Approved afforestation and reforestation baseline and monitoring methodology AR-AMxxxx

"Afforestation or reforestation on degraded land for sustainable wood production"

Source

This methodology is based on the draft CDM-AR-PDD: "Reforestation on degraded land for sustainable wood production of woodchips in the eastern coast of the Democratic Republic of Madagascar".

Section I. Summary and applicability of the baseline and monitoring methodologies

1. Selected baseline approach from paragraph 22 of the CDM A/R modalities and procedures

"Existing or historical, as applicable, changes in carbon stocks in the carbon pools within the project boundary"

2. Applicability

This methodology is applicable to afforestation or reforestation (hereafter, A/R) activities on degraded (or degrading)[1] land, and may be applied only to projects that meet the following conditions:

1. Lands to be afforested or reforested are degraded.
2. The application of the procedure for determining the baseline scenario in Section II.4 leads to the conclusion that baseline approach 22(a) [existing or historical changes in carbon stocks in the carbon pools with the project boundary] is the most appropriate choice for determination of the baseline scenario, and that the land would be expected to remain degraded in the absence of the project activity.
3. The project activity does not lead to a shift of pre-project activities outside the project boundary, i.e. the land under the proposed CDM A/R project activity can continue to provide at least the same amount of goods and services as in the absence of the project activity.
4. Environmental conditions and human-induced degradation prevent the encroachment of natural forest vegetation.
5. Biomass of non-tree vegetation is either at steady-state or is decreasing under the baseline land use.
6. Litter and dead wood—including harvest residues—are left at the plantation site, and wildfire is not common.
7. Site preparation involving slash-and-burn practices shall be restricted to non-tree vegetation, and burning shall be carried out in such a manner as to avoid damage to trees existing within the project area at the start of the project.
8. Grazing shall not occur within the project boundary.
9. Site preparation does not cause significant longer term net emissions from soil organic carbon pool.
10. Lands to be afforested or reforested are not drained wetlands or organic soils (e.g., peat-lands).

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[1] Henceforth in this document, any reference to degraded land shall be considered to also include the case of degrading lands: this methodology is applicable to either situation.

3. Selected carbon pools:

Table A: Selected carbon pools

Carbon pools	Selected (answer with Yes or No)	Justification / Explanation of choice
Above ground	Yes	Major carbon pool subject to the project activity
Below ground	Yes	Major carbon pool subject to the project activity
Dead wood	No	Conservative approach under applicability condition
Litter	No	Conservative approach under applicability condition
Soil organic carbon	No	Conservative approach under applicability condition

4. Summary of baseline and monitoring methodologies

Baseline methodology (summary/steps)

The methodology is only applicable for a proposed A/R project activity on degraded (or degrading) land, and comprises the following major elements:

- *Definition of the project boundary.* The project boundary is defined for all discrete parcels of land to be afforested or reforested. Until new procedures to demonstrate the eligibility of lands within the project boundary for A/R project activities under the clean development mechanism are approved by the Executive Board, the eligibility of land for a CDM A/R project activity shall be demonstrated based on definitions provided in Paragraph 1 of the Annex to Decision 16/CMP.1 ("Land use, land-use change and forestry"), as requested by Decision 5/CMP.1 ("Modalities and procedures for A/R project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol").

- *Carbon pools accounted.* Carbon stock changes in only the above-ground and below-ground biomass of living trees are estimated. The omission of the other pools (soil organic matter, dead wood and litter) is conservative because it can be justified that these pools would either decrease more or increase less in the absence of the proposed A/R project activity, relative to the project scenario. Removals in non-tree vegetation present under baseline conditions are not accounted because of the project applicability condition requiring that such vegetation exhibit static or declining biomass.

- *Baseline approach and additionality.* The methodology applies Approach 22(a) as the baseline approach for the proposed A/R project activity, taking into account historic land use/cover changes; national, local and sectoral policies that influence land use within the boundary of the proposed A/R project activity; the economic attractiveness of the project relative to the baseline; and barriers to implementation of project activities in the absence of CDM finance. The methodology uses the latest version of the "Tool for the demonstration and assessment of additionality for afforestation and reforestation CDM project activities" approved by the CDM Executive Board[2]

- *Stratification and biomass estimation.* The proposed A/R project area is stratified in a manner consistent with available information on key factors controlling average carbon stocks, and GHG emissions and removals, in the above- and below-ground biomass pools. Baseline net GHG removals by sinks are determined separately for each stratum. For strata without growing trees, this methodology assumes that the carbon stock in above-ground and below-ground biomass would in the absence of the project activity remain constant or decline. As a consequence, baseline net GHG removals by sinks are conservatively assumed to be zero. For strata with growing trees, baseline net

[2] Throughout this document, the "A/R additionality tool" refers to the document approved by the Executive Board of the CDM and available at<http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html.>

GHG removals by sinks are estimated based on methods in the IPCC's Good Practice Guidance for Land use, Land-use Change, and Forestry (GPG-LULUCF)[3].

- *Project emissions.* The loss of non-tree living biomass from the site due to site preparation or competition from planted trees is accounted as an emission within the project boundary. This is done in a conservative manner, by assuming all non-tree living biomass is oxidized at the start of the project. In addition, increases in GHG emissions as a result of the following activities inside the project boundary are accounted: burning of fossil fuels, biomass burning, application of nitrogenous fertilizers, and decay of residues from nitrogen-fixing trees.
- *Leakage emissions.* Leakage is accounted as emissions from use of fossil fuel in transportation of staff, seedlings, materials or products attributable to implementation of the proposed A/R project activity.

Monitoring methodology (summary/steps)

The monitoring methodology is based on standard forest inventory practice, and comprises the following major elements:

- *Assessment of project implementation.* Provision of information, recorded in the project design document (PDD), to establish that:
  - o The geographic position of the project boundary is recorded for all parcels.
  - o Applicability conditions are met.
  - o Commonly accepted principles of forest inventory are implemented.
  - o Implementation of forest planting and management activities are in accordance with the project plan used as the basis for making *ex ante* estimates of net GHG removals by sinks;
- *Stratification and sampling.* The methodology requires stratification of the project area based important variations in trees species, age, and stocking, and in climate, existing vegetation and site class. Stratification can be achieved with the aid of the forest planting and management plan, land use/cover maps, remote sensing data, soil maps, and GPS and field surveys. The methodology uses permanent sample plots to monitor carbon stock changes in living biomass pools. The methodology first estimates the number of plots needed in each stratum to reach a targeted precision level in estimated biomass of ± 10% of the mean at a 95% confidence level.
- *Estimation of actual net GHG removals and emissions.* Estimates of project removals by sinks are based on standard plot-based forest inventory methodology. Increases in GHG emissions within the project boundary are estimated for use of: nitrogen fertilizers; machinery/vehicle use in site preparation, transportation of seedlings, thinning and logging; nitrogen-fixing trees; removal of existing non-tree vegetation including any biomass burning as part of site preparation; and loss of biomass by wildfire or other disturbance.
- *Estimation of leakage emissions.* Estimates of emissions are made for use of fossil fuel during transportation outside the project boundary of staff, seedlings, materials or products attributable to implementation of the proposed A/R project activity.

It is not mandatory that baseline net GHG removals by sinks be determined *ex post*. However, project

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[3] Throughout this document, "GPG-LULUCF" means the Good Practice Guidance for Land Use, Land Use Change and Forestry from the Intergovernmental Panel on Climate Change (2003). This document is available at the following URL: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.htm.

participants may choose to determine baseline removals *ex post* if required. The methodology also requires that assumptions and applicability conditions relating to the baseline state be re-assessed if a renewal of the crediting period is chosen, and baseline removals re-calculated if necessary.

Section II. Baseline methodology description

1. Project boundary

The A/R project activity may comprise more than one discrete parcel of land, and all parcels shall have a unique geographically-referenced identifier. The geographic boundary of each parcel shall also be delineated to make the entire project boundary geographically verifiable. The project boundary data shall be recorded, archived, and listed in the CDM-AR-PDD.

All parcels of land within the project boundary shall either be under the control of the project participants at the starting date of the project activity, or expected to come under the control of the project participants during the crediting period as a result of implementation of the project activity. Parcels of land not under the control of the project participants at the start date of the proposed A/R project activity, but expected to come under the control of the project participants during the crediting period, may be included within the project boundary only if all of the following conditions are met:

- The total area (hectares) of those parcels of land not yet under the control of the project participants is clearly defined in the CDM-AR-PDD; and
- A justification describing the conditions under which these parcels of land will come under the control of the project participants is provided in the CDM-AR-PDD; and
- The candidate land areas among which the particular parcels of land will be chosen have been identified and are unambiguously geographically identified in the CDM-AR-PDD using GPS coordinates, maps, or other georeferenced data of sufficient accuracy; and
- All candidate land areas have been included in the baseline assessment and it can be shown that the candidate areas are not significantly different from the land areas already under the control of the project participants at the start of the proposed AR CDM project activity in terms of land eligibility, baseline net GHG removal by sinks, actual net GHG removal by sinks, leakage, and socio-economic and environmental impacts.

The project boundary includes the emission sources and gases listed in Table B**.**

Table B: Emissions sources included in or excluded from the project boundary

Sources	Gas	Included/ excluded	Justification / Explanation of choice
Use of fertilizers	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Potentially significant emission source
Use of nitrogen-fixing tree species	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Potentially significant emission source
Combustion of fossil fuels	CO_2	Included	Potentially significant emission source
	CH_4	Excluded	Potential emission is negligibly small
	N_2O	Excluded	Potential emission is negligibly small
Biomass burning	CO_2	Included	Carbon stock decreases due to burning are accounted as a carbon stock change

Sources	Gas	Included/ excluded	Justification / Explanation of choice
	CH_4	Included	Potentially significant emission source
	N_2O	Included	Potentially significant emission source

2. Eligibility of land

When new procedures to demonstrate the eligibility of lands for A/R project activities under the clean development mechanism are approved by the Executive Board, these shall be used. Until such procedures are available, the eligibility of land for an A/R project activity shall be demonstrated based on definitions provided in Paragraph 1 of the Annex to Decision 16/CMP.1 (“Land use, land-use change and forestry”), as requested by Decision 5/CMP.1 (“Modalities and procedures for A/R project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol”).

3. Ex ante stratification

If the project activity or area is not homogeneous, simple stratification should be carried out to improve the accuracy and precision of *ex ante* biomass estimates. Stratification may optionally make use of remote sensing data[4] acquired close to the time the project commences, to assist with determining the homogeneity of strata. For *ex ante* estimation of baseline GHG removals by sinks, or *ex ante* estimation actual GHG removals by sinks, strata should be defined by:

(i) Using procedures to stratify lands for A/R project activities under the clean development mechanism as approved by the Executive Board; or

(ii) On the basis of parameters that are key variables in any method (e.g., growth models, or yield curves/tables) used to estimate biomass:

- *For baseline GHG removals by sinks:* as baseline removals for degraded (or degrading) land are expected to be small in comparison to project removals, it will usually be sufficient to treat the project area as a single stratum, and to only estimate average baseline carbon stocks (and/or removals, as necessary) for each major vegetation type (i.e. trees, shrubs and grasses)—together with estimation of the area covered by each of these major vegetation types.
- *For actual net GHG removals by sinks:* the project area should be stratified according to the project planting plan—that is, by forest species, age class (planting date), and possibly management regime.

Further subdivision of the project strata to represent spatial variation in the distribution of baseline or project biomass/removals is not usually warranted, unless methods used for *ex ante* estimates explicitly include variables for which spatial data also exist. For example, stratification by rainfall or pruning regime is not warranted when estimating biomass stocks or removals unless the estimation methods are formulated with rainfall or pruning regime as explicit variables.

4. Procedure for selection of most plausible baseline scenario

Project participants should determine the most plausible baseline scenario using the following steps:

Step 1: Identify and list plausible alternative land uses—including known future public or private activities on similar degraded lands (such as any similar A/R activity undertaken as a non-CDM project, or any other feasible land development activities)—and also considering relevant national and or sectoral

[4] Detailed guidelines on the preparation and use of remote sensing data are given in Annex 1.

land-use policies that would impact the proposed project area. This step should make use of land records, field surveys, data and feedback from stakeholders, and information from other appropriate sources. As part of this, at least the land use alternatives below shall be considered:

- Plantation forestry for commercial wood production, equivalent to the proposed project;
- Plantation forestry for other than commercial wood production (e.g., conservation forest);
- Permanent agricultural cropping activities;
- Remaining as the existing land use, namely, degraded non-forest land.

Step 2: Demonstrate that under the scenarios identified in Step 1, the most plausible scenario is that the project area would remain in the existing or historical land use in absence of the project activity. This shall be assessing by determining the attractiveness of the plausible alternative land uses in terms of benefits to the project participants, and identifying barriers for alternative land uses. This can be done in at least one of the following ways:

- *Generally:* by demonstrating that similar lands in the vicinity are not, and are not planned to be, used for these alternative land uses. Show that apparent financial and/or other barriers, which prevent the plausible alternative land uses, can be identified;
- *Specifically for forest as an alternative land use:* apply Step 2 (investment analysis) or Step 3 (barrier analysis) of the "*Tool for the demonstration and assessment of additionality*", to demonstrate that this land use, in the absence of the CDM A/R activity, is unattractive;
- *Specifically for any alternative agricultural land uses:* either demonstrate that the project lands are legally restricted to forestry purposes only, and that these restrictions are generally complied with in the vicinity of the project area; or alternatively, use Step 2 (investment analysis) or Step 3 (barrier analysis) of the "*Tool for the demonstration and assessment of additionality*", to demonstrate that alternative agricultural land uses are financially non-viable.

Step 3: To support the findings above, demonstrate that the A/R project lands are really "degraded"[5]:

Analyze the historical and existing land use/cover changes in the context of climate, soil and socio-economic conditions for the project area and/or surrounding similar lands, and identify key factors that influence land use/cover changes over time. This procedure should use multiple sources of data including archived information, maps, or remote sensing data of land use/cover around 1990, and also before the start of the proposed A/R project activity. Supplementary field investigation, land-owner interviews, as well as collection of data from other sources may also be required. A degraded state is indicated if there is evidence that one or more of the following is commonly present within the proposed project boundary:

- Vegetation degradation, for example:
  - The cover and/or health of vegetation—as determined by visual assessment (or similar indicator-based) scoring[6]—has decreased by at least 25% below undisturbed lands adjacent to the project area, and has not recovered.

[5] In this section, the term "degraded" is interpreted only in the context of non-forest land, the subject of this methodology. Degradation of existing forests is not covered. Therefore the definition of degradation is more constrained than in the IPCC report on "Definitions and Methodological Options to Inventory Emissions from Direct Human-induced Degradation of Forests and Devegetation of Other Vegetation Types, see <http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/degradation.htm>.

- Soil degradation, for example:,
    - Soil erosion has increased significantly between at least two points in time, and has not recovered, or;
    - Soil organic matter has decreased significantly between at least two points in time, and has not recovered.
- Anthropogenic influences leading to degradation, for example:
    - There is a documented history of on-going loss of soil and vegetation cover due to anthropogenic influences; or
    - Evidence can be provided that anthropogenic actions, which are likely to continue in the absence of the A/R project activity, can be documented as the cause of on-going loss of soil and/or vegetation cover on similar lands elsewhere.
- Provision of any other evidence that transparently demonstrates project lands are in a degraded state.

Step 4: To support the findings above, demonstrate that no natural encroachment of trees sufficient to exceed the host country's forest threshold is likely, by:

- Demonstration of a lack of an on-site and external seed pools/sources that may result in natural regeneration; or
- Demonstration of limited possibilities for seed germination and/or growth of seedlings or young trees; or
- Demonstration of a lack of possible natural regeneration activity, by use of supplementary surveys of the project area as well as in similar surrounding areas for two different years that cover a minimum time period of ten years; or
- Any other evidence that demonstrates in a verifiable way that natural encroachment of trees is unlikely.

Step 5: Demonstrate that national and/or sectoral land-use policies or regulations that create policy-driven market distortions that give comparative advantage to A/R activities, and that have been adopted before 11 November 2001, do not influence the area of the proposed A/R project activity (e.g., because the policy is not implemented, the policy does not target this area, or because there are prohibitive barriers to the policy in this area, etc[7]). If the policies (implemented before 11 Nov 2001) significantly impact the project area, then this methodology can not be used.

Step 6: This methodology is applicable only if project proponents can clearly show that application of Steps 1 to 5 above results in identification of baseline approach 22(a)—existing or historical changes in carbon stocks in the carbon pools with the project boundary)—is the most plausible baseline scenario. To ensure transparency when establishing whether lands are degraded all information used in the analysis shall be verifiable, archived, and listed in the CDM-AR-PDD.

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[6] Assessment scores should be supported by photographic evidence whenever possible, including a sequence of photographs showing the range in scores that relate to conditions that span land conditions considered undisturbed to completely degraded.
[7] This is to comply with a ruling of the Executive Board of the CDM, see Annex 3 of the 16th meeting of the Board at http://cdm.unfccc.int/EB/Meetings.

5. Additionality

To prove additionality this methodology uses the latest version of the *"Tool for the demonstration and assessment of additionality for afforestation and reforestation CDM project activities"* approved by the CDM Executive Board[8], but requires that Step 2 (Investment analysis) shall be conducted whether Step 3 (Barrier analysis) is conducted or not. This is because project activities will generate financial benefit other than CDM related income, and so either the Investment Comparison Analysis (Option II) or the Benchmark Analysis (Option III) shall be selected.

6. Estimation of baseline net GHG removals by sinks

The baseline is determined *ex ante*, and may also be determined *ex post* if required—and remains fixed during the subsequent crediting period. When estimating baseline net GHG removals by sinks, a conservative approach should be taken when choosing parameters and making assumptions. That is, if different values or assumptions for a parameter are plausible, a value that does not lead to an under-estimation of baseline net GHG removals by sinks should be applied. Estimation of baseline removals by sinks proceeds by:

a. Determining the sum of carbon stock changes for each stratum:

- For those strata without growing trees, the sum of carbon stock changes in above-ground and below-ground non-tree biomass is set as zero based on the applicability condition of the methodology, which requires steady-state or decreasing non-tree biomass in the baseline, and no natural encroachment of trees (as required to be demonstrated in Section II.3, Step 3);

- For those strata with growing trees, the sum of carbon stock changes in above-ground and below-ground tree biomass is determined based on the projection of their number and growth, made using growth models (e.g., yield tables), biomass expansion factors or allometric equations, and local, national, or IPCC default parameters (details below, in this section).

b. Summing the baseline net GHG removals by sinks across all strata.

The baseline net GHG removals by sinks are calculated as:

$$\Delta C_{BSL,t} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} \Delta C_{ij,baseline,t} \qquad \textbf{(1)}$$

where:

$\Delta C_{BSL,t}$	the sum of the changes in carbon stocks in living biomass of trees for year *t*; t CO2–e yr^{-1} for year *t*
$\Delta C_{ij,baseline,t}$	average annual carbon stock change in living biomass of trees for stratum *i* species *j* in the absence of the project activity; t CO_2–e yr^{-1} for year *t*
i	strata (n_{st} = total number of strata)
j	tree species or type (n_{sp} = total number of species)
t	1 to length of crediting period (yrs)

For strata without growing trees, $\Delta C_{ij,baseline,t}$ = 0. For strata with growing trees, $\Delta C_{ij,baseline,t}$ is estimated as $\Delta C_{ij,t}$ using one of following two methods, chosen on the basis of availability of data.

[8] Hereinafter referred as the "A/R additionality tool". Please refer to http://cdm.unfccc.int/goto/ARappmeth

(a) Method 1 (Carbon gain-loss method)[9]

$$\Delta C_{ij,t} = \Delta C_{G,ij,t} - \Delta C_{L,ij,t} \qquad \textbf{(2)}$$

where:

$\Delta C_{ij,t}$	average annual carbon stock change in living biomass of trees for stratum *i* species *j*; t CO_2–e yr^{-1} for year *t*
$\Delta C_{G,ij,t}$	average annual increase in carbon due to biomass growth of living trees for stratum *i* species *j*; t CO_2–e yr^{-1} for year *t*
$\Delta C_{L,ij,t}$	average annual decrease in carbon due to biomass loss of living trees for stratum *i* species *j*; t CO_2–e yr^{-1} for year *t*.

Note that as a conservative assumption in this methodology, $\Delta C_{L,ij,t} = 0$.

$$\Delta C_{G,ij,t} = A_{ij} \cdot G_{TOTAL,ij,t} \cdot CF_j \cdot 44/12 \qquad \textbf{(3)}$$

where:

$\Delta C_{G,ij,t}$	average annual increase in carbon due to biomass growth of living trees for stratum *i* species *j*; t CO_2–e yr^{-1} for year *t*
A_{ij}	area of stratum *i* species *j*; hectare (ha)
$G_{TOTAL,ij,t}$	average annual increment of total dry biomass of living trees for stratum *i* species *j*; t d. m. $ha^{-1}yr^{-1}$ for year *t*
CF_j	carbon fraction of dry matter for species or type *j*; t C (t d.m.)$^{-1}$
44/12	ratio of molecular weight of CO_2 to carbon; dimensionless

and:

$$G_{TOTAL,ij,t} = G_{w,ij,t} \cdot (1 + R_j) \qquad \textbf{(4)}$$

$$G_{w,ij,t} = I_{V,ij,t} \cdot D_j \cdot BEF_{1,j} \qquad \textbf{(5)}$$

where:

$G_{TOTAL,ij,t}$	average annual increment of total dry biomass of living trees for stratum *i* species *j*; t d. m. $ha^{-1}yr^{-1}$ for year *t*
$G_{w,ij,t}$	average annual aboveground dry biomass increment of living trees for stratum *i* species *j*; t d. m. ha^{-1} yr^{-1} for year *t*
R_{1j}	root-shoot ratio appropriate to above-ground biomass increment for species *j*; dimensionless
$I_{V,ij,t}$	average annual increment in merchantable volume for stratum *i* species *j*; m^3 ha^{-1} yr^{-1} for year *t*

[9] IPCC 2006 Guidelines Equations 2.7, 2.9, 2.10, 2.11, 2.12, 2.13, and 2.14

D_j	wood density for species *j*; t d.m. m^{-3}
$BEF_{1,j}$	biomass expansion factor for conversion of annual net increment in merchantable volume to total above-ground biomass increment for species *j*; dimensionless
44/12	ratio of molecular weight of CO_2 to carbon; dimensionless

(b) Method 2 (stock change method)[10]

$$\Delta C_{ij,t} = (C_{ij,2} - C_{ij,1}) / T \cdot 44/12 \tag{6}$$

$$C_{ij,t} = C_{AB,ij,t} + C_{BB,ij,t} \tag{7}$$

$$C_{AB,ij,t} = A_{ij} \cdot V_{ij,t} \cdot D_j \cdot BEF_{2,j} \cdot CF_j \tag{8}$$

$$C_{BB,ij,t} = C_{AB,ij,t} \cdot R_j \tag{9}$$

where:

$\Delta C_{ij,t}$	average annual carbon stock change in living biomass of trees for stratum *i* species *j*; t CO_2–e yr^{-1} for year *t*
$C_{ij,2}$	total carbon stock in living biomass for stratum *i* species *j* time 2; t C
$C_{ij,1}$	total carbon stock in living biomass for stratum *i* species *j* time 1; t C
T	number of years between times 2 and 1
$C_{ij,t}$	total carbon stock in living biomass for stratum *i* species *j*; t C for year *t*
$C_{AB.ij,t}$	carbon stock in aboveground biomass for stratum *i* species *j*; t C for year *t*
$C_{BB,ij,t}$	carbon stock in belowground biomass for stratum *i* species *j*; t C for year *t*
A_{ij}	area of stratum *i* species *j*; ha
$V_{ij,t}$	merchantable volume for stratum *i* species *j*; m^3 ha^{-1} for year *t*
D_j	wood density for species *j*; t d.m. m^{-3} merchantable volume
$BEF_{2,j}$	biomass expansion factor for conversion of merchantable volume to above-ground tree biomass for species *j*; dimensionless
CF_j	carbon fraction of dry matter for species or type *j*; t C (t d.m.)$^{-1}$
R_{2j}	root-shoot ratio appropriate for above-ground biomass stock of species *j*; dimensionless

The biomass stocks at time points 1 and 2, from which ΔC_{ij} is determined, must be broadly representative of the mean biomass of trees that are the age and species of those in the baseline situation during the crediting period.

$C_{AB,ij}$ can also be estimated through the use of an allometric equation, together with a growth model or

[10] IPCC 2006 Guidelines Equations 2.8

yield table:

$$C_{AB,ij,t} = A_{ij} \cdot CF_j \cdot f_j(DBH_t, H_t) \quad \textbf{(10)}$$

where:

$C_{AB,ij,t}$	carbon stock in aboveground biomass for stratum *i* species *j*-; t C for year *t*
A_{ij}	area of stratum *i* species *j*; ha
CF_j	carbon fraction of dry matter for species or type *j*; t C (t d.m.)$^{-1}$
$f_j(DBH_t, H_t)$	an allometric equation linking aboveground biomass (d.m. ha^{-1}) to tree diameter at breast height (DBH) and possibly tree height (H) for species *j*.

Note: mean DBH and H values should be estimated for stratum *i* species *j* and time *t* using a growth model or yield table that gives the expected tree dimensions as a function of tree age. The allometric relationship between above-ground biomass of trees and DBH (and possibly H) is a function of the species considered, and any application of a single equation to multiple species shall be transparently justified in the CDM-AR-PDD.

In choosing Methods 1 or 2, there is no priority in terms of transparency and conservativeness[11]. The choice should mainly depend on the availability of parameters. $V_{ij,t}$ and $I_{v,ij,t}$ shall be estimated based on the number of trees and growth curves/tables that usually can be obtained from national or local forestry inventory. If national or local growth curves/tables are not available, default values in Table 3A.1.5 of the GPG-LULUCF can be used.

D_j, $BEF_{1,j}$, $BEF_{2,j}$, CF_j and R_j are regionally and species specific, and shall be chosen with the following priority:

1. Existing local species-specific data of sufficient reliability; or
2. National species-specific data (e.g., from national GHG inventory); or
3. Species-specific data from neighboring countries with similar climatic conditions. In the case of a large country that encompasses very different biome types, option 3 might be preferable to option 2 if project conditions differ substantially from national mean climatic conditions; or
4. Global species-specific data (e.g., from the GPG-LULUCF).

If species-specific information is not available, information for similar species (e.g., with similar shape, broadleaved vs. deciduous, etc) can be used, with the data source priority as listed for species-specific information. If ranges of values for BEF, R and D are available, the values used for estimation of baseline removals should be chosen conservatively from the upper end of the ranges. Note that trees under the baseline scenario are trees outside of a forest, as BEFs for such isolated trees are generally higher than for forest trees.

When choosing from global or national databases because local data are of limited reliability, local data shall if possible be used to confirm that global/national data does not lead to under-estimation of baseline net GHG removals by sinks, as far as can be judged. Local data used for confirmation may be drawn from the literature and local forestry inventory, or measured directly by project participants—especially for BEF and root-shoot ratios that are age- and species-dependent.

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[11] The same approach, that is Method 1 or Method 2, should be used during both *ex ante* and *ex post* determination of baseline net GHG removals by sinks, if *ex post* determination is used.

7. Ex ante actual net GHG removals by sinks

In choosing parameters and making assumptions, project participants should retain a conservative approach, i.e. if different values for a parameter are plausible, a value that does not lead to an over-estimation of actual net GHG removals by sinks should be applied.

(a) Verifiable changes in carbon stocks in the carbon pools

The average annual carbon stock change between two monitoring events in above- and below-ground biomass in living trees established by the project for stratum *i* species *j*, ($\Delta C_{L,ij}$), shall be estimated using one of the two Methods described in Section II 4, i.e. equations (2) to (10). The choice of methods and parameters shall be made in the same way as described in Section II 5. However, when Method 1 (Carbon gain-loss method) is used for these estimates, its general form becomes:

$$\Delta C_{L,ij} = (L_{fellings,ij} + L_{fuelwood,ij} + L_{otherloss,ij}) \cdot 44/12 \qquad \textbf{(11)}$$

where the terms $L_{fellings}$, $L_{fuelwood}$, $L_{otherloss}$ account for biomass loss in the A/R project due to harvesting of trees, fuelwood gathering, and disturbance, respectively, and are calculated as:

$$L_{fellings,ij} = H_{ij} \cdot D_j \cdot BEF_{2,j} \cdot \left(1 + R_{2j}\right) \cdot CF_j \qquad \textbf{(12)}$$

$$L_{fuelwood,ij} = FG_{ij} \cdot D_j \cdot BEF_{2,j} \cdot \left(1 + R_{2j}\right) \cdot CF_j \qquad \textbf{(13)}$$

$$L_{otherloss,ij} = A_{disturbance,ij} \cdot F_{disturbance,ij} \cdot B_{w,ij} \cdot \left(1 + R_{2j}\right) \cdot CF_j \qquad \textbf{(14)}$$

where:

$\Delta C_{L,ij}$	average annual decrease in carbon due to biomass loss of living trees for stratum *i* species *j*; t CO_2 yr^{-1}
$L_{fellings,ij}$	annual carbon loss due to commercial felling and thinning for stratum *i* species *j*; t C yr^{-1}
$L_{fuelwood,ij}$	annual carbon loss due to fuelwood harvesting of planted trees for stratum *i* species *j*; t C yr^{-1}
$L_{otherloss,ij}$	annual disturbance-related losses of carbon in living trees for stratum *i* species *j*; t C yr^{-1}
H_{ij}	annually extracted merchantable volume for stratum *i* species *j*; m^3 yr^{-1}
D_j	wood density for species *j*, ; t d.m.m^{-3} merchantable volume
$BEF_{2,j}$	biomass expansion factor for conversion of merchantable volume to above-ground tree biomass for species *j*; dimensionless
CF_j	carbon fraction of dry matter for species or type *j*; t C (t d.m.)$^{-1}$
R_{2j}	root-shoot ratio appropriate for above-ground biomass stock of species *j*; dimensionless
FG_{ij}	annual volume of fuelwood harvesting of living trees for stratum *i* species *j*; m^3 yr^{-1}
$A_{disturbance,ij}$	area affected by disturbances in stratum *i* species *j*; ha yr^{-1}
$F_{disturbance,ij}$	the fraction of the biomass in living trees for stratum *i* species *j* affected by disturbance; dimensionless

$B_{w,ij}$	average biomass stock of living planted trees for stratum *i* species *j*; t d. m. ha^{-1}
44/12	ratio of molecular weight of CO_2 to carbon; dimensionless

Note—when applying the equations above in the context of this methodology:

- Only harvesting losses are accounted *ex ante*[12]. That is, the terms $L_{fuelwood}$ and $L_{otherloss}$ are set equal to zero. This is because fuelwood gathering is not permitted due an applicability condition of the project, and because the extent to which disturbance may occur is unknown *ex ante*.
- In any more general application of the equations (e.g., in the *ex post* section of this methodology), double counting of biomass losses due to harvesting and fuelwood gathering, or disturbance and fuelwood gathering, must be avoided.

(b) GHG emissions by sources

The A/R project activity may cause GHG emissions within the project boundary. The emission of CO_2, CH_4 and N_2O from the following sources, also listed in Table **B** in Section II.1, may occur as a result of the proposed A/R project activity[13]:

- Emissions of GHG from combustion of fossil fuels for site preparation, thinning and logging;
- Decrease in carbon stocks in living biomass of non-tree vegetation that existed at the time the project commenced, caused either by site preparation or competition from planted trees;
- Emissions of non-CO_2 GHG from biomass burning during slash-and-burn site preparation[14];
- Direct N_2O emissions caused by nitrogen fertilization application;
- Direct N_2O emissions caused by nitrogen input from residues from planted nitrogen-fixing trees.

The GHG emissions that result from implementation of the proposed A/R project activity within the project boundary are calculated as:

$$GHG_E = E_{FuelBurn} + E_{biomassloss} + E_{Non-CO2,BiomassBurn} + N_2O_{direct-N_{fertilizer}} + N_2O_{direct-N_{N-fixing}} \quad \textbf{(15)}$$

where:

GHG_E	GHG emissions resulting from implementation of the A/R project activity within the project boundary; t CO_2-e yr^{-1}
$E_{FuelBurn}$	CO_2 emissions from combustion of fossil fuels; t CO_2-e yr^{-1}
$E_{biomassloss}$	CO_2 emissions from a decrease in carbon stock in living biomass; t CO_2-e yr^{-1}
$E_{Non-CO2, BiomassBurn}$	non-CO_2 emissions from burning of biomass burning, if this is to be used; t CO_2-e

[12] It is possible that disturbance after the project starts may also cause emissions from trees existing at the time the project commences. Because the extent of disturbance is unknown ex *ante*, such emissions are not considered here, but are for generality included as part of the monitoring methodology, in Sections III. 5. (b). (ii). and III.5. (b). (iii).

[13] Refer to Box 4.3.1 and Box 4.3.4 in GPG-LULUCF, and 2.4 and 11.1 in IPCC 2006 Guidelines Volume 4.

[14] It is possible that wildfire after the project starts may also cause emissions from trees existing at the time the project commences. Because the extent of such disturbance is unknown ex *ante*, such emissions are not considered here, but are for generality included as part of the monitoring methodology, in Sections III. 5. b.ii and iii.

$N_2O_{direct-Nfertilizer}$	direct N_2O emissions that result from application of nitrogenous fertilizer; t CO_2-e yr^{-1}
$N_2O_{direct-NN\text{-}fixing}$	direct N_2O emission from residues from nitrogen-fixing trees; t CO_2-e yr^{-1}

Note—when estimating GHG_E in the context of this methodology:

- Only emissions from non-tree vegetation existing at the start of the project need be considered as part of estimating *ex ante* emissions by sources, as an applicability condition requires that trees existing in the project area at the time the project starts must be protected from any slash-and-burn activities.
- Accounting of emissions from non-tree vegetation is performed once, during the first monitoring period.

(i) Calculation of GHG emissions from burning fossil fuels

Fossil fuels may be consumed during the following activities inside the project boundary: site preparation, planting, forest management and harvesting; and transportation of seedlings, materials, staff or products. The CO_2 emissions from these activities can be estimated as follows[15]:

$$E_{FuelBurn} = \sum_{v}\sum_{f}(EF_{vf} \cdot CSP_{vf}) \cdot 0.001 \qquad \textbf{(16)}$$

where:

$E_{FuelBurn}$	CO_2 emissions from combustion of fossil fuels within the project boundary; t CO_2-e yr^{-1}
EF_{vf}	emission factor for vehicle or machinery type *v,* using fuel type *f*; kg CO_2 $litre^{-1}$
$CSP_{vf:}$	consumption of fuel type *f,* by vehicle or machinery type *v*; litre yr^{-1}
0.001	conversion factor: kilograms to tonnes

National CO_2 emission factors should be used whenever possible. If these are not available, default emission factors provided in the IPCC's Revised 2006 Guidelines should be used. Emission factors should be chosen conservatively from IPCC literature when national data are not available for a particular fuel or vehicle/machinery type.

(ii) Calculation of the decrease in carbon stock in living biomass of existing non-tree vegetation

It is assumed that all non-tree vegetation within the project area will be oxidized instantaneously at the start of the project due to site preparation—including possible use of slash-and-burn methods—or due to competition from planted trees. This is a conservative assumption because there will likely be some non-tree vegetation re-growth in the project scenario. The biomass loss is calculated as:

$$E_{biomassloss,non-tree} = \sum_{i=1}^{n_{st}} A_i \cdot B_{non-tree,i} \cdot (1 + R_{non-tree}) \cdot CF_{non-tree} \cdot 44/12 \qquad \textbf{(17)}$$

where:

$E_{biomassloss,}$ CO_2 emissions that result from a decrease in carbon stock in living biomass of non-tree

[15] Refer to Equation 3.2.1 in IPCC 2006 Revised Guidelines, Volume 2

non-tree	vegetation; t CO_2-e yr^{-1}.
A_i	area of stratum i, cleared for site preparation; ha
$B_{non\text{-}tree,i}$	average non-tree above-ground biomass stock on land within stratum *i*; t d.m. ha^{-1}
$R_{non\text{-}tree}$	average root-shoot ratio appropriate for above-ground biomass stock; dimensionless
$CF_{non\text{-}tree}$	carbon fraction of dry biomass in non-tree vegetation; t C (tonne d.m.)$^{-1}$
i	strata (n_{st} = total number of strata)
44/12	ratio of molecular weights of CO_2 and carbon; dimensionless

Values for non-tree biomass can be obtained from local, regional or national inventory data, or from peer-reviewed literature or official reports—taking into account the project circumstances (species, mean crown cover etc). Alternatively, default data may be conservatively chosen from the GPG-LULUCF. Non-tree biomass may also be directly measured: see Section III.5.b.(ii) for details.

(iii) Calculation of emissions from biomass burning

If slash-and-burn methods are practiced during site preparation for planting or replanting, this results in non-CO_2 emissions from burning of above-ground biomass—CO_2 emissions from above-ground biomass will always be accounted in those sections of the methodology that deal with biomass loss (e.g., Sections II.6.a, or II.6.b.(ii), above).

Based on the GPG-LULUCF[16], non-CO_2 emissions from biomass burning can be calculated as:

$$E_{Non-CO2,BiomassBurn} = E_{BiomassBurn,N2O} + E_{BiomassBurn,CH4} \quad \textbf{(18)}$$

where:

$E_{Non\text{-}CO2,BiomassBurn}$	non-CO_2 emissions that result from burning of biomass; t CO_2-e yr^{-1}.
$E_{BiomassBurn,\ N2O}$	N_2O emissions from biomass as a result of burning of biomass; t CO_2-e yr^{-1}
$E_{BiomassBurn,\ CH4}$	CH_4 emissions from biomass as a result of burnng of biomass; t CO_2-e yr^{-1}

and:

$$E_{BiomassBurn,N2O} = E_{BiomassBurn,C} \cdot \left(N/_C\, ratio \right) \cdot ER_{N2O} \cdot 44/_{28} \cdot GWP_{N2O} \quad \textbf{(19)}$$

$$E_{BiomassBurn,CH4} = E_{BiomassBurn,C} \cdot ER_{CH4} \cdot 16/_{12} \cdot GWP_{CH4} \quad \textbf{(20)}$$

where:

$E_{BiomassBurn,C}$	C loss in above-ground biomass due to burning of biomass; t C yr^{-1}
N/C ratio	nitrogen-carbon ratio; dimensionless (IPCC default: 0.01)
ER_{N2O}	IPCC default emission ratio for N_2O = 0.007
ER_{CH4}	IPCC default emission ratio for CH_4 = 0.012

[16] Refers to equation 3.2.20 in GPG for LULUCF

GWP_{N2O}	Global Warming Potential for N_2O; kg CO_2-e (kg N_2O)$^{-1}$ (IPCC default = 310, valid for the first commitment period)
GWP_{CH4}	Global Warming Potential for CH_4, kg CO_2-e (kg CH_4)$^{-1}$ (IPCC default = 21, valid for the first commitment period)
44/28	ratio of molecular weights of N_2O and nitrogen; dimensionless
16/12	ratio of molecular weights of CH_4 and carbon; dimensionless

and:

$$E_{BiomassBurn,C} = \sum_{i=1}^{n_{st}} A_{burn,i} \cdot B_{AB,i} \cdot CE \cdot CF \qquad \textbf{(21)}$$

where:

$E_{BiomassBurn,C}$	loss of carbon stock in above-ground biomass during burning; t C yr^{-1}
$A_{burn,\,i}$	area of stratum i subject to burning; ha yr^{-1}
$B_{AB,i}$	average above-ground biomass before burning for stratum i; t d.m.ha^{-1}
CE	average combustion efficiency for above-ground biomass; dimensionless (IPCC default: 0.5)
CF	average carbon fraction of dry biomass in above-ground biomass; t C (tonne d.m)$^{-1}$, IPCC default: 0.5
i	strata (n_{st} = total number of strata)

Combustion efficiencies may be chosen from Table 3.A.1.14 of GPG-LULUCF. If no appropriate value is available from this Table, the IPCC default of 0.5 should be used—see Section 3.2.1.4.2.2 in the GPG LULUCF. The nitrogen-carbon ratio (N/C ratio) is approximated as 0.01 (GPG-LULUCF). This is a general default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if data are available.

Note—when estimating non-CO_2 emissions from biomass burning in the context of this methodology:

- Only emissions from non-tree vegetation existing at the start of the project need be considered as part of estimating *ex ante* emissions by sources, as an applicability condition requires that trees existing in the project area at the time the project starts must be protected from any slash-and-burn activities.
- Accounting of non-CO_2 emissions from non-tree vegetation is performed once, during the first monitoring period, if biomass burning is used.
- For *ex ante* estimates of non-CO_2 emissions, if required, the average above-ground biomass before burning, $B_{AB,i}$, used in eqn. 21, is equal to $B_{non\text{-}tree,\,i}$, which is derived in Section II.6.b.(ii).

(iv) Calculation of nitrous oxide emissions from nitrogen fertilization practices

Direct N_2O emissions from nitrogen fertilization[17] may be estimated as follows, using the methods provided by the 1996 IPCC Guidelines, the GPG-2000 or the GPG LULUCF:

$$N_2O_{direct-N_{fertilizer}} = \left(F_{SN} + F_{ON}\right) \cdot EF_1 \cdot 44/28 \cdot GWP_{N2O} \quad \textbf{(22)}$$

$$F_{SN} = N_{SN-fert} \cdot (1 - Frac_{GASS}) \quad \textbf{(23)}$$

$$F_{ON} = N_{ON-fert} \cdot (1 - Frac_{GASO}) \quad \textbf{(24)}$$

where:

$N_2O_{direct-N_{fertilizer}}$	direct N_2O emission as a result of nitrogen application within the project boundary; t CO_2-e yr^{-1}
F_{SN}	mass of synthetic fertilizer nitrogen applied, adjusted for volatilization as NH_3 and NO_X; t N yr^{-1}
F_{ON}	mass of organic fertilizer nitrogen applied, adjusted for volatilization as NH_3 and NO_X; t N yr^{-1}
EF_1	emission factor for nitrogen fertilizer inputs; t N_2O-N (t N input) $^{-1}$
$N_{SN-fert}$	total mass of synthetic fertilizer nitrogen applied; t N yr^{-1}
$N_{ON-fert}$	total mass of organic fertilizer nitrogen applied; t N yr^{-1}
$Frac_{GASS}$	the fraction of N that volatilises as NH3 and NO_X for synthetic fertilizers; dimensionless
$Frac_{GASO}$	the fraction of N that volatilises as NH3 and NO_X for organic fertilizers; dimensionless
GWP_{N2O}	Global Warming Potential for N_2O; kg CO_2-e (kg N_2O)$^{-1}$ (IPCC default = 310, valid for the first commitment period)
44/28	ratio of molecular weights of N_2O and nitrogen; dimensionless

As noted in the revised IPCC 2006 Guidelines, the default emission factor (EF_1) is 1%[18] of applied nitrogen, and this value should be used when country-specific factors are unavailable. If a country-specific EF_1 which has already been adjusted for volatilization is used, the effects of volatilization can be included by applying country-specific factors for synthetic and organic fertilizers, namely $Frac_{GASS}$ and $Frac_{GASO}$. If not, $Frac_{GASS}$ and $Frac_{GASO}$ should be set to zero[19]. Project participants may use validated specific emission factors that are more appropriate for their project, if these are available. Good practice guidance on how to derive specific emission factors is given in Box 4.1 of the GPG 2000.

(v) Calculation of nitrous oxide emissions from residues of nitrogen-fixing trees[20]

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[17] Based on the guidance on accounting of emissions of N_2O from fertilizer application agreed at EB26: only direct (e.g. volatilization) emissions of N_2O from application of fertilizers within the project boundary shall be accounted in A/R project activities.

[18] Volume 4, Chapter 11, Table 11.1, p.11.11 of IPCC 2006 Guidelines

[19] Volume 4, Chapter 11, footnote 11, p.11.12 of IPCC 2006 Guidelines

[20] Equation 11.6 in Volume 4, Chapter 11 of IPCC 2006 Guidelines was modified.

If nitrogen-fixing trees are planted as part of A/R project activities, their residues—mainly fallen leaves—provide nitrogen inputs to soils and consequently increase direct N_2O emissions. This type of emission can be estimated as follows:

$$N_2O_{direct-N_{N-fixing,t}} = F_{TN,t} \cdot EF_1 \cdot 44/28 \cdot GWP_{N_2O} \quad \textbf{(25)}$$

$$F_{TN,t} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} \left(\Delta B_{AB\_tree_{ij},t} \cdot LF_j \cdot Tree_{NCRBF_j} \cdot A_{ij} \right) \quad \textbf{(26)}$$

where:

$N_2O_{direct-NN\text{-}fixing,t}$	annual N_2O emissions from nitrogen-fixing trees; t CO_2-e yr^{-1} for year *t*
$F_{TN,t}$	amount of nitrogen in foliage litter from nitrogen-fixing trees; t N yr^{-1} for year *t*
EF_1	emission factor for nitrogen fertilizer inputs; t N_2O-N (t N input) $^{-1}$
$\Delta B_{AB\_tree,ij\ t}$	annual increase of above-ground biomass in nitrogen-fixing trees for stratum *i* species *j*; t d.m.$ha^{-1}yr^{-1}$ for year *t*
LF_j	ratio of annual allocation of foliage biomass to the annual increase in above-ground biomass, in nitrogen-fixing tree species *j*; dimensionless
$Tree_{NCRBF,j}$	fraction of foliage biomass that is nitrogen for species *j*; dimensionless
A_{ij}	area planted in nitrogen-fixing trees (ha)
GWP_{N2O}	global warming potential for N_2O; kg CO_2-e (kg N_2O)$^{-1}$ (IPCC default = 310, valid for the first commitment period)
i	strata (n_{st} = total number of strata)
j	tree species or type (n_{sp} = total number of species)
44/28	ratio of molecular weights of N_2O and nitrogen; dimensionless

Country-specific values of the N_2O emission factor (EF_1) should be used where possible. If a country-specific emission factor is not available, EF_1 values from other countries with comparable management and climatic conditions are good alternatives. Otherwise, the IPCC default value of 1% of input N should be used for EF_1[21].

Local, regional or national data shall be used for $Tree_{NCRBF,j}$ shall be used, if available. If these data are not available, default values may be chosen from Table 11.2 in the IPCC Revised 2006 Guidelines.

Note—when estimating N_2O emissions for nitrogen fixing trees:

- $\Delta B_{AB\_tree,ij\ t}$ is obtained from the results of Section II.6.a,
- There are no default values available for LF_j. If appropriate values for LF_j are not available from national inventories or peer-reviewed studies, it may be useful to note that the product $\Delta B_{AB\_treeij,t} \cdot LF_j$ in eqn. (26) will in general be equal to annual foliage litterfall (t d.m. ha^{-1} yr^{-1}). A further alternative is to note that annual foliage litterfall is equal to the total foliage biomass divided by the foliage turnover rate (in years), and values may be available for these parameters from national

[21] Volume 4, Chapter 11, Table 11.1, p.11.11 of IPCC 2006 Guidelines

inventory or peer-reviewed studies. If values for these alternative parameters are not available either, then annual foliage litterfall may need to be measured—using free-draining litter collection traps to prevent litter decomposition before drying and weighing.

(c) Actual net GHG removals by sinks

The actual net GHG removals by sinks are calculated as:

$$\Delta C_{ACTUAL} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} \Delta C_{ij} - GHG_E \quad \textbf{(27)}$$

where:

ΔC_{ACTUAL}	actual net GHG removals by sinks; t CO_2-e yr^{-1}
ΔC_{ij}	average annual carbon stock change in living biomass of trees for stratum *i* species *j*; t CO_2-e yr^{-1}
GHG_E	GHG emissions by sources within the project boundary as a result of implementation of the A/R project activity; t CO_2-e yr^{-1}
i	strata (n_{st} = total number of strata)
j	tree species or type (n_{sp} = total number of species)

8. Leakage

In choosing parameters and making assumptions about leakage, project participants should retain a conservative approach, i.e. if different values for a parameter are plausible, a value that does not lead to an under-estimation of leakage emissions should be applied.

The only potential leakage emissions attributable to the proposed A/R project activity are those from vehicle fossil fuel combustion during transportation of seedlings, labor, materials and harvest products to and/or from project sites (while avoiding double-counting of emissions accounted for in $E_{FuelBurn}$, above).

$$LK = LK_{FuelBurn} \quad \textbf{(28)}$$

$$LK_{FuelBurn} = \sum_{v} \sum_{f} (EF_{vf} \cdot CSP_{vf}) \cdot 0.001 \quad \textbf{(29)}$$

where:

LK	total GHG emissions due to leakage activities; t CO_2-e yr^{-1}
$LK_{FuelBurn}$	the CO_2 leakage emissions from combustion of fossil fuels outside the project boundary; t CO_2-e yr^{-1}
EF_{vf}	emission factor for vehicle or machinery type *v,* using fuel type *f*; kg CO_2 $litre^{-1}$
$CSP_{vf:}$	consumption of fuel type *f,* by vehicle or machinery type *v*; litre yr^{-1}
0.001	conversion factor: kilograms to tonnes

National CO_2 emission factors should be used whenever possible. If these are not available, default emission factors provided in the IPCC’s Revised 2006 Guidelines should be used. Emission factors should be chosen conservatively from IPCC literature when national data are not available for a particular fuel or vehicle/machinery type.

Table C: Emissions sources included in or excluded from leakage

Sources	Gas	Included/ excluded	Justification / Explanation of choice
Combustion of fossil fuels by vehicles	CO_2	Included	
	CH_4	Excluded	Potential emission is negligibly small
	N_2O	Excluded	Potential emission is negligibly small

9. Ex ante net anthropogenic GHG removal by sinks

Net anthropogenic GHG removals by sinks are calculated as actual net GHG removals by sinks, minus the baseline net GHG removals by sinks, minus leakage:

$$C_{AR\_CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK \quad \textbf{(30)}$$

where:

C_{AR_CDM} net anthropogenic GHG removals by sinks; t CO_2-e yr^{-1}

ΔC_{ACTUAL} actual net GHG removals by sinks; t CO_2-e yr^{-1}

ΔC_{BSL} baseline net GHG removals by sinks; t CO_2-e yr^{-1}

LK total GHG leakage emissions; t CO_2-e yr^{-1}

Calculation of tCERs and lCERs

Calculation of tCERs and lCERs shall be performed using the equations provided by the CDM Executive Board (EB22 Meeting Report, Annex 15). The following quantities estimated by this methodology shall be used in the calculation:

- Carbon stocks for the A/R project at the time of verification, $C_P(t_v)$; t CO_2
- Carbon stocks for the baseline scenario at the time of verification $C_B(t_v)$; t CO_2
- Project emissions in year t, E_t; t CO_2-e
- Leakage emissions in year t, LK_t; t CO_2-e
- Year of verification, t_v; years
- Time span between two verifications, κ ; years

10. Uncertainties

To help reduce uncertainties in 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 participants identify 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[22]; or
- 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 PDD. For any data provided by experts, the PDD shall also record the experts name, affiliation, and principal qualification as an expert (e.g., that they are a member of a country's national forest inventory technical advisory group)—plus inclusion of 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 participants should retain a conservative approach, i.e. if different values for a parameter are equally plausible, a value that does not lead to over-estimation of *ex ante* net anthropogenic GHG removals by sinks should be selected.

11. Data needed for *ex ante* estimations

A list of the data required for *ex ante* estimations is given in Annex 3.

Section III: Monitoring methodology description

1. Monitoring project implementation

Information shall be provided, and recorded in the project design document (PDD), to establish that:

a. The geographic position of the project boundary is accurately and precisely recorded for all parcels; and
b. Applicability conditions of the methodology are met; and
c. The implementation of forest planting and management activities are in accordance with the project plan used as the basis for making *ex ante* estimates of net GHG removals by sinks; and
d. Commonly accepted principles of forest inventory are implemented

Information taken as sufficient to confirm the requirements above may comprise, *inter alia:*

(i) To confirm the project boundary:

- Establish the geographic coordinates of the designed project boundary such that the area of the project is accurately established. This can be achieved by field survey (e.g., using GPS), or by using georeferenced spatial data (e.g., maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images).
- Once project activities are at a point that the physical limits of the boundary are evident,

[22] 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 PDD if there is any likelihood such reports may not be permanently available.

check that all land areas are within the designed boundary according to procedures in Section II.1. Exclude all areas outside the designed boundary.

- Record and archive the final boundary geographic coordinates, and the geographic coordinates of any stratification inside the boundary.

(ii) To confirm applicability conditions:

- Information in peer-reviewed publications or official reports can be used to justify that the applicability conditions are valid; or
- Time sequential historical photographs, satellite images, maps, or other digital datasets can be used to provide evidence that applicability conditions are valid—including quantifying the degraded or degrading state of lands, the rates of decline in (or the static nature of) vegetation cover and/or extent bare ground, and that there is no significant natural forest regeneration; or
- Time sequential photographs from the time the project commences may be used to prove applicability conditions are valid—for example, by showing existing trees are not damaged by slash-and-burn practices, or that erosion is not increased by project implementation; or
- Documented interviews with local people can be used to justify applicability conditions, for example to establish the project lands will continue to provide the same amount of goods and services after the project commences; or
- Applicability conditions not able to be proven by one of the above approaches must be justified by provision of other credible evidence or quantitative measurement, that is recorded in the PDD.

(iii) To confirm forest planting and management activities:

- Record in the PDD the forest planting and management plan used as the basis for *ex ante* estimates of net GHG removals by sinks, together with a record of the plan as actually implemented during the project.
- Develop standard operating procedures (SOPs) for actions likely to minimise soil erosion in those circumstances in which site preparation or planting involves soil disturbance likely to permanently increase rates of soil erosion above baseline rates.

(iv) To confirm commonly accepted principles of forest inventory are implemented:

- Develop, and document in the PDD, SOPs and quality control/quality assurance (QA/QC) procedures for forest inventory. Use or adaptation of standard procedures in published handbooks, or from the GPG LULUCF, is recommended.
- Ensure training courses are completed by all staff unfamiliar with these procedures.

2. Stratification and sampling design

(a) Stratification

If the project activity or area is not homogeneous, stratification of the project area should be carried out to improve the accuracy and precision of *ex post* biomass estimates. Stratification may optionally make use of remote sensing data[23] acquired close to the time the project commences. For *ex post* estimation of baseline GHG removals by sinks, or of actual GHG removals by sinks, strata shall be defined by:

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[23] Detailed guidelines on the preparation and use of remote sensing data are given in Annex 1.

(i) Using procedures to stratify lands for A/R project activities under the clean development mechanism as approved by the Executive Board; or

(ii) For *ex post* estimation of baseline GHG removals by sinks: using the methodology in Section II.3; and

(iii) For actual net GHG removals by sinks:

a. Using appropriate *ex post* stratification methodology from approved CDM A/R methodologies; or

b. Any other stratification approach that can be shown in the PDD to estimate biomass stocks in each stratum to the targeted precision level of ±10% of the mean at a 95% confidence level.

(b) Sampling plots

Permanent sampling plots are strongly recommended for monitoring changes in carbon stocks of above- and below-ground biomass. Permanent sampling plots are generally more statistically efficient than temporary sampling plots in estimating changes in carbon stocks over time, because there is typically a high covariance between observations at successive sampling dates. However, it should be ensured that the plots are treated in the same way as other lands within the project boundary—e.g., during site preparation, weeding, fertilization, irrigation, thinning, etc—and should not be destroyed over the monitoring interval. Ideally, staff involved in management activities should not be aware of the location of permanent sample plots. Where local markers are used, these should not be obvious. Use of a buried metal rod, that is later located using a metal detector, is suggested—together with recording of GPS coordinates to assist with locating the rods in future. If there is any modification of the stratification during the project to improve homogeneity within each stratum, the existing permanent sample plots in the affected strata shall be retained, and new plots added as necessary.

(i) Determining sample size

To determine the sample size, 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*", approved by the CDM Executive Board[24]. The targeted precision level for biomass estimation within each stratum is ±10% of the mean at a 95% confidence level.

(ii) Randomly locating sampling plots

To avoid subjective choice of plot locations (location of plot centres, plot reference points, or movement of plot centres to more "convenient" positions), permanent sample plots shall be located randomly, which is considered good practice (GPG-LULUCF). The geographical position (preferably, GPS coordinates), administrative location, and stratum series number of each plot shall be recorded and archived.

Sample plots must be distributed across the entire project area. For example, if one stratum is spread across multiple parcels, then the number of sample plots estimated to be required to meet the designed sampling precision should be spread among the parcels according to the percentage area that each parcel contributes to the stratum. For example, consider a single stratum spread across 3 parcels, with the parcels contributing 10%, 30% and 60% of the stratum area respectively. In this case, the 3 parcels should also contain 10%, 30% and 60%, respectively, of the total sample plots for that stratum.

Locating the plots randomly within a parcel can be achieved using either of the following two methods:

[24] Hereafter referred as the "Sample number tool". Please see http:// cdm.unfccc.int/EB/031/eb31_repan15.pdf.

(i) Use a random position for the first plot, and thereafter locate plots sequentially at a fixed distance and direction from the last plot. The arrangement of the plots should take account of the total number of plots required to fit into the stratum area, without going outside of the stratum

(ii) Sample plot locations can be selected using available spatial data (i.e. GIS polygons, or georeferenced remote sensing imagery) that shows parcel and stratum boundaries. The stratum area in a parcel is divided into cells equal to the sample plot dimensions, and a random number between 1 and the total cell number are assigned to each cell. Sample plots (or sample plot centres) are then assigned to those cells with sequential numbers that lie entirely within the stratum boundary—until the required number of sample plots has been assigned to the stratum area in the current parcel. The method is based on that provided by Stolbovoy et al. (2005), and is outlined in more detail in Annex 2.

(iii) Sample plot size and shape

The size of sample plots depends on the density of trees—in general between 100 m^2 for dense stands and 1000 m^2 for open stands. Sample plots may be circular, square, or rectangular in shape—although circular plots are recommended because they are usually the simplest to implement and they also reduce the chance of bias in selection of corner positions in systematically planted plantations. However, if square or rectangular plots are used, the sides of each plot shall be placed parallel to the rows of planted trees, and each corner of the plot shall be set at a point which is at a distance as near as possible equal from surrounding trees. This may mean that the plots are of slightly varying sizes, and in which case plot dimensions must be carefully noted and checked.

***(iv)* Treatment of sample plots containing trees existing at the start of the project**

Sample plots located for determining biomass of planted trees may sometimes also include within the plot perimeter trees existing at the time the project commences. The presence of such trees should be carefully noted so that their biomass contribution is excluded from estimates of net GHG removals by sinks.

3. Determination of *ex-post* baseline net GHG removals by sinks, if required

Project participants may optionally determine baseline net GHG removals by sinks *ex post,* by making plot-based or other measurements of biomass and biomass increment for vegetation that existed inside the project boundary at the time the project commenced. Alternatively, control sample plots may be established outside the project boundary for determining baseline net GHG removals by sinks *ex post*. The location of control plots should be chosen carefully to ensure environmental and other conditions are as similar as possible those within the project boundary.

The sample plot size should be sufficient to include on average 10-15 trees, with at least 5 plots spread across the spatial extent of each stratum. A large difference in the carbon stock change between the baseline scenario with relatively few trees, and the project scenario with more densely planted trees, is normally expected. If the trees are very sparse, fewer than 5 plots could be used provided 10–15 trees are measured, as the accuracy of the estimate of baseline removals will have a very limited effect on net anthropogenic GHG removals. However, if the project is being carried out in a host country that has adopted a high value for the crown cover threshold as part of its forest definition, and trees exist in the project area close to that threshold at the time the project commences, then inventory of baseline biomass/removals should attempt to meet a similar precision to that for the project (i.e. an estimate of biomass stocks in each stratum to a targeted precision level of ±10% of the mean at a 95% confidence level).

The baseline net GHG removals by sinks are calculated by:

$$\Delta C_{BSL,t} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} \Delta C_{ij,baseline,t} \qquad \textbf{(1)}$$

where:

$\Delta C_{ij,baseline,t}$	average annual carbon stock change in living biomass of trees for stratum *i* species *j* in the absence of the project activity; t CO_2-e yr^{-1} for year *t*
i	strata (n_{st} = total number of strata)
j	tree species or type (n_{sp} = total number of species)
t	1 to end of crediting period (yrs)

For those strata without growing trees, $\Delta C_{ij,baseline,t}$ is set equal to zero under the applicability conditions of the methodology. For those strata with growing trees, $\Delta C_{ij,baseline,t}$ is estimated using equations (2) to (10) in Section III.5, below.

4. Data to be collected and archived for of baseline net GHG removals by sinks

A list of the of the data to be collected and archived for of baseline net GHG removals by sinks is given in Annex 4.

5. Calculation of *ex post* actual net GHG removal by sinks

Actual net GHG removals by sinks represent the sum of the verifiable changes in carbon stocks in the carbon pools within the project boundary, minus the increase in GHG emissions measured in CO_2 equivalents by the sources that are increased as a result of the implementation of an A/R project activity within the project boundary and attributable to the A/R project activity—while avoiding double counting.

Actual net GHG removals by sinks are therefore calculated as:

$$\Delta C_{ACTUAL,t} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} \Delta C_{ij,t} - GHG_{E,t} \qquad \textbf{(2)}$$

where:

$\Delta C_{ACTUAL,t}$	actual net GHG removals by sinks; t CO_2 yr^{-1} for year *t*
$\Delta C_{ij,t}$	verifiable changes in the carbon stock of living biomass resulting from implementation of the A/R activity for stratum *i* species *j*; t CO_2-e yr^{-1} in year *t*
$GHG_{E,t}$	increase in GHG emissions by the sources within the project boundary resulting from implementation of the A/R project activity; t CO_2-e yr^{-1} in year *t*
i	strata (n_{st} = total number of strata)
j	tree species or type (n_{sp} = total number of species)
t	1 to the end of crediting period (yrs)

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 participants 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 participants should choose data such that it tends to under-estimate, rather than over-estimate, net GHG removals by sinks.

(a) Verifiable changes in carbon stocks in the carbon pools

Since carbon stock changes in pools of soil organic matter, litter and dead wood are conservatively neglected in this methodology, the verifiable changes in carbon stocks are equal to the carbon stock changes in above- and below-ground biomass resulting from the A/R activity within the project boundary. This is calculated[25] as:

$$\Delta C_{ij,t} = (\Delta C_{AB,ij,t} + \Delta C_{BB,ij,t}) \cdot 44/12 \qquad \textbf{(3)}$$

$$\Delta C_{AB,ij,t} = (C_{AB,ij,m2} - C_{AB,ij,m1})/T \qquad \textbf{(4)}$$

$$\Delta C_{BB,ij,t} = (C_{BB,ij,m2} - C_{BB,ij,m1})/T \qquad \textbf{(5)}$$

where:

$\Delta C_{ij,t}$	verifiable changes in carbon stock in living biomass for stratum *i* species *j*; t CO_2-e yr^{-1} in year *t*
$\Delta C_{AB,ij,t}$	changes in carbon stock in above-ground biomass for stratum *i* species *j*; t C yr^{-1} in year *t*
$\Delta C_{BB,ij,t}$	changes in carbon stock in below-ground biomass for stratum *i* species *j*; t C yr^{-1} in year *t*
$C_{AB,ij,m2}$	carbon stock in above-ground biomass for stratum *i* species *j*, calculated at monitoring point *m2*; t C
$C_{AB,ij,m1}$	carbon stock in above-ground biomass for stratum *i* species *j*, calculated at monitoring point *m1*; t C
$C_{BB,ij,m2}$	carbon stock in below-ground biomass for stratum *i* species *j*, calculated at monitoring point *m2*; t C
$C_{BB,ij,m1}$	carbon stock in below-ground biomass for stratum *i* species *j*, calculated at monitoring point *m1*; t C
T	number of years between monitoring point *m2* and *m1*—5 in this methodology
44/12	ratio of molecular weights of carbon and CO_2; dimensionless

The total carbon stock in living biomass for each stratum, at each monitoring time *m*, is calculated from the area of each stratum and the mean carbon stock per unit area in above- and below-ground biomass resulting from the A/R activity, given by:

$$C_{AB,ij,m} = A_{ij} \cdot MC_{AB,ij,m} \qquad \textbf{(6)}$$

$$C_{BB,ij,m} = A_{ij} \cdot MC_{BB,ij,m} \qquad \textbf{(7)}$$

[25] Refers to GPG-LULUCF Equation 3.2.3

where:

$C_{AB,ij,m}$	carbon stock in above-ground biomass in stratum *i* species *j* at monitoring time *m*; t C
$C_{BB,ij,m}$	carbon stock in below-ground biomass in stratum *i* species *j* at monitoring time *m*; t C
A_{ij}	area of stratum *i* comprising species *j*; ha
$MC_{AB,ij,m}$	mean carbon stock in above-ground biomass per unit area for stratum *i* species *j* at monitoring time *m*; t C ha^{-1}
$MC_{BB,ij,m}$	mean carbon stock in below-ground biomass per unit area for stratum *i* species *j* at monitoring time *m*; t C ha^{-1}

The mean carbon stock per unit area in above- and below-ground biomass resulting from the A/R activity is estimated from field measurements at the permanent sample plots—being careful to exclude from measurements any trees that existed at the time of project commenced and that fall within the sample plot perimeter. The mean carbon stock resulting from the A/R activity can be estimated using one of two methods: the Biomass Expansion Factors (BEF) method, or the Allometric Equations method.

BEF Method

Step 1: Measure the diameter at breast height (DBH; at 1.3 m above ground), and also preferably height, of all the trees above some minimum DBH in the permanent sample plots that result from the A/R activity. The minimum DBH varies depending on tree species and climate; for instance, the minimum DBH may be as small as 2.5 cm in arid environments where trees grow slowly, whereas it could be up to 10 cm for humid environments where trees grow rapidly (GPG-LULUCF).

Step 2: Estimate the volume of the commercial (merchantable) component of trees based on locally derived equations, expressed as volume per unit area (e.g., m^3/ha). It is possible to combine steps 1 and 2 if there are field instruments (e.g., a relascope) that measure the volume of each tree directly.

Step 3: Choose a BEF, and root-shoot ratio (R): these parameters vary with local environmental conditions, tree species and age, and the volume of the commercial component of trees. Values for the BEF and R can be determined by developing local regression equations through destructive harvest. Alternatively, values can be selecting from national inventory, from Table 3A.1.10 of Annex 3A.1 of the GPG-LULUCF, or from other reliable published sources.

If suitable values are not available from published sources, and significant effort is required to develop project-specific BEF and R values—involving, for instance, harvest of trees—then it is recommended to instead use the resources to develop local allometric equations (see the *Allometric Methods* section below; and also Chapter 4.3 in the GPG-LULUCF). If that is not possible either, national species-specific defaults for the BEF and R can be used. Since both BEF and R values are age dependent, it is desirable to use age-dependent equations whenever possible. Using an average BEF value may result in significant errors for both young and old stands, as BEFs are usually large for young stands and rather small for old stands. It is therefore preferable to use allometric equations, if the equations are available or can be developed, and to otherwise use age-dependent BEF and R values.

Step 4: Convert the volume of the commercial component of trees into carbon stock in above- and below-ground biomass using wood density, the selected values for BEF and R, and the carbon fraction:

$$MC_{AB} = V \cdot D \cdot BEF_2 \cdot CF \qquad \textbf{(8)}$$

$$MC_{BB} = MC_{AB} \cdot R_2 \qquad \textbf{(9)}$$

where:

MC_{AB}	mean carbon stock in above-ground biomass; t C ha^{-1}
MC_{BB}	mean carbon stock in below-ground biomass; t C ha^{-1}
V	merchantable volume; m^3 ha^{-1}
D	volume-weighted average wood density; t d.m.m^{-3} merchantable volume
BEF_2	biomass expansion factor for conversion of biomass of merchantable volume to above-ground biomass; dimensionless
CF	carbon fraction; t C (tonne d.m)$^{-1}$, IPCC default value = 0.5
R_2	Root-shoot ratio appropriate for biomass stock; dimensionless

Allometric method

Step 1: As with Step 1 in the BEF Method, the diameter and preferably height of all trees above some minimum diameter is measured.

Step 2: Choose or establish an appropriate allometric equation.

$$B_{AB} = f(DBH, H) \qquad \textbf{(10)}$$

where:

B_{AB}	above-ground biomass; t d.m ha^{-1}
$f(DBH,H)$	an allometric equation linking above-ground biomass (d.m ha^{-1}) to tree diameter at breast height (DBH), and possibly also to tree height (H).

The allometric equations used should preferably be locally-derived and species-specific. When more generic allometric equations are selected from biome-wide databases—such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of GPG-LULUCF—it is necessary to verify their applicability by destructive harvesting. This is carried out within the project area but outside the sample plots, for a few trees of different sizes, and the measured biomass is compared to that predicted by the selected generic equation. If the biomass of the harvested trees is within about ±10% of that predicted by the selected generic equation, and is not biased—or if biased is wrong on the conservative side (i.e., the equation tends to under- rather than over-estimate project removals)—the generic equation may be used. If this is not the case, it is recommended that local allometric equations be developed for project use. For this, a sample of trees, representing different size classes, is destructively harvested, and total biomass per tree determined. The number of trees to be destructively harvested and measured depends on the range of size classes and number of species—the greater the heterogeneity the more trees are required. An allometric equation is then constructed by a regression analysis that relates the measured biomass to values of easily measured variables, such as the DBH and total height (see the guidance provided in Chapter 4.3, GPG LULUCF).

Step 3: Estimate carbon stock in above-ground biomass using selected or developed allometric equations applied to the tree measurements made in Step 1.

$$MC_{AB} = B_{AB} \cdot CF \qquad \textbf{(11)}$$

where:

B_{AB}	above-ground biomass; t d.m ha^{-1}
CF	carbon fraction; t C (tonne d.m)$^{-1}$, IPCC default value = 0.5

Step 4: Estimate the carbon stock in below-ground biomass using root-shoot ratios as described in equation **(15),** and then calculate the total carbon stock due to implementation of the A/R project activity.

(b) GHG emissions by sources

The increase in GHG emissions resulting from implementation of the A/R project activity within the project boundary are calculated as:

$$GHG_{E,t} = E_{FuelBurn,t} + E_{biomassloss,t} + E_{Non-CO2,BiomassBurn,t} + N_2O_{direct-N_{fertilizer},t} + N_2O_{direct-N_{N-fixing},t} \quad \textbf{(12)}$$

where:

$GHG_{E,t}$	Increase in GHG emissions resulting from implementation of the A/R project activity; t CO_2-e yr^{-1} in year *t*
$E_{FuelBurn,t}$	Increase in GHG emission as a result of burning of fossil fuels; t CO_2-e yr^{-1} in year *t*
$E_{biomassloss,t}$	Decrease in carbon stock in living biomass (from causes other than harvesting, thinning, pruning etc); t CO_2-e yr^{-1} in year *t*
$E_{Non-CO2,BiomassBurn,t}$	Increase in non-CO_2 emissions as a result of burning of biomass; t CO_2-e yr^{-1} in year *t*
$N_2O_{direct-Nfertilizer}$	Direct N_2O emissions as a result of fertilizer application; t CO_2-e yr^{-1} in year *t*
$N_2O_{direct-NN\text{-}fixing}$	Direct N_2O emissions from residues of nitrogen-fixing trees; t CO_2-e yr^{-1} in year *t*

Note that the biomass loss and biomass burning components of eqn. 18 may involve different biomass elements under different circumstances, and care is required to avoid double counting. This is considered in detail in Sections 5.b.(ii) and 5.b.(iii), below.

(i) GHG emissions from burning of fossil fuel

Fossil fuels may be consumed during the following activities inside the project boundary: site preparation, planting, forest management and harvesting; and transportation of seedlings, materials, staff or products. These CO_2 emissions can be estimated as follows:

Step 1: Monitor the type and amount of fossil fuel consumed in project activities.

Step 2: Choose emission factors. National CO_2 emission factors should be used whenever possible. If these are not available, default emission factors provided in the IPCC's Revised 2006 Guidelines should be used. Emission factors should be chosen conservatively from IPCC literature when national data are not available for a particular fuel or vehicle/machinery type.

Step 3: Estimate the GHG emissions from the burning of fossil fuel, by[26]:

[26] Refer to Equation 3.2.1 in IPCC 2006 Guidelines Volume 2

$$E_{FuelBurn} = \sum_{v}\sum_{f}(EF_{vf} \cdot CSP_{vf}) \cdot 0.001 \qquad \textbf{(13)}$$

where:

$E_{FuelBurn}$	CO_2 emissions from combustion of fossil fuels within the project boundary; t CO_2-e yr^{-1}
EF_{vf}	emission factor for vehicle or machinery type *v,* using fuel type *f*; kg CO_2 $litre^{-1}$
$CSP_{vf:}$	consumption of fuel type *f,* by vehicle or machinery type *v*; litre yr^{-1}
0.001	conversion factor: kilograms to tonnes

(ii) Decrease in carbon stock in living biomass of existing vegetation

Emissions of CO_2 from living biomass that existed within the project boundary at the start of the project may occur as a result of:

- Site preparation—CO_2 emissions may occur due to biomass loss in shrubs and herbaceous vegetation existing at the time the project commences due to site preparation or competition from planted trees Emissions are accounted under an instant oxidation assumption, during the first monitoring period. Note that an applicability condition for this methodology ensures trees existing with the project area at the start of the project are protected from any site preparation activities.
- Disturbance after the project commences—CO_2 emissions may occur due to biomass loss in trees that existed at the start of the project, as a result of disturbance (e.g., wind-throw or wildfire). Emissions are accounted when and if they occur.

The decrease in carbon stocks of vegetation that existed at the time the project started can be estimated from *ex ante* data, or from *ex post* measurements if these are performed (Sections II.5, or III.3, respectively). Note that CO_2 emissions associated with loss of biomass created as part of the project A/R activity will always be determined as an integral part of plot-based inventory (Section III.5.a), and to avoid double-counting must not be included in estimates made in this Section.

Step 1: Estimate above- and below-ground biomass of existing non-tree vegetation, either from *ex ante* estimates or by determination of biomass *ex post*.

(i) The biomass of herbaceous vegetation can be determined by simple harvesting techniques. A small frame of known area (either circular or square), usually encompassing about 0.1–0.25 m^2, is used in this task. The material inside the frame is cut to ground level and weighed. The roots are dug up, washed to remove soil, and also weighed. Well-mixed samples are then taken from the above- and below-ground biomass components, and oven-dried to determine dry mass and gravimetric moisture content. The water content is then used to convert the above- and below-ground wet biomass components to equivalent oven-dry mass. Dividing by the frame area gives dry mass per unit area.

(ii) Destructive harvesting techniques similar to those used for herbaceous vegetation can also be used to measure the living above- and below-ground biomass in shrubs, if the shrubs are small. An alternative approach, if the shrubs are larger, is to develop local allometric equations based on variables such as crown area and height, or diameter at the base of the plant, or some other relevant variable (e.g., number of stems in multi-stemmed shrubs). The equations are derived by regressing (usually log-transformed) biomass versus some logical combination of the independent variables. The independent variable or variables are then measured in temporary sample plots of diameter sufficient to include about 10–15 shrubs (for further detail see Chapter 4.3, GPG-LULUCF). The result of either the harvesting or allometric approaches is an estimate of shrub dry biomass per unit area.

(iii) The mean non-tree above- and below-ground biomass per unit area is then calculated from the above data.

Step 2: Estimate above- and below-ground biomass of trees existing within the project boundary at the time the project commences, either from *ex ante* estimates of biomass and projected removals up until time t, or by determination of biomass *ex post*. The biomass of existing trees can be determined using the plot-based inventory methodology described in Section III.5.(a). Temporary sample plots may be installed for these measurements. Mean biomass stocks in above- and below-ground biomass are calculated using equations (2) to (10) in section III.5.a.

Step 3: Estimate the decrease in carbon stock of existing vegetation

$$E_{biomassloss,\,total\text{-}existing,t} = E_{biomassloss,\,non\text{-}tree,t} + E_{biomassloss,\,tree,t} \quad \textbf{(14)}$$

where:

$E_{biomass,\ total\text{-}existing,\ t}$	decrease in total carbon stock of living biomass of vegetation existing in the project area at the start of the project; t CO_2-e yr^{-1} in year *t*
$E_{biomassloss,non\text{-}tree,\ t}$	decrease in carbon stock in living biomass of non-tree vegetation existing in the project area at the start of the project; t CO_2-e yr^{-1} in year *t*
$E_{biomassloss,tree,\ t}$	Decrease in total carbon stock of living biomass of trees existing in the project area at the start of the project; t CO_2-e yr^{-1} in year *t*

If t ≠ 1 then $E_{biomassloss,non\text{-}tree,\ t} = 0$, otherwise:

$$E_{biomassloss,\,non\text{-}tree,t} = \sum_{i=1}^{n_{st}} A_i \cdot (B_{AB,non-tree,t,i} + B_{BB,non-treet,i}) \cdot CF_{non-tree} \cdot 44/12 \quad \textbf{(15)}$$

If there is no disturbance, $E_{biomassloss,tree,\ t} = 0$, otherwise:

$$E_{biomassloss,\,tree,t} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} A_{disturbance,i} \cdot (B_{AB,tree,t,ij} + B_{BB,tree,t,ij}) \cdot CF_j \cdot 44/12 \quad \textbf{(16)}$$

where:

$E_{biomassloss,non\text{-}tree,\ t}$	decrease in carbon stock in living biomass of existing non-tree vegetation; t CO_2-e yr^{-1} in year *t*
A_i	area of stratum *i*; ha
$B_{AB,non\text{-}tree,\ i}$	average biomass stock of above-ground non-tree vegetation in the project area at the start of the A/R project for stratum *i*; t d.m.ha^{-1}
$B_{BB,non\text{-}tree,\ i}$	average biomass stock of below-ground non-tree vegetation in the project area at the start of the A/R project for stratum *i*; t d.m.ha^{-1}
$CF_{non\text{-}tree}$	the carbon fraction of dry biomass in existing non-tree vegetation; t C (tonne d.m)$^{-1}$
$E_{biomassloss,tree,\ t}$	Decrease in total carbon stock of living biomass of trees existing in the project area at the start of the project; t CO_2-e yr^{-1} in year *t*

$A_{disturbance,\ i}$	area subject to disturbance in stratum i; ha
$B_{AB,tree,t,ij}$	average biomass stock in above-ground biomass of trees existing in the project area at the start of the project, for stratum i species j in year t; t d.m. ha^{-1}
$B_{BB,tree,t,ij}$	average biomass stock in below-ground biomass of trees existing in the project area at the start of the project, for stratum i species j in year t; t d.m. ha^{-1}
CF_j	the carbon fraction of dry biomass for tree species j; t C (tonne d.m) $^{-1}$
i	strata (n_{st} = total number of strata)
j	tree species or type (n_{sp} = total number of species)
44/12	ratio of molecular weights of CO_2 and carbon; dimensionless

(iii) Non-CO_2 GHG emissions from biomass burning

Emissions of non-CO_2 gases may occur due to biomass burning within the project boundary, as a result of:

- Site preparation—non-CO_2 emissions will occur if slash-and-burn practices are used, resulting in burning of above-ground biomass in non-tree vegetation existing at the time the project commences. Under applicability conditions for this methodology, trees existing at project commencement are protected from slash-and-burn practices, so need not be considered;
- Wildfire after the project commences—non-CO_2 emissions will occur if the project area is subject to wildfire. In this case loss of above-ground biomass will occur from both trees existing at the time the project commenced, and live biomass[27] resulting from implementation of the A/R project activity.

Step 1: Estimate the mean above-ground biomass stock in tree and non-tree vegetation that existed at the time the project commenced. This will be available from either *ex ante* or *ex post* estimates (Sections II.6 or III.5.b.ii, respectively).

Step 2: Estimate the above-ground biomass stock resulting from the A/R activity. This will have been determined as part of Section III.5.a above if at least one cycle of monitoring has been completed, or if not can be obtained from *ex ante* estimates.

Step 3: Estimate combustion efficiencies and emission factors.

The combustion efficiencies may be chosen from Table 3.A.1.14 of the GPG-LULUCF. If no appropriate combustion efficiency is applicable to the project circumstances, the IPCC default of 0.5 should be used. The nitrogen-carbon ratio (N/C ratio) is approximated as 0.01 (GPG-LULUCF). This is a general default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if data are available.

Step 4: Estimate non-CO_2 GHG emissions from biomass burning.

The following calculations are based on the revised IPCC 1996 Guidelines for LULUCF, and the GPG-LULUCF:

$$E_{Non-CO2,BiomassBurn,t} = E_{BiomassBurn,N2O} + E_{BiomassBurn,CH4} \qquad \textbf{(17)}$$

[27] An applicability condition of this methodology is that wildfire is not common: that is, it is assumed that on average deadwood and litter are largely decayed at the time any wildfire occurs, and therefore do not contribute significantly to non-CO_2 emissions.

where:

$E_{Non\text{-}CO2,BiomassBurn,t}$	the increase in non-CO_2 emission as a result of biomass burning; t CO_2-e yr^{-1}
$E_{BiomassBurn,\ N2O}$	N_2O emission from biomass burning; t CO_2-e yr^{-1}
$E_{BiomassBurn,\ CH4}$	CH_4 emission from biomass burning; t CO_2-e yr^{-1}

and:

$$E_{BiomassBurn,N2O} = E_{BiomassBurn,C} \cdot \left(N/C\ ratio \right) \cdot ER_{N2O} \cdot 44/28 \cdot GWP_{N2O} \qquad \textbf{(18)}$$

$$E_{BiomassBurn,CH4} = E_{BiomassBurn,C} \cdot ER_{CH4} \cdot 16/12 \cdot GWP_{CH4} \qquad \textbf{(19)}$$

where[28]:

$E_{BiomassBurn,C}$	loss of carbon stock in above-ground living biomass due to biomass burning; t C yr^{-1}
N/C ratio	nitrogen-carbon ratio; dimensionless (IPCC default: 0.01)
ER_{N2O}	IPCC default emission ratio for N_2O = 0.007
ER_{CH4}	IPCC default emission ratio for CH_4 = 0.012
GWP_{N2O}	Global Warming Potential for N_2O; kg CO_2-e (kg $N_2O)^{-1}$ (IPCC default = 310, valid for the first commitment period)
GWP_{CH4}	Global Warming Potential for CH_4; kg CO_2-e (kg $CH_4)^{-1}$ (IPCC default = 21, valid for the first commitment period)
44/28	ratio of molecular weights of N_2O and nitrogen; dimensionless
16/12	ratio of molecular weights of CH_4 and carbon; dimensionless

The appropriate value of above-ground living biomass, $E_{BiomassBurn,C,}$ depends on when the burning occurs. Only non-tree biomass is involved if slash-and-burn site preparation is being considered. However, if wildfire occurs after project establishment, then non-CO_2 emissions from loss of both trees that existed at the time the project started[29], and living biomass created as part of the A/R project activity, must be considered. That is:

If t = 1, then:

$$E_{BiomassBurn,C} = \sum_{i=1}^{n_{st}} A_{burn,i} \cdot B_{AB,non-tree,i} \cdot CE_{non-tree} \cdot CF_{non-tree} \qquad \textbf{(20)}$$

otherwise:

$$E_{BiomassBurn,C} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} A_{burn,i} \cdot B_{AB,ij} \cdot CE_j \cdot CF_j \qquad \textbf{(21)}$$

[28] Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in GPG LULUCF

[29] Appropriately incremented to account for significant growth since the start of the project.

where:

$E_{BiomassBurn,C}$	loss of carbon stock in above-ground living biomass due to biomass burning; t C yr yr^{-1}
$A_{burn,i}$	area of biomass burning for stratum i; ha yr^{-1}
$B_{non\text{-}tree,i}$	average above-ground living biomass stock of non-tree vegetation before burning for stratum i; t d.m.ha^{-1}
$CE_{non\text{-}tree}$	combustion efficiency for non-tree vegetation; dimensionless
$CF_{non\text{-}tree}$	the carbon fraction of dry biomass in non-tree vegetation; t C (tonne d.m)$^{-1}$, IPCC default =0.5
$B_{AB,ij}$	average above-ground stock of living biomass resulting from the A/R activity, plus that in trees that existed within the project boundary at the time the project commenced[31], for stratum i species j; t d.m.ha^{-1}
CE_j	combustion efficiency for tree species j; dimensionless
CF_j	carbon fraction of dry biomass for tree species j; t C (tonne d.m.)$^{-1}$, IPCC default =0.5
i	strata (n_{st} = total number of strata)
j	tree species or type (n_{sp} = total number of species)

(*iv*) *Nitrous oxide emissions from nitrogen fertilization practices*

Direct N_2O emissions from nitrogen fertilization[30] are estimated using methods provided by the 1996 IPCC Guidelines, the GPG-2000 or the GPG LULUCF:

Step 1: Monitor fertilizer use, and calculate the amount of nitrogen in the synthetic and organic fertilizer applied within the project boundary. This may be done using standard laboratory analytical techniques (e.g., Kjeldahl analysis, C/N analyzers, etc).

Step 2: Select emission factors. As noted in IPCC 2006 Guidelines, the default emission factor for N_2O emissions (EF_1) is 1%[31] of applied nitrogen, and this value should be used when country-specific factors are unavailable. If a country-specific EF_1 which has already been adjusted for volatilization is used, the effects of volatilization can be included by applying country-specific factors for synthetic and organic fertilizers, namely $Frac_{GASS}$ and $Frac_{GASO}$. If not, $Frac_{GASS}$ and $Frac_{GASO}$ should be set to 0[32]. Project participants may use validated specific emission factors that are more appropriate for their project, if these are available. Good practice guidance on how to derive specific emission factors is given in Box 4.1 of the GPG 2000.

Step 3: Calculate direct N_2O emissions from nitrogen fertilization[33]

$$N_2O_{direct-N_{fertilizer}} = \left[\left(F_{SN} + F_{ON}\right) \cdot EF_1\right] \cdot 44/28 \cdot GWP_{N2O} \qquad \textbf{(22)}$$

[30]Based on the guidance on accounting of emissions of N_2O from fertilizer application agreed at EB26: only direct (e.g. volatilization) emissions of N_2O from application of fertilizers within the project boundary shall be accounted in A/R project activities.

[31] Volume 4, Chapter 11, Table 11.1, p.11.11 of IPCC 2006 Guidelines

[32] Volume 4, Chapter 11, footnote 11, p.11.12 of IPCC 2006 Guidelines

[33] Refers to Equation 3.2.18 in IPCC GPG-LULUCF; Equation 4.22 and Equation 4.23 in GPG-2000

$$F_{SN} = N_{SN-Fert,t} \cdot (1 - Frac_{GASS}) \quad \textbf{(23)}$$

$$F_{ON} = N_{ON-Fert,t} \cdot (1 - Frac_{GASO}) \quad \textbf{(24)}$$

where:

$N_2O_{direct-N_{fertilizer}}$	direct N_2O emissions from nitrogen application within the project boundary; t CO_2-e yr^{-1}
F_{SN}	mass of synthetic fertilizer nitrogen applied, adjusted for volatilization of NH_3 and NOx; t N yr^{-1}
F_{ON}	mass of organic fertilizer nitrogen applied, adjusted for volatilization of NH_3 and NOx; t N yr^{-1}
EF_1	Emission factor for emissions from nitrogen fertilizer inputs; t N_2O-N (t N input) $^{-1}$
$N_{SN\text{-}fert}$	total mass of synthetic fertilizer nitrogen applied; t N yr^{-1}
$N_{ON\text{-}fert}$	total mass of organic fertilizer nitrogen applied; t N yr^{-1}
$Frac_{GASS}$	the fraction of N that volatilises as NH_3 and NOx for synthetic fertilizers; dimensionless
$Frac_{GASO}$	the fraction of N that volatilises as NH_3 and NOx for organic fertilizers; dimensionless
44/14	ratio of molecular weights of N_2O and nitrogen; dimensionless
GWP_{N2O}	Global Warming Potential for N_2O; kg CO_2-e (kg N_2O)$^{-1}$ (IPCC default = 310, valid for the first commitment period)

(v) Calculation of nitrous oxide emissions from residues of nitrogen-fixing trees

If nitrogen-fixing trees are planted their residues—mainly fallen leaves—provide nitrogen inputs to soils and consequently increase direct N_2O emissions. These emissions can be calculated by:

Step 1: Estimate the average annual change of above-ground biomass of living nitrogen-fixing trees for each stratum and species, $\Delta B_{AB\_tree,ij\ t}$. This can be included as part of estimating verifiable changes in carbon stocks in the carbon pools, using equations (9) to (17) in Section III 5.

Step 2: Determining the ratio of annual biomass allocation to foliage, to the annual increase in above-ground biomass, in nitrogen-fixing tree species; LF_j. There are no default values available for LF_j. If appropriate values for LF_i are not available from national inventories or peer-reviewed studies, it may be useful to note that the product $\Delta B_{AB\_treeij,t} \cdot LF_j$ in eqn. 32 will in general be equal to annual foliage litterfall (t d.m. ha^{-1} yr^{-1}). A further alternative is to note that annual foliage litterfall is equal to the total foliage biomass divided by the foliage turnover rate (in years), and values may be available for these parameters from national inventory or peer-reviewed studies. If values for these alternative parameters are not available either, then annual foliage litterfall may need to be measured—using free-draining litter collection traps to prevent litter decomposition before drying and weighing.

Step 3: Calculating direct N_2O emissions from the residues from nitrogen-fixing trees. The emission factor (EF_1) and global warming factor for N_2O (GWP_{N2O}) used in Section II.b.v above are also applied here.

$$N_2O_{direct-N_{N-fixing,t}} = F_{TN,t} \cdot EF_1 \cdot 44/28 \cdot GWP_{N_2O} \quad \textbf{(25)}$$

$$F_{TN,t} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} \left(\Delta B_{AB\_tree_{ij},t} \cdot LF_j \cdot Tree_{NCRBF_j} \cdot A_{ij} \right) \quad \textbf{(26)}$$

where:

$N_2O_{direct-NN\text{-}fixing,t}$	annual N_2O emissions from nitrogen-fixing trees; t CO_2-e yr^{-1} for year t
$F_{TN,t}$	amount of nitrogen in foliage litter from nitrogen-fixing trees; t N yr^{-1} for year t
EF_1	emission factor for nitrogen fertilizer inputs; t N_2O-N (t N input) $^{-1}$
$\Delta B_{AB\_tree,ij,\,t}$	annual increase of above-ground biomass in nitrogen-fixing trees for stratum i species j; t d.m.$ha^{-1}yr^{-1}$ for year t
LF_j	ratio of annual allocation of foliage biomass to the annual increase in above-ground biomass, in nitrogen-fixing tree species j; dimensionless
$Tree_{NCRBF,j}$	fraction of foliage biomass that is nitrogen for species j; dimensionless
A_{ij}	area planted in nitrogen-fixing trees (ha)
GWP_{N2O}	global warming potential for N_2O; kg CO_2-e (kg N_2O)$^{-1}$ (IPCC default = 310, valid for the first commitment period)
i	strata (n_{st} = total number of strata)
j	tree species or type (n_{sp} = total number of species)
44/28	ratio of molecular weights of N_2O and nitrogen; dimensionless

The annual increase in above-ground biomass in nitrogen-fixing trees, $\Delta B_{AB\_tree,ij,\,t}$, is obtained from the results of Section II.6.a.

6. Data to be collected for calculation of actual net GHG removals by sinks

A list of the data to be collected for calculation of actual net GHG removals by sinks is given in Annex 5.

7. Leakage

The only potential leakage emissions attributable to the proposed A/R project activity are those from vehicle fossil fuel combustion during transportation of seedlings, labor, materials and harvest products to and/or from project sites (while avoiding double-counting of combustion emissions within the project boundary and accounted for as $E_{FuelBurn}$, in Section III.5.b.i above). Leakage emissions can be estimated by:

Step 1: Recording the distance travelled by different types of vehicles, using different fuel types.

Step 2: Determining the emission factors for different types of vehicles using different fuel types. National CO_2 emission factors should be used whenever possible. If these are not available, default emission factors provided in the IPCC's Revised 2006 Guidelines should be used. Emission factors should be chosen conservatively from IPCC literature when national data are not available for a particular fuel or vehicle/machinery type.

Step 3: Estimating the CO_2 emissions using the bottom-up approach described in the GPG 2000 for the energy sector.

$$LK = LK_{FuelBurn} \quad \textbf{(27)}$$

$$LK_{FuelBurn} = \sum_{v}\sum_{f}(EF_{vf} \cdot CSP_{vf}) \cdot 0.001 \qquad \textbf{(28)}$$

where:

LK	total GHG emissions due to leakage activities; t CO_2-e yr^{-1}
$LK_{FuelBurn}$	the CO_2 leakage emissions from combustion of fossil fuels outside the project boundary; t CO_2-e yr^{-1}
EF_{vf}	emission factor for vehicle or machinery type *v,* using fuel type *f*; kg CO_2 $litre^{-1}$
$CSP_{vf:}$	consumption of fuel type *f,* by vehicle or machinery type *v*; litre yr^{-1}
0.001	conversion factor: kilograms to tonnes

8. Data to be collected for calculation of leakage

A list of the data to be collected for calculation of leakage is given in Annex 6.

9. Ex post net anthropogenic GHG removal by sinks

Net anthropogenic GHG removals by sinks are calculated as actual net GHG removals by sinks, minus the baseline net GHG removals by sinks, minus leakage:

$$C_{AR\_CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK \qquad \textbf{(29)}$$

where:

ΔC_{ACTUAL}	actual net GHG removals by sinks; t CO2-e yr^{-1}
ΔC_{BSL}	baseline net GHG removals by sinks; t CO2-e yr^{-1}
LK	leakage; t CO2-e yr^{-1}

Calculation of tCERs and lCERs:

Calculation of tCERs and lCERs shall be performed according to the equations provided by the CDM Executive Board (EB22 Meeting Report, Annex 15). The following quantities estimated by this methodology shall be used in the calculation:

- Carbon stocks for the A/R project at the time of verification, $C_P(t_v)$; t CO_2
- Carbon stocks for the baseline scenario at the time of verification $C_B(t_v)$; t CO_2
- Project emissions in year *t,* E_t; t CO_2-e
- Leakage emissions in year *t,* LK_t; t CO_2-e
- Year of verification, t_v; years
- Time span between two verifications, κ ; years

10. Uncertainties

To help reduce uncertainties in 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 participants identify 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[34]; or
- 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 PDD. For any data provided by experts, the PDD shall also record the experts name, affiliation, and principal qualification as an expert (e.g., that they are a member of a country's national forest inventory technical advisory group)—plus inclusion of 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 participants 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 participants should choose data such that it tends to under-estimate, rather than over-estimate, net GHG removals by sinks.

Section IV: Lists of variables, acronyms and references

Lists of variables, acronyms and references used in this methodology are given in Annex 7.

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[34] 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 PDD if there is any likelihood such reports may not be permanently available.

Annex 1

Analysis of Remote Sensing Data

An analysis of remote sensing data may, if required, be conducted to give supplementary information for stratification. If conducted it is recommended the analysis be based on use of vegetation indices, as these can provide semi-quantitative indicators of both vegetation cover and carbon stocks in forests (e.g., Lu *et al.* 2004, Patenaude *et al.* 2005).

For use in stratification, remotely sensed imagery must be at least georeferenced, and more advanced image pre-processing steps may also need to be completed before indices can provide reliable information: for example, radiance calibration, reflectance correction, or topographic correction. Images may also have to be mosaiced if large areas are to be covered. These procedures can be carried out using commercial software, and/or purpose-built algorithms. The following guidance is provided to ensure accurate and reproducible derivation of vegetation indices from remotely sensed data.

(a) Selection of remote sensing image data

The image data shall have the following characteristics:

- The project area must be cloud and noise free;
- The acquisition date must take appropriate account of seasonality in phenological characteristics of the vegetation in the project area, as well as the timing of any field inventory and/or stratification process;
- If more than one scene is needed to cover the project area, the scenes must be obtained close together in time using the same sensor;
- The spatial resolution of the data must be less than or equal to the spatial dimensions of forest inventory plots;
- Imagery shall have been processed to at least Level 1 by the supplier (i.e. at least radiometrically and geometrically corrected).

(b) Selection of a vegetation index

The vegetation index used shall be one of (in order of preference): the Enhanced Vegetation Index[35] (EVI), the Atmospherically Resistant Vegetation Index[36] (ARVI), or the Normalized Difference Vegetation Index[37] (NDVI) (Table A1). The EVI and ARVI require image data that includes the blue, red and near-infrared spectral bands (e.g., Landsat TM/ETM+, LDCM/OLI), whereas the NDVI only requires images with red and near-infrared spectral bands (e.g., SPOT).

[35] The EVI shows higher sensitivity at higher biomass, a reduced atmospheric effect, and also a reduced soil effect. However, it is affected by steeper topography, and should not be used in such conditions unless topographic correction is also performed.

[36] The ARVI shows a reduced atmospheric effect similar to the EVI, but greater sensitivity to bare soil . Like the EVI it is affected by steeper topography, and should not be used in such conditions unless topographic correction is performed.

[37] The NDVI is a simple and widely-used index. It is affected by topography to only a limited extent, and its use is recommended in steeper topography if topographic correction can not be performed. However, it is less sensitive to biomass variation at higher biomass than the EVI, and much more affected by atmospheric effects than either the EVI or ARVI—and should not be used if imagery suffers from significant atmospheric haze or turbidity (including very thin cirrus cloud, that can be hard to detect).

Table A1. Vegetation indices for use in stratification. The spectral bands referred to are : Blue—450 to 550 nm; Red—600 to 700 nm; and NIR (near-infrared)—750 to 900 nm.

Index	Formula	Source
EVI	G*(NIR – Red)/(NIR+C1*Red+C2*Blue+L) where G = 2.5, L = 1, C1 = 6, C2 = 7.5 The coefficients given are for MODIS and Landsat TM/ETM+	Huete et al., 1997
ARVI	(NIR – rb)/(NIR+rb) where rb = Red – c(Blue – Red); c = 1 (for typical use)	Kaufman and Tanre, 1992
NDVI	(NIR-Red)/(NIR+Red)	Rouse et al., 1973 Rouse et al., 1974

(c) Pre-processing of imagery

The following pre-processing steps may need to be completed before vegetation indices derived from remote sensing imagery can be used reliably for stratification.

Step 1: Georeferencing

Image data shall either be rectified, or orthorectified. If both the terrain is relatively flat (<10º slopes), and imagery is acquired at a near-nadir view (e.g., Landsat TM/ETM+ imagery), simple rectification without using a Digital Elevation Model (DEM) is sufficient. In other cases, orthorectification using an appropriate DEM must be completed. The DEM must have a spatial resolution better than or equal to the spatial dimensions the image pixels. The rectification (or orthorectification) root-mean-square (RMS) error must be less than the spatial dimensions of inventory plots—preferably less than half this dimension. Ground control points for rectification (or orthorectification) should be measured with a GPS, with use of higher quality GPS recommended (e.g., 8 or more channels).

Step 2: Reflectance conversion

This process is only mandatory if the EVI is used, because the coefficients of the EVI are defined in terms of top-of-atmosphere (exoatmospheric) reflectance data. The process requires use of post-launch gain and offset data published for the sensor, and usually included in the image header data.

The spectral radiance (L_λ) is first calculated as:

$$L_\lambda = LMIN_\lambda + gain \cdot DN \quad \textbf{(A1)}$$

$$gain = \left(\frac{LMAX_\lambda - LMIN_\lambda}{DNMAX} \right) \quad \textbf{(A2)}$$

where:

DN	image digital numbers
$LMIN_\lambda$	spectral radiance at DN = 0 (bias or offset)
$LMAX_\lambda$	spectral radiance at DN = DNMAX
DNMAX	maximum value of DN (e.g., 255 for TM/ETM+)
L_λ	radiance ($W/(m^2*sr*\mu m)$

The exoatmospheric reflectance (e_p) is then calculated as:

$$\rho_P = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda \cdot \cos\theta_s} \qquad \textbf{(A3)}$$

where:

ρ_P	reflectance; %
L_λ	radiance ($W/(m^2*sr*\mu m)$
d	mean Earth-Sun distance in astronomical units
$ESUN_\lambda$	mean solar exoatmospheric irradiance
θ_λ	Solar zenith angle; degrees

The handbook or users guide for the sensor used will include the parameters for equation A3.[38]

Step 5: Topographic correction

Topographic correction shall be conducted if the EVI or ARVI is used and the project area includes steeper slopes and/or the data are acquired at lower sun elevations. Topographic correction is best carried out according to Dymond and Shepherd (2004), or by using some other non-Lambertian approach (e.g., the Minnaert correction; Blesius and Weirich 2005). Approaches based on simple Lambertian correction shall not be used. The DEM used as part of topographic correction must have a sufficient spatial resolution and elevation accuracy to represent slopes accurately at the spatial resolution of the image. Topographic correction is not usually required for the NDVI, which as a band ratio is expected to reduce the effect of topography to insignificant levels provided all slopes remain directly illuminated by the Sun.

Step 6: Mosaicing

A mosaiced image shall be prepared when more than one scene is needed to cover the entire project area. Data to be mosaiced must be from the same sensor, acquired at a similar time (i.e. similar Sun elevation, and forest phenological state), and at the same product processing level. Any pre-processing steps must also have been performed consistently for all images used in the mosaic.

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[38] For example, see the Landsat 7 Users Guide at: http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_htmls/chapter11/chapter11.html

List of the major satellite sensors potentially suitable for A/R projects

Satellite	Sensor	Spatial Resolution	Data Acquisition Period			
			–1990	1990–1999	2000–2007	2008–2012
Optical Sensor						
Landsat	MSS	80m	A	A		
Landsat	TM	30m, 120m	PA	A	PA	
Landsat	ETM+	15m (pan), 30m, 60m			PA	
EO-1	ALI/Hyperion	10m, 30m			PA	
Terra	ASTER	15m, 30m, 90m			PA	MA
JERS-1	OPS	18m* 24m		PA		
ALOS	PRISM (Pan)	2.5m			PA	MA
SPOT-1,2,3,4,5	HRV/HRVIR/HRG	(2.5m), 10m, 20m	PA	A	A	PA
IRS-1C/D	LISS-3	6m/23m		PA	PA	
IKONOS	Multi	4m			A	MA
QuickBird	Multi	2.5m			PA	MA
Orbview-3	Multi	4m			PA	MA
Rapid Eye	Multi	6.5m			PA	A
DMC	MS	32m			PA	PA
GeoEye-1	Multi	1.64m				A
WorldView-1,2	Multi	1.8m				A
Pleiades	Multi	2.8m				PA

Key:
* Non-US government user
A: available for the entire period indicated
PA: available for a portion of the period indicated
MA: may be available during the period indicated

There are many other satellite and airborne sensors, and products, besides those listed in the Table above. Project participants should select the appropriate sensors according to project circumstances, and data availability and cost.

List of approximate product prices for the major satellite sensors

Satellite	Sensor	Product	Bands	Price* ($US/km^2)
Landsat	ETM+	Level 1G	VNIR, SWIR, TIR	0.02
SPOT	HRV	Level 2A	VNIR, SWIR	0.69
		Level 2A	VNIR, SWIR	1.22
		Level 3 (ortho)	VNIR, SWIR	0.99
		Level 3 (ortho)	VNIR, SWIR	1.54
		Level 3 (ortho)	VNIR, SWIR	2.72
Terra	ASTER	Level 1B	VNIR, SWIR, TIR	0.02
		Level 3A-01,ortho	VNIR, SWIR, TIR	0.05
IKONOS	Multi	Geo	Multi (VNIR)	57.52
		Geo	Pan-sharpen (VNIR)	70.80
		Geo ortho	Multi (VNIR)	106.19
		Geo ortho	Pan-sharpen (VNIR)	132.74
QuickBird	Multi	Standard	Multi (VNIR)	31.86
		Standard	Pan-sharpen (VNIR)	40.71
		Ortho (1:5,000)	Multi (VNIR)	48.67
		Ortho (1:5,000)	Pan-sharpen (VNIR)	57.52
Orbview-3	Multi	OrbView basic, 1:24k	Multi (VNIR)	19.00
		OrbView ortho, 1:24k	Multi (VNIR)	24.00

*Prices indicated are only approximate, and minimum orders may apply.

Annex 2

Random Selection of Sample Plot Locations Using Spatial Data

To avoid subjective choice of plot locations (location of plot centres, plot reference points, or movement of plot centres to more "convenient" positions), sample plots shall be located randomly, which is considered good practice (GPG-LULUCF). Sample plot locations can be selected using available spatial data (i.e. GIS polygons, or georeferenced remote sensing imagery) that shows parcel and stratum boundaries. The stratum area in a parcel is placed inside a bounding box and divided into cells equal to the sample plot area The number of cells in the stratum bounding box is calculated, and random numbers between 1 and the total cell number are assigned (without replacement) to each cell. Sample plots are then assigned to those cells with sequential numbers that lie entirely within the stratum boundary—until the required number of sample plots has been assigned to the stratum area in the current parcel. The process is then repeated for all strata.

The procedure outlined below is based on that provided by Stolbovoy *et al.* (2005), and assumes for the purposes of explanation that a parcel contains only a single stratum. To select the sample plots, the procedure is to:

(i) Draw the project boundary for each parcel as a polygon and set an orthogonal frame around the polygon (Figure A1).

(ii) Partition the framed area into cells that are equal in size and shape (if square or rectangular plots are used, or into square cells with dimensions equal to the plot diameter if circular plots are used) to the sample plots. For example, in Figure A1 square plots are assumed, and the framed area is partitioned into 96 cells.

(iii) Allocate to the cells random numbers drawn without replacement between 1 and the total number of the cells within the framed area: that is, 1 to 96 in Figure A1.

(iv) Sequentially select cells, beginning at cell 1. Sample plot locations are assigned to those cells with sequential numbers that lie entirely within the parcel boundary—until the required number of sample plots has been assigned to the current parcel (or, more generally, assigned to the stratum area within a given parcel). In Figure A1 the selected cells are those with solid lines: those with dashed lines fall only partially within the parcel boundary, and are rejected.

The geographical position, administrative location, and stratum series number of each plot shall be recorded and archived. If one stratum consists of multiple geographically separated parcels, then calculate the number of sample plots for the stratum area in each parcel as:

$$n_{parcel,k,i} = A_{parcel,k,i} \cdot \left(n_i / A_i \right) \qquad \textbf{(A4)}$$

where:

$n_{parcel,k,i}$	number of sample plots for parcel *k* in stratum *i*
$A_{parcel,k,i}$	area of parcel *k* in stratum *i*; ha
n_i	number of sample plots for stratum *i*
A_i	area of stratum *i*; ha

If $n_{parcel,k,i}$ is a decimal number, the integer portion is retained as the number of sample plots for the current parcel, and the remainder is added to the value of $n_{parcel,k,i}$ calculated for the next parcel. The process is repeated until sample plots have been assigned to all parcels. The total number of sample plots for the parcels will then equal the number required for the stratum, n_i.

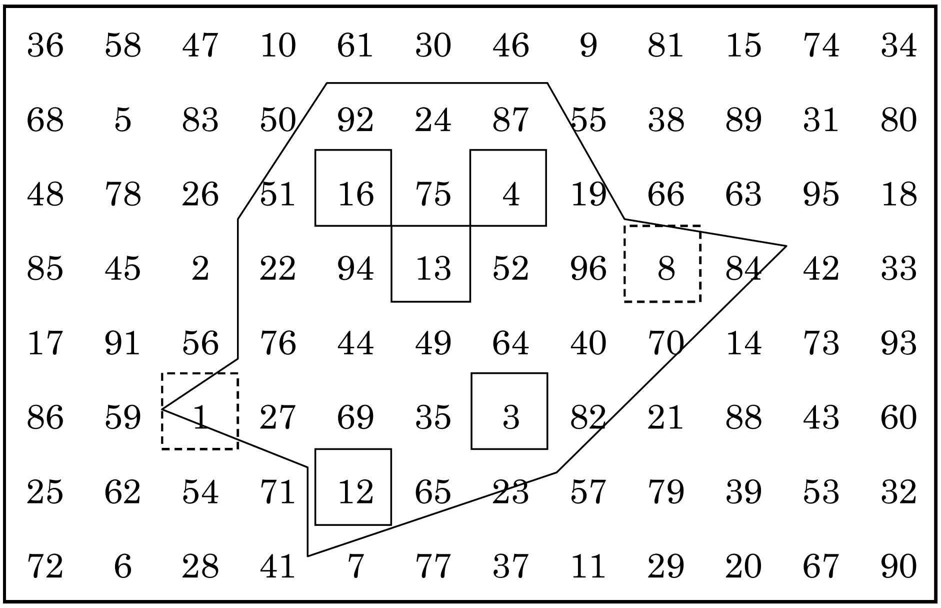

Figure A1: Location of sample plots (according to Stolbovoy, 2005; modified). The polygon represents the parcel boundary, located inside an orthogonal frame or bounding box. The numbers are assigned randomly to cells within the frame, where the cells represent the locations of possible sampling plots. The (square, in this example) cells with solid lines are those randomly selected as sample plot locations, and the cells with dotted lines are candidate sample plots that have been rejected because they lie partially outside the parcel boundary. In this example the parcel comprises a single stratum.

Annex 3

Data needed for *ex ante* estimations

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
Historical land use/cover data		Determining baseline approach Demonstrating eligibility of land	Earliest possible up to now	Publications, national or regional forestry inventory, local government, interview
Land use/cover Map		Demonstrating eligibility of land, stratifying land area	Demonstrating eligibility of land, stratifying land area	Forestry inventory
Remote sensing data		Demonstrating eligibility of land, stratifying land area	1989/1990 and most recent	e.g. Landsat/TM,ETM+, ASTER
Digital Elevation Model (DEM)		Demonstrating eligibility of land, stratifying land area	most recent	e.g. SRTM, ASTER
Landform map		Stratifying land area	Stratifying land area	Local government
Soil map		Stratifying land area	most recent date	Local government and institutional agencies
National and sectoral policies		Additionality consideration	Before 1998	
UNFCCC decisions			1997 up to now	UNFCCC website
IRR, NPV cost benefit ratio, or unit cost of service		Indicators of investment analysis	Most recent date	Calculation
Investment costs		Including land purchase or rental, machinery, equipments, buildings, fences, site and soil preparation seedling, planting, weeding, pesticides, fertilization, supervision, training, technical consultation, etc. that occur in the establishment period	Most recent date, taking into account market risk	Local statistics, published data and/or survey
Operations and maintenance costs		Including costs of thinning, pruning, harvesting, replanting, fuel, transportation, repairs, fire and disease control,	Most recent date, taking into account	Local statistics, published data and/or survey

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
		patrolling, administration, etc.	market risk	
Transaction costs		Including costs of project preparation, validation, registration, monitoring, etc.	Most recent date	
Revenues		Those from timber, fuelwood, non-wood products, with and without CER revenues, etc.	Most recent date, taking into account market risk	Local statistics, published data and/or survey
ΔC_{BSL}	t CO_2-e yr^{-1}	Baseline net GHG removals by sinks		
$\Delta C_{ij,baseline}$	t CO_2-e yr^{-1}	Average annual carbon stock change in living biomass of trees in baseline		Estimated
$\Delta C_{G,ij}$	t CO_2-e yr^{-1}	Average annual increase in carbon due to biomass growth	Most recent	GPG-LULUCF, national and local forestry inventory
$\Delta C_{L,ij}$	t CO_2-e yr^{-1}	Average annual decrease in carbon due to biomass loss	Most recent	GPG-LULUCF, national and local forestry inventory
Aij	ha	Area of stratum and species		
$G_{TOTAL,ij}$	t d. m. $ha^{-1}yr^{-1}$	Annual average increment rate in total biomass per hectare for stratum	Most recent	GPG-LULUCF, national and local forestry inventory
CF	t C (t d.m.)$^{-1}$	Carbon fraction		GPG-LULUCF, national GHG inventory
44/12	dimensionless	Ration of molecular weights of CO2 and carbon		IPCC
$G_{w,ij}$	t d. m. $ha^{-1}yr^{-1}$	Average annual aboveground biomass increment		GPG-LULUCF, national GHG inventory
$R_{1,j}$ $R_{2,j}$	dimensionless	Root-shoot ratios for tree species j, appropriate for biomass increment, and biomass stock, respectively		GPG-LULUCF, national GHG inventory, local survey

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
$I_{V,ij}$	$m^3\ ha^{-1}\ yr^{-1}$	Average annual net increment in volume suitable for industrial processing		GPG-LULUCF, national GHG inventory, local survey
D_j	t d.m. m^{-3}	Species specific basic wood density		GPG-LULUCF, national GHG inventory, local survey
$BEF_{1,j}$	dimensionless	Species specific biomass expansion factor for conversion of annual net increment (including bark) to aboveground biomass increment		GPG-LULUCF, national GHG inventory, local survey
$BEF_{2,j}$	dimensionless	Species specific biomass expansion factor for conversion of merchantable volume to aboveground tree biomass		GPG-LULUCF, national GHG inventory, local survey
$C_{ij,2}$ $C_{ij,1}$	t C	Total carbon stock in living biomass of trees, calculated at time 2 or 1		GPG-LULUCF, national GHG inventory, local survey
V_{ij}	$m^3\ ha^{-1}$	Merchantable volume		Forestry inventory, yield table, local survey
$C_{AB,ij}$	t C	Carbon stock in aboveground biomass		Calculated
$C_{BB,ij}$	t C	Carbon stock in belowground biomass		Calculated
$f_j(DBH,H)$		Allometric equation		Forestry inventory, published data, local survey
ΔCij	t CO_2-e yr^{-1}	Average annual carbon stock change in living biomass of trees		Calculated
$L_{fellings,ij}$	t C yr^{-1}	Annual carbon loss due to commercial fellings		Calculated
$L_{fuelwood,ij}$	t C yr^{-1}	Annual carbon loss due to fuel wood gathering of trees		Calculated
$L_{other\ losses,ij}$	t C yr^{-1}	Annual natural losses of carbon in living trees		Calculated
H_{ij}	$m^3\ yr^{-1}$	Annually extracted volume		Monitoring
FG_{ij}	$m^3\ yr^{-1}$	Annual volume of harvested fuel wood		Monitoring
$A_{disturbance,ij}$	ha yr^{-1}	Areas affected by disturbances		Monitoring
$F_{disturbance,ij}$	dimensionless	The fraction of the biomass in living trees for stratum i species j affected by disturbance		Monitoring

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
$B_{W,i,j}$	t d. m. ha^{-1}	Average biomass stock of living trees		Local survey
$E_{FuelBurn}$	t CO_2-e yr^{-1}	Emissions from burning of fossil fuels		Estimated
$E_{biomassloss}$	t CO_2-e yr^{-1}	Decrease in carbon stock in living biomass of existing vegetation		Estimated
$E_{Non\text{-}CO2,BiomassBurn}$	t CO_2-e yr^{-1}	The increase in non-CO2 emission as a result of biomass burning within the project boundary		Estimated
$N_2O_{direct-Nfertilizer}$	t CO_2-e yr^{-1}	The increase in N2O emission as a result of direct nitrogen application within the project boundary		Estimated
$N_2O_{direct-NN\text{-}fixing}$	t CO_2-e yr^{-1}	The increase in N2O emission from residues of nitrogen-fixing trees within the project boundary		Estimated
CSP	litre yr^{-1}	Amount of fuel consumption		Monitored
EF_{vf}	kg CO_2 $litre^{-1}$	Emission factor		IPCC Guideline, GPG 2000, national inventory
$B_{non\text{-}tree,i}$	t d.m. ha^{-1}	Average above-ground non-tree biomass stock on land to be planted before the start of a proposed A/R CDM project activity		Local survey
$CF_{non\text{-}tree}$	t C (tonne d.m.)$^{-1}$	The carbon fraction of dry biomass in non-tree vegetation		GPG-LULUCF, national GHG inventory, local survey
$R_{non\text{-}tree}$	dimensionless	The average root:shoot ratio appropriate for biomass stocks of non-tree vegetation		GPG-LULUCF, national GHG inventory, local survey
$E_{BiomassBurn,C}$	t C yr^{-1}	Loss of carbon due to slash and burn		Estimated
$E_{BiomassBurn,\ N2O}$	t CO2-e yr^{-1}	N2O emission from biomass burning in slash and burn		
$E_{BiomassBurn,\ CH4}$	t CO2-e yr^{-1}	CH4 emission from biomass burning in slash and burn		
N/C ratio	dimensionless	Nitrogen-carbon ratio		IPCC
44/28	dimensionless	Ration of molecular weights of N2O and nitrogen		IPCC

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
16/12	dimensionless	Ration of molecular weights of CH_4 and carbon		IPCC
ER_{N2O}	dimensionless	Emission ration for N2O		IPCC
ER_{CH4}	dimensionless	Emission ration for CH_4		IPCC
GWP_{N2O}	kg CO_2-e (kg N_2O)$^{-1}$	Global Warming Potential for N_2O		IPCC
GWP_{CH4}	kg CO_2-e (kg CH_4)$^{-1}$	Global Warming Potential for CH_4		IPCC
$A_{burn,i}$	ha yr^{-1}	Area of biomass burning		Survey
$CE_{non\text{-}tree}$	dimensionless	Average biomass combustion efficiency for non-tree		IPCC GPG-2000, national GHG inventory
F_{SN}	t N yr^{-1}	Annual amount of synthetic fertilizer nitrogen adjusted for volatilization as NH_3 and NOX		Estimated
F_{ON}	t N yr^{-1}	Annual amount of organic fertilizer nitrogen adjusted for volatilization as NH3and NOX		Estimated
EF1	t N2O-N (t N input)$^{-1}$	Emission Factor for emissions from N inputs		GPG 2000
$Frac_{GASS}$	dimensionless	The fraction that volatilises as NH3 and NOX for synthetic fertilizers		IPCC Guideline
$Frac_{GASO}$	dimensionless	The fraction that volatilises as NH_3 and NOX for organic fertilizers		IPCC Guideline
$N_{SN\text{-}fert}$	t N yr^{-1}	Amount of synthetic fertilizer nitrogen applied		Monitored
$N_{ON\text{-}fert}$	t N yr^{-1}	Amount of organic fertilizer nitrogen applied		Monitored
F_{TN}	t N yr^{-1}	Amount of nitrogen fixed by nitrogen-fixing trees planted		Calculated
LF_j	dimensionless	The ratio of annual allocation to leaf biomass to the annual increase in above-ground biomass of the nitrogen-fixing tree species *j*		
$Tree_{NCRBF,j}$	dimensionless	The fraction of nitrogen-fixing tree leaf biomass that is nitrogen		

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
ΔC_{ACTUAL}	t CO_2-e yr^{-1}	Actual net GHG removals by sinks		Calculated
GHG_E	t CO_2-e yr^{-1}	Increase in GHG emissions by the sources within the project boundary as a result of the implementation of an A/R project activity		Calculated
LK	t CO_2-e yr^{-1}	Total GHG emissions caused by leakage		
$LK_{FuelBurn}$	t CO_2-e yr^{-1}	CO_2 emissions from combustion of fossil fuels at the outside the project boundary		Estimated
CAR_CDM	t CO_2-e yr^{-1}	net anthropogenic GHG removals by sinks		Calculated

Annex 4

Data to be collected and archived for of baseline net GHG removals by sinks

ID number	Data Variable	Data Unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
1.1.1.01	Stratum ID, *i*	Alpha numeric	Stratification map		Before the start of the project	100%	Each stratum has a particular combination of soil type, climate, existing vegetation and landform
1.1.1.02	Number of sample plots			c	Before the start of the project	100%	For each stratum
1.1.1.03	Sample plot ID	Alpha numeric	Project and plot map		Before the start of the project	100%	Numeric series ID will be assigned to each permanent sample plot
1.1.1.04	Plot location		Project and plot map and GPS locating	m	5years	100%	Using GPS to locate before start of the project and at time of each field measurement
1.1.1.05	Tree species or types		Monitoring activity		5 years	100%	
1.1.1.06	Number of trees	number	Plot measurement	m	5 years	100% trees in plots	Counted in plot measurement
1.1.1.07	Diameter at breast height (DBH)	cm	Plot measurement	m	5 year	100% trees in plots	Measuring at each monitoring time
1.1.1.08	Mean DBH	cm	Calculated	c	5 year	100% of sampling plots	Calculated via 1.1.1.06 and 1.1.1.07
1.1.1.09	Tree height	m	Plot measurement	m	5 year	100% trees in plots	Measuring at each monitoring time
1.1.1.10	Mean tree height	m	Calculated	c	5 year	100% of sampling plots	Calculated via 1.1.1.06 and 1.1.1.09

ID number	Data Variable	Data Unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
1.1.1.11	Wood density, *D*	t d.m. m^{-3}	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species specific value have the priority
1.1.1.12	Biomass expansion factor, *BEF*	dimensionles s	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species specific value have the priority
1.1.1.13	Carbon fraction, *CF*	t C.(t d.m) $^{-1}$	Local, national, IPCC	e	5 year	100% of sampling plots	Local-derived and species specific value have the priority
1.1.1.14	Root-shoot ratio, *R*	dimensionles s	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species specific value have the priority
1.1.1.15	Carbon stock in above-ground biomass of plots	t C ha^{-1}	Calculated	c	5 year	100% of sampling plots	Calculated from equations (14) or (16) and (17) via 1.1.1.08-1.1.1.15
1.1.1.16	Carbon stock in below-ground biomass of plots	t C ha^{-1}	Calculated	c	5 year	100% of sampling plots	Calculated from equation (15) (11) via 1.1.1.15
1.1.1.17	Mean carbon stock in above-ground biomass per unit area per stratum per species or types, $MC_{AB,ij}$	t C ha^{-1}	Calculated	c	5 year	100% of strata and sub-strata	Calculated from 1.1.1.02 and 1.1.1.15
1.1.1.18	Mean Carbon stock in below-ground biomass per unit area per stratum per species or types, $MC_{BB,ij}$	t C ha^{-1}	Calculated	c	5 year	100% of strata and sub-strata	Calculated from 1.1.1.02 and 1.1.1.16
1.1.1.19	Area of stratum per species or types, A_{ij}	ha	Stratification map and data	m	5 year	100% of strata and sub-strata	Actual area of each stratum

ID number	Data Variable	Data Unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
1.1.1.20	Carbon stock in above-ground biomass of stratum per species or types, $C_{AB,ij}$	t C	Calculated	c	5 year	100% of strata and	Calculated from equation (12) via 1.1.1.17 and 1.1.1.19
1.1.1.21	Carbon stock in belowground biomass of stratum per species or types, $C_{BB,ij}$	t C	Calculated	c	5 year	100% of strata and sub-strata	Calculated from equation (13) 1.1.1.18 and 1.1.1.19
1.1.1.22	Carbon stock change in above-ground biomass of stratum per species or types, $\Delta C_{AB,ij}$	t C yr^{-1}	Calculated	c	5 year	100% of strata and sub-strata	Calculated from equation (10) via 1.1.1.20
1.1.1.23	Carbon stock change in below-ground of biomass of stratum per species or types, $\Delta C_{BB,ij}$	t C yr^{-1}	Calculated	c	5 year	100% of strata and sub-strata	Calculated from equation (11) via 1.1.1.21
1.1.1.24	Average annual carbon stock change in living biomass of trees of stratum per species or types in the absence of the project activity, ΔCij	t CO2-e yr^{-1}	Calculated	c	5 year	100% project area	Summing up carbon stock change in 1.1.1.22 and 1.1.1.23 for all strata and tree species or types
1.1.1.25	Baseline net GHG removals, ΔC_{BSL}	t CO2-e yr^{-1}	Calculated	c	5 year	100% project area	Calculated from equation (7) via 1.1.1.24

Annex 5

Data to be collected for calculation of actual net GHG removals by sinks

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.01	Stratum ID, *i*	Alpha numeric	Stratification map		Before the start of the project	100%	Each stratum has a particular combination of soil type, climate, existing vegetation and landform
2.1.1.02	Sub-stratum ID, *j*	Alpha numeric	Stratification map		Before the start of the project	100%	Each sub-stratum has a particular year to be planted under each stratum
2.1.1.03	Confidence level	%			Before the start of the project	100%	For the purpose of QA/QC and measuring and monitoring precision control
2.1.1.04	Precision level	%			Before the start of the project	100%	For the purpose of QA/QC and measuring and monitoring precision control
2.1.1.05	Standard deviation of each stratum, n_h			e	Before the start of the project	100%	Used for estimating numbers of sample plots of each stratum and substratum
2.1.1.06	Number of sample plots, n_h			c	Before the start of the project	100%	For each stratum and substratum, calculated from 2.1.1.03-2.1.1.05 using equation (4)-(5)

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.07	Sample plot ID, *p*	Alpha numeric	Project and plot map		Before the start of the project	100%	Numeric series ID will be assigned to each permanent sample plot
2.1.1.08	Plot location		Project and plot map and GPS locating	m	5years	100%	Using GPS to locate before start of the project and at time of each field measurement
2.1.1.09	Tree species		Project design map		5years	100%	Arranged in CDM-AR-PDD
2.1.1.10	Age of plantation	year	Plot measurement	m	5 years	100% of sampling plots	Counted since the planted year
2.1.1.11	Number of trees	number	Plot measurement	m	5 years	100% trees in plots	Counted in plot measurement
2.1.1.12	Diameter at breast height (DBH)	cm	Plot measurement	m	5 year	100% trees in plots	Measuring at each monitoring time per sampling method
2.1.1.13	Mean DBH	cm	Calculated via 2.1.1.12	c	5 year	100% of sampling plots	Calculated via 2.1.1.11 and 2.1.1.12
2.1.1.14	Tree height	m	Plot measurement	m	5 year	100% trees in plots	Measuring at each monitoring time per sampling method
2.1.1.15	Mean tree height	m	Calculated via 2.1.1.14	c	5 year	100% of sampling plots	Calculated via 2.1.1.11 and 2.1.1.14
2.1.1.16	Merchantable volume, *V*	m^3 ha^{-1}	Calculated or plot measurement	c/m	5 year	100% of sampling plots	Calculated via 2.1.1.13 and 2.1.1.15 using local-derived equations, or directly measured by field instrument

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.17	Wood density, *D*	t d.m. m^{-3}	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species specific value have the priority
2.1.1.18	Biomass expansion factor, *BEF*	dimensionless	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species specific value have the priority
2.1.1.19	Carbon fraction, *CF*	t C.(t d.m) $^{-1}$	Local, national, IPCC	e	5 year	100% of sampling plots	Local-derived and species specific value have the priority
2.1.1.20	Root-shoot ratio, *R*	dimensionless	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species specific value have the priority
2.1.1.21	Carbon stock in aboveground biomass of plots, MC_{AB}	t C ha^{-1}	Calculated	c	5 year	100% of sampling plots	Calculated from equation (14) via 2.1.1.16-2.1.1.19, or from equation (16) and (17) via 2.1.1.13, 2.1.1.15 and 2.1.1.19
2.1.1.22	Carbon stock in belowground biomass of plots, MC_{BB}	t C ha^{-1}	Calculated	c	5 year	100% of sampling plots	Calculated from equation (5) via 2.1.1.20-2.1.1.21
2.1.1.23	Mean Carbon stock in aboveground biomass per unit area per stratum and species, $MC_{AB,ij}$	t C ha^{-1}	Calculated	c	5 year	100% of strata and sub-strata	Calculated via 2.1.1.06 and 2.1.1.21

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.24	Mean Carbon stock in belowground biomass per unit area per stratum and species, $MC_{BB,ij}$	$t\ C\ ha^{-1}$	Calculated	c	5 year	100% of strata and sub-strata	Calculated via 2.1.1.06 and 2.1.1.22
2.1.1.25	Area of stratum and species, A_{ij}	ha	Stratification map and data	m	5 year	100% of strata and sub-strata	Actual area of each stratum and sub-stratum
2.1.1.26	Carbon stock in aboveground biomass of stratum and species,-$C_{AB,ij,p}$	t C	Calculated	c	5 year	100% of strata and	Calculated from equation (12) via 2.1.1.23 and 2.1.1.25
2.1.1.27	Carbon stock in belowground biomass of stratum and species, $C_{BB,ij,p}$	t C	Calculated	c	5 year	100% of strata and sub-strata	Calculated from equation (13) 2.1.1.24 and 2.1.1.25
2.1.1.28	Carbon stock change in aboveground biomass of stratum and species, $\Delta C_{AB,ij}$	$t\ C\ yr^{-1}$	Calculated	c	5 year	100% of strata and sub-strata	Calculated from equation (10) via 2.1.1.26
2.1.1.29	Carbon stock change in belowground biomass of stratum and species, $\Delta C_{BB,ij}$	$t\ C\ yr^{-1}$	Calculated	c	5 year	100% of strata and sub-strata	Calculated from (11) via 2.1.1.27

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.30	Total carbon stock change of stratum and species, ΔC_{ij}	t CO_2-e yr^{-1}	Calculated	c	5 year	100% project area	Summing up carbon stock change in 2.1.1.28 and 2.1.1.29 for all strata, substrata and tree species
2.1.2.01	Fuel type, f		On-site monitoring	m	annually	100%	Diesel or gasoline
2.1.2.02	Vehicle or machinery type, v		On-site monitoring	m	annually	100%	
2.1.2.03	Amount of fuel consumption per fuel type and vehicle or machinery type, CSP_{vf}	litter	On-site monitoring or recording fulfilled amount	m	annually	100%	Measuring either fuel consumption per unit area, or per unit volume planted, logged or thinned
2.1.2.04	Emission factor per fuel type and vehicle or machinery type EF_{vf}	kg/ litter	GPG 2000, IPPCC Guidelines, national inventory	e	At beginning of the project	100%	National inventory value should has priority
2.1.2.05	Emission from fossil fuel use within project boundary, $E_{FluelBurn}$	t CO2-e yr^{-1}	Calculated	e	annually	100%	Calculating using equation (19) via 2.1.2.01-2.1.2.04

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.06	Average biomass stock of non-tree vegetation on land to be planted before the start of a proposed A/R project activity, $B_{non\text{-}tree}$	t d.m.ha^{-1}	Measured before biomass removal	m	Annually during first rotation	100%	Sampling survey for different strata and substrata before biomass removal
2.1.2.07	Area of wildfire, $A_{wildfire}$	ha	Measured during implementation	m	annually	100%	Measured for different strata
2.1.2.08	Biomass combustion efficiency, $CE_{non\text{-}tree}$	dimensionless	GPG LULUCF National inventory	e	Before the start of the project	100%	IPCC default value (0.5) is used if no appropriate value
2.1.2.9	Carbon fraction, $CF_{non\text{-}tree}$	t C.(t d.m)$^{-1}$	Local, national, IPCC	m	5 years	100%	2.1.1.19 can be used if no appropriate value
2.1.2.10	Biomass combustion efficiency, CE_j	dimensionless	GPG LULUCF National inventory	e	Before the start of the project	100%	IPCC default value (0.5) is used if no appropriate value
2.1.2.11	Carbon fraction, CF_j	t C.(t d.m)$^{-1}$	Local, national, IPCC	m	5 years	100%	2.1.1.19 can be used if no appropriate value
2.1.2.12	Decrease in carbon stock in living biomass of existing vegetation, $E_{biomassloss}$	t CO_2-e yr^{-1}	Calculated	c	5 years	100%	Calculated using equation (20) or (21) via 2.1.2.6 – 2.1.2.11

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.13	Loss of aboveground biomass carbon due to biomass burning, $E_{BiomassBurn,C}$	t C yr^{-1}	Calculated	c	5 year	100%	Calculated using equation (27)
2.1.2.14	N/C ratio	dimensionless	GPG LULUCF National inventory, publications	e	Before the start of the project	100%	IPCC default value (0.01) is used if no appropriate value
2.1.2.15	N2O emission from biomass burn, $E_{BiomassBurn,N2O}$	t CO2-e yr^{-1}	Calculated	c	5 year	100%	Calculated using equation (25) via 2.1.2.13-2.1.2.14
2.1.2.16	CH4 emission from biomass burn, $E_{BiomassBurn,CH4}$	t CO2-e yr^{-1}	Calculated	c	5 year	100%	Calculated using equation (26) via 2.1.2. 13
2.1.2.17	The increase in non-CO2 emission as a result of biomass burning, $E_{Non-CO2,BiomassBurn}$	t CO2-e yr^{-1}	Calculated	c	5 year	100%	Calculated using equation (23) via 2.1.2.15 - 2.1.2.16
2.1.2.24	Amount of synthetic fertilizer N applied per unit area, F_{SN}	kg N ha^{-1} yr^{-1}	Monitoring activity	m	annually	100%	For different tree species and/or management intensity
2.1.2.25	Amount of organic fertilizer N applied per unit area, F_{ON}	kg N ha^{-1} yr^{-1}	Monitoring activity	m	annually	100%	For different tree species and/or management intensity

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.26	Area of land with N applied, *A*	ha yr^{-1}	Monitoring activity	m	annually	100%	For different tree species and/or management intensity
2.1.2.27	Amount of synthetic fertilizer N applied, $N_{SN\text{-}Fert}$	t N yr^{-1}	Calculated	c	annually	100%	Calculated using equation (28) via 2.1.2.26
2.1.2.28	Amount of organic fertilizer N applied, $N_{ON\text{-}Fert}$	t N yr^{-1}	Calculated	c	annually	100%	Calculated using equation (29) via 2.1.2.26
2.1.2.29	Fraction that volatilizes as NH3 and NOX for synthetic fertilizers, $Frac_{GASS}$	dimensionless	National inventory	e	Before start of monitoring	100%	To be set 0 if no data available
2.1.2.30	Fraction that volatilizes as NH3 and NOX for organic fertilizers, $Frac_{GASO}$	dimensionless	National inventory	e	Before start of monitoring	100%	To be set 0 if no data available
2.1.2.31	Emission factor for emission from N input, EF_1	t N2O-N (t N input)$^{-1}$	IPCC Guideline National inventory	e	Before start of monitoring	100%	IPCC default value (1%) is used if no more appropriate data
2.1.2.32	Direct N2O emission due to of fertilizer applica-tion, $N_2O_{direct\text{-}Nfetilizer}$	t CO2-e yr^{-1}	Calculated	c	annually	100%	Calculated using equation (30) via 2.1.2.24-2.1.2.31

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.33	Annual stock change of aboveground biomass of nitrogen-fixing species, $\Delta B_{AB\_tree,ij}$	t d.m.ha^{-1}yr^{-1}	Calculated	c	5 years	100%	Calculated via 2.1.1.23
2.1.2.34	The fraction of nitrogen-fixing- tree foliage biomass that is nitrogen, $Tree_{NCRBF,j}$	dimensionless		e	Before start of monitoring	100%	
2.1.2.35	the ratio of annual allocation of biomass to foliage, to the annual increase in above-ground biomass, in nitrogen-fixing tree species, LF_j	dimensionless		e	Before start monitoring	100%	
2.1.2.36	Amount of nitrogen fixed by nitrogen-fixing trees, F_{TN}	t N	Calculated	c	5 years	100%	Calculated using equation (34) via 2.1.1.25, 2.1.2.33 to 2.1.2.35

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.37	The increase in annual N_2O emission as a result of planting of nitrogen-fixing trees, $N_2O_{N\,fixing}$	t CO_2-e yr^{-1}	Calculated	c	5 years	100%	Calculated using equation (33) via 2.1.2.31 and 2.1.2.36
2.1.2.38	Total increase in GHG emission, GHG_E	t CO2-e yr^{-1}	Calculated	c	annually	100%	Calculated using equation (18) via 2.1.2.05, 2.1.2.12, 2.1.2.17, 2.1.2.32 and 2.1.2. 37

Annex 6

Data to be collected for calculation of leakage

ID number	Data Variable	Data unit	Data source	Measured (m) Calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.1.1.01	Amount of diesel consumption on outside the boundary	Litre	Recording fulfilled amount	m	annually	100%	Measuring diesel consumed for timber transportation and following activities
3.1.1.02	Amount of gasoline consumption-on outside the boundary	Litre	Recording fulfilled amount	m	annually	100%	Measuring gasoline consumed for timber transportation and following activities
3.1.1.03	Emission factor for diesel	kg/ litre	GPG 2000, IPPCC Guidelines, national inventory	e	At beginning of the project	100%	National inventory value should has priority
3.1.1.04	Emission factor for gasoline	kg/ litre	GPG 2000, IPPCC Guide-lines, national inventory	e	At beginning of the project	100%	National inventory value should has priority
3.1.1.05	Emission from fossil fuel use outside project boundary	t CO2-e yr^{-1}	Calculated from equation (14)	e	annually	100%	Calculating using equation (36) via 3.1.1.01-3.1.1.04
3.1.1.06	Leakage	t CO2-e yr^{-1}	Calculated	c	annually	100%	Calculated using equation (35) via 3.1.1.04 and 3.1.1.05

Annex 7

1. Lists of variables, acronyms and references

Variable	SI Unit	Description
0.001	dimensionless	Conversion kilograms to tonnes
44/12	dimensionless	Ratio of molecular weight of CO_2 and carbon
16/12	dimensionless	Ratio of molecular weights of CH_4 and carbon
44/28	dimensionless	Ratio of molecular weights of N2O and nitrogen
$A_{burn,i}$	ha yr^{-1}	Area of slash and burn for stratum *i*
$A_{disturbance,ij}$	ha yr^{-1}	Area affected by disturbances in stratum *i* species *j*
A_i	ha	Area of stratum *i*
A_{ij}	ha	Area of stratum *i* species *j*
$A_{wildfire,i}$	ha	Area burnt due to wildfire in stratum *i*
$B_{AB,ij}$	t d.m. ha^{-1}	Above-ground biomass in the stratum *i* species *j*
$B_{BB,ij}$	t d.m. ha^{-1}	Below-ground biomass in the stratum *i* species *j*
$BEF_{1,j}$	dimensionless	Biomass expansion factor for conversion of annual net increment in merchantable volume to total aboveground biomass increment for species *j*, dimensionless
$BEF_{2,j}$	dimensionless	Biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j*
$B_{non\text{-}tree,i}$	t d.m.ha^{-1}	Average non-tree biomass stock on land to be planted before the start of a proposed A/R project activity for stratum *i*
$B_{w,ij}$	t d.m.ha^{-1}	Average biomass stock of living trees for stratum *i* species *j*
$C_{1,ij}$	t C	Total carbon stock in living biomass for stratum *i* species *j*, calculated at time 1
$C_{2,ij}$	t C	Total carbon stock in living biomass for stratum *i* species *j*, calculated at time 2
$C_{AB,mij}$	t C	Carbon stock in above-ground biomass for stratum *i* substratum *j* at monitoring point *m*
$C_{AB.ij}$	t C	Carbon stock in aboveground biomass for stratum *i* species *j*
CAR_CDM	t CO_2-e yr^{-1}	Net anthropogenic GHG removals by sinks
$C_B(t_v)$	t CO_2	Estimated carbon stocks of the baseline scenario at time of verification t_v,

Variable	SI Unit	Description
$C_{BB,ij}$	t C	Carbon stock in below-ground biomass for stratum *i* species *j*
$C_{BB,mij}$	t C	Carbon stock in belowground biomass for stratum *i* substratum *j* at monitoring point *m*
CE_j	dimensionless	Combustion efficiency for tree species *j*
$CE_{non\text{-}tree}$	dimensionless	Combustion efficiency for non-tree vegetation
CF_j	t C (t d.m.)$^{-1}$	Carbon fraction of dry matter for species or type *j*
$CF_{non\text{-}tree}$	t C (tonne d.m.)$^{-1}$	Carbon fraction of dry biomass in non-tree vegetation
C_h	dimensionless	Cost to select a plot of the stratum *h*
$C_P(t_v)$	t CO_2	Existing carbon stocks at the time of verification t_v
$CSP_{vf:}$	litre yr^{-1}	Amount of consumption of fuel type *f* of vehicle type *v*
$\Delta CACTUAL$	t CO_2-e yr^{-1}	Actual net GHG removals by sinks
$\Delta CBSL$	t CO_2-e yr^{-1}	Baseline net GHG removals by sinks
$\Delta C_{G,ij,t}$	t CO_2-e yr^{-1}	Average annual increase in carbon due to biomass growth of living trees for stratum *i* species *j* for year *t*
ΔC_{ij}	t CO_2-e yr^{-1}	Average annual carbon stock change in living biomass of trees for stratum *i* species *j*
$\Delta C_{ij,baseline,t}$	t CO_2-e yr^{-1}	Average annual carbon stock change in living biomass of trees for stratum *i* species *j* for year *t*
$\Delta C_{L,ij,t}$	t CO_2-e yr^{-1}	Average annual decrease in carbon due to biomass loss of living trees for stratum *i* species *j* for year *t*
D_j	t d.m. m^{-3}	Basic wood density for species *j*
E	Dimensionless	allowable error (□10% of the mean)
$E(t)$	t CO_2	Project emissions in year *t*
$E_{BiomassBurn,\ CH4}$	t CO2-e yr^{-1}	CH4 emission from biomass burning
$E_{BiomassBurn,\ N2O}$	t CO2-e yr^{-1}	N2O emission from biomass burning
$E_{BiomassBurn,C}$	t C yr yr^{-1}	C loss of carbon stock in aboveground biomass due to biomass burning
$E_{biomassloss}$	t CO2-e yr^{-1}	The CO2 emissions as a result of a decrease in carbon stock in living biomass of existing vegetation. This is an initial loss, and therefore accounted once upfront as part of the first monitoring interval
$EF1$	t N2O-N (t N input)$^{-1}$	Emission Factor for emissions from N inputs

Variable	SI Unit	Description
$E_{FuelBurn}$	t CO_2-e yr^{-1}	The CO2 emissions from combustion of fossil fuels
EF_{vf}	kg CO_2 $litre^{-1}$	Emission factor for vehicle or machinery type *v* with fuel type *f*
$E_{Non-CO2,\ BiomassBurn}$	t CO2-e	The non-CO2 emissions as a result of a decrease in carbon stock in living biomass of existing vegetation.
$E_{Non-CO2,BiomassBurn}$	t CO2-e yr^{-1}	The increase in Non-CO2 emission as a result of biomass burning
ER_{CH4}		IPCC default emission ratio for CH_4 = 0.012
ER_{N2O}		IPCC default emission ratio for N_2O = 0.007
$F_{disturbance,ij}$		Fraction of biomass in living trees affected by disturbance for stratum *i* species *j*, dimensionless
$FG_{trees,ij}$	m^3 yr^{-1}	Annual volume of fuelwood removal of whole trees for stratum *i* species *j*
$f_j(DBH, H)$		An allometric equation linking aboveground biomass (d.m. ha^{-1}) to mean diameter at breast height (DBH) and possibly tree height (H)
F_{ON}	t N yr^{-1}	Mass of organic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX
$Frac_{GASO}$	dimensionless	The fraction that volatilises as NH3 and NOX for organic fertilizers
$Frac_{GASS}$	dimensionless	The fraction that volatilises as NH3 and NOX for synthetic fertilizers
$Frac_{leaf,j}$	dimensionless	The fraction of biomass in leaves
F_{SN}	t N yr^{-1}	Mass of synthetic fertilizer nitrogen applied adjusted for volatilization as NH3 and NOX
GHG_E	t CO_2-e yr^{-1}	The GHG emissions as a result of the implementation of the A/R project activity within the project boundary
$G_{TOTAL,ij,t}$	t d. m. $ha^{-1}yr^{-1}$ for year *t*	Average annual increment of total dry biomass of living trees for stratum *i* species *j*
$G_{w,ij,t}$	t d. m. ha^{-1} yr^{-1} for year *t*	Average annual aboveground dry biomass increment of living trees for stratum *i* species *j*
GWP_{CH4}	kg CO_2-e (kg CH_4)$^{-1}$	Global Warming Potential for CH_4(IPCC default = 21, valid for the first commitment period)
GWP_{N2O}	kg CO_2-e (kg N_2O)$^{-1}$	Global Warming Potential for N_2O, (IPCC default = 310, valid for the first commitment period)
H_{ij}	m^3 yr^{-1}	Annually extracted merchantable volume for stratum *i* species *j*
i	dimensionless	Strata
$I_{V,ij,t}$	m^3 ha^{-1} yr^{-1} for year *t*	Average annual increment in merchantable volume for stratum *i* species *j*
j	dimensionless	Tree species or type

Variable	SI Unit	Description
L	dimensionless	Total number of strata
$lCER(t_v)$	t CO_2	lCERs emitted at time of verification t_v
$L_E(t)$	t CO_2	Leakage: estimated emissions by sources outside the project boundary in year t
$L_{fellings,ij}$	t C yr^{-1}	Annual carbon loss due to commercial fellings and thinnings for stratum i species j, $L_{fellings,ij}= 0$
$L_{fuelwood,ij}$	t C yr^{-1}	Annual carbon loss due to fuelwood harvesting of trees for stratum i species j. Collection of fuelwood from dead wood and litter pools will not be included, because these pools are omitted from the accounting.
$L_{otherloss,ij}$	t C yr^{-1}	Annual natural losses of carbon in living trees for stratum i species j
LK	t CO_2-e yr^{-1}	Total GHG emissions as leakage
$LK_{fuelburn}$	t CO_2-e yr^{-1}	CO_2 emissions from combustion of fossil fuels at the outside the project boundary
□		Sample mean value of the parameter
$MC_{AB,m,ij}$	t C ha^{-1}	Mean carbon stock in aboveground biomass per unit area for stratum i sub-stratum
$MC_{BB,m,ij}$	t C ha^{-1}	Mean carbon stock in belowground biomass per unit area for stratum i sub-stratum j
n	dimensionless	Total number of samples
N	dimensionless	Number of total sample units (all stratum)
N_j	t N (t d. $m)^{-1}$	Nitrogen content of fallen leaves for species j
$N/C\ ratio$	dimensionless	Nitrogen-carbon ratio
$N_2O_{\ direct-Nfertilizer}$	t CO_2-e yr^{-1}	N_2O emission as an result of direct nitrogen application within the project boundary
$N_2O_{\ direct-NN\text{-}fixing}$	t CO_2-e yr^{-1}	Direct N_2O emission from residues of nitrogen-fixing trees
n_h	dimensionless	Number of samples per stratum
N_h	dimensionless	Number of sample units for stratum h, calculated by dividing the area of stratum h by area of each plot
N_i	dimensionless	Number of plot within stratum i
$N_{ON\text{-}fert}$	t N yr^{-1}	Mass of organic fertilizer nitrogen applied
$N_{SN\text{-}fert}$	t N yr^{-1}	Mass of synthetic fertilizer nitrogen applied
R_j	dimensionless	Root-shoot ratio appropriate to increment,

Variable	SI Unit	Description
□		Sample standard deviation of the parameter
s_h	dimensionless	Standard deviation of stratum *h*
t	dimensionless	*t* value for a confidence level (95%)
t	Year	1 to end of crediting period
T		Number of years between times 2 and 1
$tCER(t_v)$	t CO_2	tCERs emitted at time of verification t_v
$T_{leaf,j}$	Year	The leaf turnover rate
t_v	Year	Year of verification
U_c	%	Combined percentage uncertainty
U_i	%	Percentage uncertainties associated with each term of the product (parameters and activity data)
U_s	%	Percentage uncertainty on the estimate of the mean parameter value
U_S	%	Percentage uncertainty of product (emission by sources or removal by sinks)
U_{si}	%	Percentage uncertainty on each term of the sum or difference
V_{ij}	m^3 ha^{-1}	Merchantable volume for stratum *i* species *j*
W_h	dimensionless	N_h/N
W_u	t d.m.	Weight of merchantable volume for transported unit *u*
$x_{est,k}$	dimensionless	Estimated value for plot *k*
x_k	dimensionless	Measured value for plot *k*
κ	Year	Time span between two verification

2. List of acronyms used in the methodologies

Acronym	Description
SRTM	Shuttle Radar Topography Mission
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
TM	Thematic Mapper
ETM+	Enhanced Thematic Mapper Plus
GPS	Global Positioning System
GIS	Geographical Information System

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