{-3}
Description:	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
Source of data:	Equation (10) and (11) The source of data must be chosen with priority from higher to lower preference as follows: (a) Research publications relevant to the project area; (b) National species-specific or group of species-specific (eg, from National GHG inventory); (c) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a); (d) Global species-specific or group of species-specific (eg, IPCC GPG-

	LULUCF). Species-specific dead wood densities may not always be available, and may be difficult to apply with certainty to decomposed wood and in the typically species rich forests of the humid tropics, hence it is acceptable practice to use dead wood densities developed for forest types.
Measurement procedures (if any):	Project-specific determination of density is most likely necessary, requiring collection of representative samples from 10-20 trees from each decomposition class. Dead wood samples are cut in discs and thickness and diameter measured to estimate green volume. Samples are oven dried (70^o C) to a constant weight in the laboratory, and density calculated as dry weight (g) per unit green volume (cm^3).
Any comment:	Basic wood density for dominant species *DS* when *j=DS*

Data / parameter:	V_{LDW}
Data unit:	m^3 ha^{-1}
Description:	Volume of lying dead wood per unit area in stratum *i*
Source of data:	Field measurements in sample plots. Used in Equation (14)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$Dia_{n,i,t}$
Data unit:	m^3 ha^{-1}
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*
Source of data:	Field measurements in sample plots. Used in Equation (14)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$B_{LDW,i,t}$
Data unit:	t d.m. ha^{-1}
Description:	Biomass of lying dead wood per unit area in stratum *i*
Source of data:	Field measurements in sample plots. Used in Equation (15)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$V_{LDW,i,t}$
Data unit:	m^3 ha^{-1}
Description:	Volume of lying dead wood per unit area in stratum *i*
Source of data:	Field measurements in sample plots. Used in Equation (15)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$D\%_{,i}$
Data unit:	% yr^{-1}
Description:	Projected annual proportion of land that will be logged in stratum *i* at year *t*. If actual annual proportion is known and documented (eg, 25% per year for 4 years), set to proportion
Source of data:	Used in Equation (17)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{biomass}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to the removal of the biomass itself at year *t*
Source of data:	Remote imagery (photographs or satellite) or by using a reported percentage that is typical for the area.
Measurement procedures (if any):	To estimate the emissions from the removal of the biomass area has to be multiplied by an average carbon stock value per hectare that is representative of the project area.
Any comment:	

Data / parameter:	$E_{felling}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to the use of equipment for removal of the biomass on the area dedicated to infrastructure
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{grading}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to road grading
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{harvesting}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to harvesting
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{extraction}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to extraction of timber from the forest to the log landings
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{transport}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to the transport of the timber from the log landings to point of onward sale/transport
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data and Parameters Monitored in the Baseline

Data / parameter:	$\Delta C_{tree\text{-}exist,i,}$
Data unit:	$t\ CO_2\text{-}e\ yr^{-1}$
Description:	Net carbon stock change in existing tree vegetation[21] in the baseline scenario in stratum *i*
Source of data:	Equation (2) Determined in Section 9.1 of methodology.
Measurement procedures (if any):	
Any comment:	

10.3 Monitoring of Project Implementation

Information must be provided, and recorded in the project description, to establish that:

(a) The geographic position of the project boundary is recorded for all areas of land:

   a. The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This can be achieved by field survey (eg, using GPS), or by using georeferenced spatial data (eg, maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images).

(b) Commonly accepted principles of forest inventory and management are implemented:

   a. 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;

   b. Apply SOPs, especially, for actions likely to minimize soil disturbances in those circumstances in which site preparation or planting involves soil disturbance capable to increase soil erosion above the baseline value;

[21] With *DBH* ≥ 5 cm.

c. 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.[22]

10.4 Monitoring of project carbon stock changes and greenhouse gas emissions

10.4.1 Updating of Strata

Stratification of the project area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. Project proponents should present in the project description an *ex-ante* stratification of the project area or justify the lack of it. The number and boundaries of the strata defined *ex-ante* may change during the project crediting period (*ex post*).

The *ex-post* stratification must be updated because of the following reasons:

- Unexpected disturbances occurring during the project crediting period (eg, due to fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;
- Forest management activities (cleaning, planting, thinning, harvesting, coppicing, re-planting) that are implemented in a way that affects the existing stratification.

Established strata may be merged if the reasons for their establishment have disappeared.[23]

10.4.2 Sampling Framework

The sampling framework, including sample size, plot size, plot shape, and determination of plot location should be specified in the project description.[24]

To determine the sample size and allocation among strata, this methodology uses the latest version of the tool for the “Calculation of the number of sample plots for measurements within A/R CDM project activities”[25], approved by the CDM Executive Board. The targeted precision level for biomass estimation within each stratum is ± 10% of the mean at a 95% confidence level.

10.4.3 Measuring and estimating carbon stock changes and GHG emissions over time

The change in carbon stocks 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.

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[22] This paragraph has been amended after AR-ACM0002 (ie, is not copied *verbatim*).

[23] AR ACM0002, Version 01

[24] Except for this sentence the entire Section 8.2.2 has been copied *verbatim* from AR-ACM0002.

[25] Available at: <http://cdm.unfccc.int/>

Data and parameters not monitored in the Project Scenario

Data / parameter:	BEF
Data unit:	dimensionless
Description:	Biomass expansion factor for the conversion of annual net increment (including bark) in stem biomass to total above-ground tree biomass increment for species *j*
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: a. Existing local and species-specific or group of species-specific; b. National and species-specific or group of species-specific (eg from national GHG inventory) c. Species-specific or group of species-specific from neighbouring countries with similar conditions (might be preferable to b under certain conditions) d. Climatic zone and forest type (eg IPCC literature: Table 3A.1.10 of the *GPG-LULUCF* (IPCC 2003) and Table 4.5 of the *AFOLU Guidelines* (IPCC 2006)
Measurement procedures (if any):	
Any comment:	• *BEFs* are age dependent, and use of average data may result in significant errors for both young and old stands—as *BEFs* are usually large for young stands and quite small for old stands; • *BEFs* in IPCC literature and national inventory are usually applicable to closed canopy forest. If applied to individual trees growing in open field it is recommended that the selected *BEF* be increased by a further 30%.[26]

[26] Applying a 30% increase to the BEF for solitary trees in severely logged over forest when estimating regrowth after logging in the baseline is leading to conservative estimates of carbon benefits of the project because it reduces net emissions in the baseline. In the project scenario less incidences of solitary trees will occur because the canopy will remain intact to a larger degree in comparison to the baseline.

Data / parameter:	R
Data unit:	t root d.m. t^{-1} shoot d.m.
Description:	Root:shoot ratio appropriate to species or forest type / biome
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: a. Existing local and species-specific or group of species-specific; b. National and species-specific or group of species-specific (eg from national GHG inventory) c. Species-specific or group of species-specific from neighbouring countries with similar conditions (might be preferable to b under certain conditions) d. Climatic zone and forest type (eg IPCC literature: Table 3A.1.8 of the *GPG-LULUCF* (IPCC 2003) and Table 4.4 of the *AFOLU Guidelines* (IPCC 2006)
Measurement procedures (if any):	
Any comment:	Guideline for conservative choice of default values: - If in the sources of data mentioned above, default data are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then mean values of default data may be used and considered conservative. - A root:shoot ratio for mature forest must be selected. Usually the root:shoot ratio for young trees is greater than for old trees. Applying a root:shoot ratio for mature forest is conservative, because it underestimates carbon in young trees in the project scenario (which are more abundant as a result of enrichment planting).

Data / parameter:	CF
Data unit:	t $d.m.^{-1}$

Description:	Carbon fraction of dry matter
Source of data:	IPCC default value 0.5. Used in Equation (39).
Measurement procedures (if any):	NA
Any comment:	

Data / parameter:	D_j
Data unit:	t d.m. m^{-3}
Description:	Basic wood density for species *j*
Source of data:	Values for *Dj* can be taken from tables generally used in the local or regional timber and forest industry, or from peer-reviewed literature applicable to the region. If no species-specific values for *Dj* are available, the average value across all species can be used, increased by 20% to ensure a conservative (higher) estimate of $C_{WPi,t}$. The source of data must be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (eg, from national GHG inventory); (b) (Group of) Species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (eg, IPCC GPG-LULUCF 2003).
Measurement procedures (if any):	NA
Any comment:	

Data / parameter:	$f_i(X, Y …)$

Data unit:	t d.m. tree^{-1}
Description:	Allometric equation for species *j* linking, for example, diameter at breast height (*DBH*) and tree height (*H*) to above-ground biomass of living trees
Source of data:	Used in Equation (39). Whenever available, use allometric equations that are species-specific or group of species-specific, provided the equations have been derived using a wide range of diameters and heights, based on datasets that comprise at least 20 trees. Otherwise, default equations from IPCC literature, national inventory reports or published peer-reviewed studies may be used—such as those provided in Tables 4.A.1 to 4.A.3 of the *GPG-LULUCF* (IPCC 2003).
Measurement procedures (if any):	NA
Any comment:	If default allometric equations are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then the equation may be used and considered conservative. Otherwise, it is necessary either to use conservatively assessed values, or to verify the applicability of the equation if mean predicted values are to be used. Allometric equations can be verified by: • Selecting at least 5 trees covering the range of *DBH* existing in the project area, and felling and weighing the above-ground tree biomass to determine the total (wet) weight of the stem and branch components; • Extracting and immediately weighing sub-samples from each of the wet stem and branch components, followed by oven drying at 70ºC to determine dry biomass; • Determining 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. If the biomass of the harvested trees is within about ±10% of the mean values predicted by the selected default allometric equation, and is not biased—or if biased is wrong on the conservative side (ie, use of the equation results in an under- rather than over-estimate of project net anthropogenic removals by sinks)—then mean values from the default equation may be used. (IPCC Good Practice Guidance for LULUCF, 2003, Section 4.3.3.5.1, under direct approach step 3)

Data and Parameters Monitored in Project Scenario

Data / parameter:	$A_{i,t}$
Data unit:	Ha
Description:	Area of stratum *i* at year *t*
Source of data:	Monitoring of strata and stand boundaries must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). Used in Equation (35)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{sp,i}$
Data unit:	Ha
Description:	Total area of all sample plots in stratum *i*
Source of data:	Field measurements. Used in Equation (38).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	DBH
Data unit:	cm
Used in equations:	
Description:	Diameter at breast height of tree
Source of data:	Field measurement in sample plots
Measurement procedures (if any):	Typically measured 1.3 m above ground. Measure all the trees above 5 cm *DBH* in the permanent sample plots.

Any comment:	For *ex-ante* estimations, tree dimension variables (eg, diameter at breast height (*DBH*) and possibly height (*H*)) should be estimated for tree species *j* in stratum *i*, at year *t* using a growth model based on these tree dimensions.

Data / parameter:	H
Data unit:	m
Description:	Height of tree
Source of data:	Field measurement in sample plots
Measurement procedures (if any):	
Any comment:	For *ex-ante* estimations, tree dimension variables (eg, diameter at breast height (*DBH*) and possibly height (*H*)) should be estimated for tree species *j* in stratum *i*, at year *t* using a growth model based on these tree dimensions.

Data / parameter:	$Dia_{n,i,t}$
Data unit:	cm
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*, at year *t*
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Lying dead wood can be sampled using the line intersect method (Harmon and Sexton 1996[27]). Two 50-meter lines are established bisecting each sample plot and the diameters of the lying dead wood (≥ 10 cm diameter) intersecting the lines are measured.
Any comment:	

27 Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of woody detritus in forest ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

Data / parameter:	BDia
Data unit:	cm
Description:	Basal diameter of standing dead tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Measured at ground level. Measure all trees above some minimum *BDia* in the sample plots, typically $\geq$ 10 cm.
Any comment:	

Data / parameter:	H_{SDW}
Data unit:	cm
Description:	Height of standing dead tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Height measured from ground level to either the top of a standing bole or to the base of crown if crown is persistent. Height is measured either directly or by using an instrument such as a clinometers, relascope or laser inventory instrument.
Any comment:	

Data / parameter:	N
Data unit:	dimensionless
Description:	Total number of wood pieces intersecting the transect
Source of data:	Field measurements
Measurement procedures (if any):	
Any comment:	

Data / parameter:	V_{extr}
Data unit:	m^3
Description:	The volume of timber extracted from within the project boundary (does not include slash left onsite), preferably reported by species and wood product class. Where no direct information on volume by wood product class is available (eg, illegal logging) 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.
Source of data:	Timber harvest records and/or estimates derived from field measurements or remote assessments with aerial photography or satellite imagery.
Measurement procedures (if any):	
Any comment:	Note that this volume does not include logging slash left onsite (tracked as part of the dead wood pool). Data compilers should also make sure that extracted volumes reported are gross volumes removed (ie, reported volume does not already discount for estimated wood waste, as is often the practice in harvest records)

Data / parameter:	t_2 and t_1
Data unit:	yr
Description:	Years of the monitoring activity
Source of data:	Field measurement in sample plots
Measurement procedures (if any):	
Any comment:	$T = t_2 - t_1$

Data / parameter:	$\Delta C_{P,i,t}$
Data unit:	$t\ CO_2\text{-e}\ yr^{-1}$

Description:	Net carbon stock change due to forest regrowth and silvicultural interventions in the with-project scenario in stratum *i* at year *t*
Source of data:	Used in Equation (34).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$\Delta C_{AGB,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Net carbon stock change in above-ground tree biomass[28] in the with-project scenario in stratum *i*
Source of data:	Used in Equation (34) and (35).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$\Delta C_{BGB,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Net carbon stock change in below-ground tree biomass in the with-project scenario in stratum *i*
Source of data:	Used in Equation (34) and (40).
Measurement procedures (if any):	
Any comment:	

[28] With *DBH* ≥ 5 cm.

Data / parameter:	$\Delta C_{DW,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Net carbon stock change in dead wood in the with-project scenario in stratum *i* at year *t*
Source of data:	Used in Equation (34) and (41).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$\Delta C_{WP,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Net carbon stock change in wood products in the with-project scenario in stratum *i* at year *t*
Source of data:	Used in Equation (34) and (42).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{biomassloss,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to site preparation for project activities in stratum *i* at year *t*
Source of data:	Used in Equation (34).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{AGB,l,j,sp,i,t}$
Data unit:	t C tree^{-1}
Description:	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at year *t*
Source of data:	Used in Equation (36), (37) and (39).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$V_{l,j,sp,i}$
Data unit:	m^3 tree^{-1}
Description:	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i*
Source of data:	Used in Equation (36).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{AGB,,sp,i,t}$
Data unit:	t C
Description:	Carbon stock in trees in plot *sp* in stratum *i* at year *t*
Source of data:	Used in Equation (37) and (38).
Measurement procedures (if any):	
Any comment:	

Leakage

Data and parameters not monitored (default, documented value, or possibly measured one time)

Data / parameter:	LF_{ME}
Data unit:	dimensionless
Description:	Leakage factor for market-effects calculations
Source of data:	Analysis of issuance of new concessions being assigned within the national boundaries, and associated annual extracted volumes. Used in Equation (44).
Measurement procedures (if any):	
Any comment:	Documented history of extracted volumes per hectare of existing concessions can be used as evidence.

Data / parameter:	NCS
Data unit:	t CO_2-e ha^{-1}
Description:	The mean national forest carbon stock
Source of data:	National statistics from Forest Department or other reliable sources
Measurement procedures (if any):	
Any comment:	

Data and parameters monitored

Data / parameter:	C_{BSL}
Data unit:	t CO_2-e ha^{-1}
Description:	Mean carbon stock across strata in all pools in the baseline
Source of data:	Determined in Section 9.1 of methodology
Measurement procedures (if any):	
Any comment:	

11 UNCERTAINTY AND QUALITY MANAGEMENT

Quality management procedures are required for the management of data and information, including the assessment of uncertainty, relevant to the project and baseline scenarios. As far as practical, uncertainties related to the quantification of GHG emission reductions and removals by sinks should be reduced.

To help reduce uncertainties in the accounting of emissions and removals, this methodology uses whenever possible the proven methods from the GPG-LULUCF, GPG-2000, and the IPCC's Revised 2006 Guidelines. As well, tools and guidance from the CDM Executive Board on conservative estimation of emissions and removals are also used. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from, for example, biomass expansion factors (BEFs) or wood density, would result in uncertainties in the estimation of both baseline net GHG removals by sinks and the actual net GHG removals by sinks - especially when global default values are used.

It is recommended that project proponent identifies key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances should then be obtained for these key parameters, whenever possible. These values should be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources;[29] or,

[29] Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date etc (or a detailed web address). If web-based reports are cited, hardcopies should be included as annexes in the project description if there is any likelihood such reports may not be permanently available.

- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or

- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value should be briefly noted in the project description. For any data provided by experts, the project description must also record the expert's name, affiliation, and principal qualification as an expert (eg, that they are a member of a country's national forest inventory technical advisory group) as well as a 1-page summary CV for each expert consulted, included in an annex.

In choosing key parameters, or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, project proponents should select values that will lead to an accurate estimation of net GHG removals by sinks, taking into account uncertainties.

If uncertainty is significant, project proponents should choose data such that it indisputably tends to under-estimate, rather than over-estimate, net GHG removals by sinks.

APPENDIX 1: TABLE FOR REPORTING THE CALCULATION OF TOTAL VCUS THROUGH NET CARBON STOCK CHANGES AND GREENHOUSE GAS EMISSION REDUCTIONS

Project year	Calendar year	ΔC_{BSL} Carbon stock changes		GHG emissions		ΔC_{WPS} Carbon stock changes		GHG emissions		ΔC_{LK} Carbon stock changes		GHG emissions		ΔC_{IFM} Carbon stocks			
		annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
Nr	yr	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
1																	
2																	
3																	
…																	
N																	

DOCUMENT HISTORY

Version	Date	Comment
v1.0	23 Nov 2010	Initial version released
v1.1	24 Aug 2011	Updates 1) Equation (7) of the wood products section is updated to correct for the error of applying carbon stocks in an equation intended for fractions (%). This makes the equations (8) and (9) redundant and they have been removed. 2) Equation (51) for the calculation of VCU's is updated to correct for the error of applying the buffer withholding percentage to GHG emissions and removals. 3) Various typographical errors: a. Reference to section 3.4.7 instead of 3.4.6 on page 17; b. delta symbols in table 3; and, c. other corrections
v1.2	23 Jul 2013	Updates 1) Procedures to account for the decay of carbon from the dead wood and harvested wood products pools have been included. 2) Minor edits to language were made (eg, the term 'must' has been used for required procedures).