Approved afforestation and reforestation baseline and monitoring methodology AR-AM0009

"Afforestation or reforestation on degraded land allowing for silvopastoral activities"

Source

This methodology is based on the draft CDM-AR-PDD: "San Nicolás CDM Reforestation Project" whose baseline study, monitoring and verification plan and project design document were prepared by CORPORACIÓN MASBOSQUES (Colombia). For more information regarding the proposal and its consideration by the Executive Board please refer to case ARNM0024-rev: "Baseline and monitoring methodologies for reforestation project activities in degraded areas and with multiple landholders" at: http://cdm.unfccc.int/goto/ARpropmeth.

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 the following afforestation or reforestation (hereafter, A/R) activities:

- Afforestation or reforestation of degraded land, which may be subject to further degradation or remains in a low carbon steady state, through assisted natural regeneration or tree planting;
- Project activities that include silvopastoral arrangements which:
  - Allow grazing within the project boundary;
  - Allow the manure from pasture and range grazing animals to lie as deposited: that is, the manure shall not be collected, stored or burned.

This methodology is applicable to projects that meet the following conditions:

- Lands to be afforested or reforested are degraded grasslands
- The application of the procedure for determining the baseline scenario in Section II.4 leads to the conclusion that the 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.
- Non-tree woody and herbaceous vegetation on lands to be afforested or reforested is absent, or its biomass is decreasing or remains in a steady state.
- Environmental conditions and human-induced degradation prevent the encroachment of natural forest vegetation.

- Site preparation shall not involve biomass burning, and trees existing at the start of the project shall not be felled or removed.
- Nitrogen-fixing (N-fixing) trees planted as part of the A/R CDM project activity account for less than 10% of the total planted forest crown area, so nitrous oxide (N_2O) emissions from decomposition of litter from the N-fixing trees can therefore be considered insignificant.
- Conifers shall not be used as part of A/R project activities.
- Conditions within the project boundary are such that application of the latest version of A/R Methodological Tool "Procedure to determine when accounting of the soil organic carbon pool may be conservatively neglected in CDM A/R project activities" to all land within the project boundary leads to the conclusion that changes in the carbon stocks of the mineral soil component of the soil organic carbon pool may be conservatively neglected.
- Flood irrigation or drainage of primarily saturated soils are not permitted as part of A/R CDM project activities, so non-CO_2 greenhouse gas emissions from these activities can therefore be neglected.
- Forage produced by the project is exclusively consumed by grazing animals within the project boundary, and manure from grazing animals remains in the field and is neither, nor stored nor burned.
- The project activity does not lead to a shift of pre-project activities outside the project boundary: that is, 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.

3. Selected carbon pools:

Table A: Selected carbon pools

Carbon pools	Selected	Justification/Explanation of choice
Aboveground	Yes	Major carbon pool related to the project activity
Belowground	Yes	Major carbon pool related to the project activity
Deadwood	Yes	Possibly significant in some types of activities covered by the methodology
Litter	Yes	Possibly significant in some types of activities covered by the methodology
Organic soil carbon	No	Conservative approach under applicability condition.

4. Summary of baseline and monitoring methodologies

Baseline methodology

The following are the main characteristics of the baseline methodology:

Definition of project boundary: The definition of the project boundary takes into account that the project activity may be implemented by multiple landholders. Discrete areas of land will have a unique geographical identification and the coordinates for all vertices of each polygon will be measured, recorded, and archived.

Stratification: The proposed A/R project area is stratified on the basis of parameters that are key variables used to estimate biomass.

Choice of baseline scenario: The methodology provides a step-by-step procedure to determine the most plausible baseline scenario. Project participants should prove that the A/R project lands are “degraded” and the natural encroachment of trees is unlikely. They should identify and list plausible alternative land use scenarios and demonstrate that the most plausible scenario is that the project area would remain in the existing or historical land use in absence of the project activity.

Ex ante calculation of the baseline net GHG removals by sinks: For strata without growing trees or in a steady state, this methodology conservatively assumes that the carbon stock would remain constant in the absence of the project activity, i.e., the baseline net GHG removals by sinks are zero. For strata with growing trees, the sum of carbon stock changes in aboveground and belowground tree biomass is determined on the basis of 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.

Demonstration of 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 (http://cdm.unfccc.int/Reference/Guidclarif

Ex ante calculation of the actual net GHG removals by sinks: The calculation of carbon stocks in aboveground biomass for planted trees is based on the mean merchantable or standing volume and biomass expansion factors; and for planted permanent non-tree vegetation, on allometric equations linking aboveground biomass to diameter base, shrub height or crown area. Below-ground biomass is estimated using root-shoot ratios. Deadwood and litter pools are estimated using the carbon gain-loss method or stock change method, accounting for annual increases and decreases due to mortality of living biomass, collected harvesting residues, and decomposition. Finally, the methodology estimates N_2O emissions from fertilizers using the latest version of the A/R methodological tool “Estimation of direct nitrous oxide emission from nitrogen fertilization”; GHG emissions from fossil fuel burning in on-site vehicles using the latest versions of the A/R methodological tool “Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities”; the 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 forest fires; and any increase in emissions due to the project supporting more grazing animals than in the baseline.

Leakage emissions: The applicability conditions as well as the design requirements of the methodology are set to prevent significant leakages. For projects that cannot support renewable sources of wood for fences, the methodology provides an equation for calculating a relevant leakage. The project also covers emissions from the transport of products, staff, seedlings, and other materials attributable to implementation of the proposed A/R project activity.

Monitoring methodology

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) on, inter alia, the geographic position of the project boundary and the confirmation that applicability conditions are met.

Stratification: The methodology requires stratification of the project area based on important variations in trees species, age, and stocking. 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 biomass pools.

Monitoring of project activity: The methodology includes provision for standard operating procedures.

Calculation of the *ex post* actual net GHG removal by sinks: The calculation of the ex post actual net GHG removals by sinks is based on measurements of the carbon pools in permanent plots. Formulas are given to estimate GHG removals for each pool included in the methodology as well as emissions by sources. As for the *ex ante* case, emissions accounted *ex post* within the project area are: N_2O emissions from fertilizers, GHG emissions from fossil fuel burning in on-site vehicles/machinery, emissions due to the decrease in carbon stocks in living biomass of non-tree vegetation that existed at the time the project commenced, emissions of non-CO_2 GHG from biomass burning during forest fires; and any increase in emissions due to the project supporting more grazing animals than in the baseline.

Estimation of leakage emissions: Estimates of emissions are made for use of fossil fuel during transportation outside the project boundary and non-renewable wood for fencing.

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 (possibly in the electronic form) 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 these parcels of land not yet under the control of the project participants is clearly defined in the CDM-AR-PDD;
- A justification describing the conditions under which these parcels of land will come under the control of the project participants, including description of a verifiable basis for expectation that these parcels of land will come under the control of the project participants, is provided in the CDM-AR-PDD;
- 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;
- 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.

All parcels of land within the project boundary shall comply with applicability conditions of the latest version of A/R Methodological Tool "Procedure to determine when accounting of the soil organic carbon pool may be conservatively neglected in CDM A/R project activities", what leads to the conclusion that changes in the carbon stocks of the mineral soil component of the soil organic carbon pool may be conservatively neglected.

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
Manure deposition and enteric fermentation (animals grazing in the project area)	CO_2	Excluded	Not applicable
	CH_4	Included	Potentially significant emission source
	N_2O	Included	Potentially significant emission source
Use of fertilizers	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Potentially significant emission source
Combustion of fossil fuels by vehicles	CO_2	Included	Potentially significant emission source
	CH_4	Excluded	Not significant
	N_2O	Excluded	Not significant
Biomass burning	CO_2	Included	Carbon stock decreases due to burning are accounted as a carbon stock change
	CH_4	Included	Potentially significant emission source
	N_2O	Included	Potentially significant emission source

Note: Project participants shall apply the "Tool for testing significance of GHG emissions in A/R CDM project activities" (Version 01), to determine which decreases in carbon pools and which increases in emissions of the greenhouse gases (measured in CO_2 equivalents) that result from the implementation of the A/R project activity are insignificant and can be neglected. This tool should also be used to ensure that it is valid to neglect the decreases in carbon pools and the increases in GHG emissions by sources, which are stated as being insignificant in the applicability conditions of this A/R CDM methodology.

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 on the basis of the 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 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:

(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 partition the project area into two strata: (i) areas without trees or with trees in steady state[1], and (ii) remaining areas. Estimation of average baseline carbon stocks (and/or their changes, as necessary) may be performed 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 tree species, age class (planting date), and possibly management regime.

For each stratum, the project participant shall define at least the following information:

(a) The different present/planted tree species and other vegetation species. The latter type includes shrubs that are difficult to characterize with tree-type biomass parameters.

(b) The species mixtures in a hectare as the number of trees for each species or percentage of vegetation cover in an hectare.

(c) Number of hectares to be planted and a planting schedule.

(d) Forest management operations (land clearance (if not avoided), planting, thinning, harvesting) including their impact on carbon pools, use of fertilizers, and required transportation to be specified relative to age within the rotation. This information is also used as the basis for the preparation of Forest Management Instructions as standard operation procedures (SOPs). See monitoring methodology.

4. Procedure for selection of most plausible baseline scenario

For each stratum project participants should determine the most plausible baseline land-use using the following steps:

Step 1: To demonstrate that the applicability condition 1 (lands to be afforested or reforested are degraded) is obeyed, prove that the A/R project lands are really “degraded”[2]:

[1] Steady state is defined as a state that does not evolve with time; hence, the carbon stocks averaged over area are approximately constant (carbon gains are approximately equal to carbon losses). To determine if the vegetation is in a steady state, project participant shall provide quantitative or qualitative (or visual assessment or similar indicator-based scoring) but verifiable evidence that the cover and composition of the vegetation have historically remained constant. Vegetation type maps of adequate scale providing information over a period of at least 10 years may be used for proving existence of the steady state, if extreme events leading to replacement of vegetation did not occur during that period.

[2] 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

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[3]—has decreased by at least 25% below that of undisturbed lands adjacent to the project area, and has not recovered.
- Soil degradation, for example:
  - Soil erosion has increased between at least two points in time, and has not recovered; or
  - Soil organic matter has decreased 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 2: To demonstrate that the applicability condition 2 (environmental conditions and human-induced degradation prevent the encroachment of natural forest vegetation) is obeyed, assess likelihood of encroachment of trees sufficient to exceed the host country’s forest threshold, 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

Human-induced Degradation of Forests and Devegetation of Other Vegetation Types, see <http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/degradation.htm>.

[3] 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.

- Any other evidence that allows assessment in a verifiable way that natural encroachment of trees is unlikely.

Step 3: Identify and list plausible alternative land uses, including known 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). In doing so, identify and take into account national, local, and sectoral land-use policies or regulations adopted before 11 November 2001 that would impact land uses in the proposed project area. Assess whether the 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, influence the area of the proposed A/R project activity (consider if the policy is implemented, the policy targets the proposed project area, or if there are any prohibitive barriers to the policy in this area, etc[4]).

The identified land-use scenarios shall include:

- At least one land-use scenario following the selected baseline approach 22(a);
- Establishment of forest on the land within the project boundary performed without being registered as the A/R CDM project activity;
- Continuation of the existing land use, if not already included above.

In doing so, make use of land-use records, field surveys, data and feedback from stakeholders, and information from other appropriate sources.

Step 4: Demonstrate that under applicability conditions of this methodology, and taking into account the land-use scenarios identified in Step 3, the most plausible scenario is that the project area would remain in the existing or historical land use in the absence of the project activity. This shall be done by determining the attractiveness of the plausible alternative land uses in terms of benefits to the project participants, or identifying barriers to alternative land uses. Apply at least one of the following:

- *Generally:* by demonstrating that similar lands in the vicinity are not, and are not planned to be, used for the alternative land uses. Show that apparent financial and/or other barriers, which prevent the plausible alternative land uses, can be identified;
- *Specifically for establishment of forest on the land within the project boundary performed without being registered as the A/R CDM project activity or agriculture as an alternative land use:* apply an approach equivalent to that used in Step 2 (investment analysis) or Step 3 (barrier analysis) of the "*Tool for the demonstration and assessment of additionality*", to demonstrate that these land uses, in the absence of the CDM incentives, are unlikely; i.e. prevented by verifiable barriers or are financially non-viable.

To ensure transparency all information used in the analysis shall be verifiable, archived, and listed in the CDM-AR-PDD.

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

[4] 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.

CDM Executive Board[5]. In the application of the tool, project participant shall include the baseline scenario as identified in Step 4 Section II.4.

6. Estimation of the baseline net GHG removals by sinks

The baseline is determined ex ante, 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 underestimation 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 trees or with tree biomass in a steady state, the sum of carbon stock changes in aboveground and belowground tree and non-tree biomass, deadwood and litter pools is conservatively set to zero, based on the applicability conditions of the methodology, which require lands to be afforested or reforested to be degraded, and to exclude areas with natural encroachment of trees;
- For those strata with growing trees, the sum of carbon stock changes in aboveground and belowground 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). Carbon changes in non-tree biomass are zero under applicability conditions of this methodology.

(b) Summing the baseline net GHG removals by sinks across all strata over the entire project area.

The baseline net GHG removals by sinks for each stratum are calculated as:

$$C_{BSL,i,t} = \sum_{j=1}^{S_{BL}} (\Delta C_{ij,BSL,t} + \Delta C_{DW,BSL,ij,t} + \Delta C_{LI,BSL,ij,t}) \quad \textbf{(B.1)}$$

where:

$C_{BSL,i,t}$	Sum of the changes in carbon stocks in the baseline for year t; t CO_2-e yr^{-1})
$\Delta C_{ij,BSL,t}$	Baseline average annual carbon stock change due to biomass growth of living trees of species j in stratum i for year t; t CO_2-e yr^{-1}
$\Delta C_{DW,BSL,ij,t}$	Baseline annual carbon stock change in the deadwood carbon pool of species j in stratum i, for year t; t CO_2-e yr^{-1}
$\Delta C_{LI,BSL,ij,t}$	Baseline annual carbon stock change in the litter carbon pool of species j in stratum i, for year t; t CO_2-e yr^{-1}
i	$1, 2, 3, \ldots M_{BL}$ strata in the baseline
j	$1, 2, 3, \ldots S_{BL}$ baseline tree species
t	$1, 2, 3, \ldots t$ years elapsed since the start of the A/R CDM project activity

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

For those strata without trees or with trees with biomass at steady-state:

$\Delta C_{ij,\,BSL,t} + \Delta C_{DW,BSL,ij,t} + \Delta C_{LI,BSL,ij,t} = 0.$

For those strata with growing trees, $\Delta C_{ij,BSL,t}$ is estimated using one of following two methods, chosen based on the availability of data.

(a) Method 1 (carbon gain-loss method)[6]

The carbon gain-loss in tree biomass in each stratum may be calculated as:

$$\Delta C_{ij,BSL,t} = (\Delta C_{G,ij,t} - \Delta C_{L,ij,t}) \quad \textbf{(B.2)}$$

where:

$\Delta C_{ij,BSL,t}$	Baseline annual carbon stock change due to biomass growth of living trees of species j in stratum i, for year *t*; t CO_2-e yr^{-1}
$\Delta C_{G,ij,t}$	Annual increase in carbon due to biomass growth of living trees of species j in stratum i, for year *t*; t CO_2-e yr^{-1}
$\Delta C_{L,ij,t}$	Annual decrease in carbon due to biomass loss of living trees for stratum *i*, species , *j,* for year *t*; t CO_2-e yr^{-1}
i	Index for strata
j	Index for species
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

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

$$\Delta C_{G,ij,t} = A_i * G_{TOTAL,ij,t} * CF_j * 44/12 \quad \textbf{(B.3)}$$

where:

$\Delta C_{G,ij,t}$	Annual increase in carbon due to biomass growth of living trees of species *j* in stratum *i,* for year *t*; t CO_2–e yr^{-1}
A_i	Area of stratum *i*; ha
$G_{TOTAL,ij,t}$	Annual increment of total dry biomass of living trees of species *j* in stratum *i,* for year *t*; t d.m. ha^{-1} yr^{-1}
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
i	Index for strata
j	Index for species
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

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

and:

$$G_{TOTAL,ij,t} = G_{w,ij,t} * (1+ R1_j) \quad \textbf{(B.4)}$$

$$G_{w,ij,t} = I_{V,ij,t} * D_j * BEF_{1,j} \quad \textbf{(B.5)}$$

where:

$G_{TOTAL,ij,t}$	Annual increment of total dry biomass of living trees of species j in stratum i, for year *t*; t d.m. ha^{-1} yr^{-1}
$G_{w,ij,t}$	Average annual aboveground dry biomass increment of living trees of species j in stratum i, for year *t*; t d.m. ha^{-1} yr^{-1}
$R1_j$	Root-shoot ratio appropriate for biomass increment for species *j*; dimensionless
$I_{V,ij,t}$	Average annual increment in merchantable volume of species j in stratum i, for year *t*; m^3 ha^{-1} yr^{-1}
D_j	Basic wood density for species *j*; t d.m. m^{-3}
$BEF_{1,j}$	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total aboveground tree biomass increment for species *j;* dimensionless
i	Index for strata
j	Index for species
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

The carbon gain-loss in the deadwood and litter pools in each stratum is calculated only for areas with trees. This is because biomass in non-tree woody vegetation is assumed, under an applicability condition for this methodology to be at steady state or declining. As such, removals in the dead organic matter pools for non-tree woody vegetation can be assumed to be zero. For trees, carbon gain-loss in the dead organic matter pools can be written as:

$$\Delta C_{DW,\ BSL,ij,\ t} = (\Delta C_{G,DW,ij,t} - \Delta C_{L,DW,ij,t}) \quad \textbf{(B.6)}$$

$$\Delta C_{LI,\ BSL,ij,\ t} = (\Delta C_{G,LI,ij,t} - \Delta C_{L,LI,ij,t}) \quad \textbf{(B.7)}$$

where:

$\Delta C_{DW,BSL,\ ij,t}$	Baseline annual carbon stock change in the deadwood carbon pool for species *j* in stratum *i*, for year *t*; t CO_2-e ha^{-1} yr^{-1}
$\Delta C_{G,DW,ij,t}$	Annual input of carbon stock to the deadwood pool for species *j* in stratum *i*, for year *t*; t CO_2-e ha^{-1} yr^{-1}
$\Delta C_{L,DW,ij,t}$	Annual loss of carbon stock in the deadwood pool for species *j* in stratum *i*, for year *t*; t CO_2-e ha^{-1} yr^{-1}
$\Delta C_{LI,BSL,\ ij,t}$	Baseline annual carbon stock change in the litter carbon pool for species *j* in stratum *i*, for year *t*; t CO_2-e ha^{-1} yr^{-1}
$\Delta C_{G,LI,ij,t}$	Annual input of carbon stock to the litter pool for species *j* in stratum *i*, for year *t*; t

	CO_2-e ha^{-1} yr^{-1}
$\Delta C_{L,LI,ij,t}$	Annual loss of carbon stock in the litter pool for species *j* in stratum *i*, for year *t*; t CO_2-e ha^{-1} yr^{-1}
i	Index for strata
j	Index for species
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

The terms in parenthesis in equations (B.6) and (B.7) above are the annual net changes in the deadwood and litter pools, respectively. It is conservatively assumed that there is no harvest of deadwood or litter for fuelwood, and so both the deadwood and litter pools will slowly gain biomass until a steady state is reached. The annual net change can then be estimated from values of the steady-state deadwood and litter biomass stocks, divided by the period required to attain such stocks. That is:

$$\Delta C_{DW,BSL,ij,t} = (B_{DW,S,\ ij} / T_S) * CF * 44/12 \quad \textbf{(B.8)}$$

$$\Delta C_{LI,BSL,ij,t} = (B_{LI,S,\ ij} / T_S) * CF * 44/12 \quad \textbf{(B.9)}$$

where:

$\Delta C_{DW,BSL,ij,t}$	Baseline annual carbon stock change due to biomass increment in the deadwood pool for species *j* in stratum *i,* for year *t*; t CO_2-e ha^{-1} yr^{-1}
$B_{DW,S,ij}$	Steady-state biomass stock in the deadwood pool for species *j* in stratum *i*; t d.m. ha^{-1}
T_S	Time taken for the deadwood or litter biomass pools to reach a steady state (IPCC default: 20 years); yrs
CF	Average carbon fraction of dead wood or litter biomass (IPCC default 0.5); t C (t d.m.)$^{-1}$
$\Delta C_{LI,BSL,ij,t}$	Baseline annual carbon stock change due to biomass increment in the litter pool for species *j* in stratum *i,* for year *t*; t CO_2-e ha^{-1} yr^{-1}
$B_{LI,S,ij}$	Steady-state biomass stock in the litter pool for species *j* in stratum *i*; t d.m. ha^{-1}
i	Index for strata
j	Index for species
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Data for $B_{DW,S\ ij}$, $B_{LI,S\ ij}$, and T_S can be obtained from regional or national inventory, or peer-reviewed publications or official reports relevant to the project area, or IPCC default data in Tables 3.2.1 and 3.2.2 of the GPG-LULUCF, unless the project specific data are available. The IPCC default for T_S is 20 years.

Note that data from regional or national inventory, or from IPCC literature, will likely be data for fully-stocked stands, whereas the situation here is that of trees in the baseline scenario that cover a relatively small fraction of the stratum. To account for this, values for $B_{DW,S,ij}$ and $B_{LI,S,ij}$ from fully stocked stands should be reduced by multiplying by a factor equal to the fractional crown cover of baseline trees in each stratum (and for species in the stratum, if applicable). Conservative estimates of the above factor as based in project specific data, including expert judgement are also appropriate.

(b) Method 2 (stock change method)[7]

For stock changes in trees:

$$\Delta C_{ij,BSL,t} = (C_{ij,t2} - C_{ij,t1}) / T * 44/12 \quad \textbf{(B.10)}$$

$$C_{ij,t} = C_{AB\_tree,ij,t} + C_{BB\_tree,ij,t} \quad \textbf{(B.11)}$$

$$C_{AB\_tree,ij,t} = A_i * V_{tree,ij,t} * D_j * BEF_{2,j} * CF_j \quad \textbf{(B.12)}$$

$$C_{BB\_tree,ij,t} = C_{AB\_tree,ij,t} * R_j \quad \textbf{(B.13)}$$

where:

$\Delta C_{ij,BSL,t}$	Baseline annual carbon stock change due to biomass growth of living trees of species j in stratum i, for year *t*; t CO_2-e yr^{-1}
$C_{ij,t2}$	Total carbon stock in living biomass of trees of species *j* in stratum *i*, calculated at time t2; t C
$C_{ij,t1}$	Total carbon stock in living biomass of trees of species *j* in stratum *i*, calculated at time t1; t C
T	Number of years between times 2 and 1; yrs
44/12	Ratio of molecular weights of CO_2 and carbon; dimensionless
$C_{AB\_tree,ij,t}$	Carbon stock in aboveground tree biomass of species *j* in stratum *i*, at time *t*; t C
$C_{BB\_tree,ij,t}$	Carbon stock in belowground tree biomass of species *j* in stratum *i*, at time *t*; t C
A_i	Area of stratum *i*; ha
$V_{tree,ij,t}$	Merchantable volume of stratum *i*, species *j*, at time *t*; m^3 ha^{-1}
D_j	Basic wood density for species *j*; t d.m. m^{-3}
$BEF_{2,j}$	Biomass expansion factor for conversion of merchantable volume to aboveground 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_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless
i	Index for strata
j	Index for species
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Time points 1 and 2, for which the stocks are estimated to determine ΔC_{ij} must be broadly representative of the typical age of the trees under the baseline scenario during the crediting period.

[7] GPG-LULUCF Equation 3.2.3

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

$$C_{AB\_tree,ij,t} = \sum_{l=1}^{N_{ij}} f_j(DBH_{ij,l,t}, H_{ij,l,t}) * CF_j * 0.001 \qquad \textbf{(B.14)}$$

where:

$C_{AB\_tree,ij,t}$	Carbon stock in aboveground tree biomass of species j in stratum i; t C
$f_j(DBH,H)$	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly tree height (*H*) to aboveground biomass of living trees; kg d.m.tree
CF_j	Carbon fraction of dry matter for species or type *j*; t C (t d.m.)$^{-1}$
N_{ij}	Number of trees of species *j* in stratum *i*; dimensionless
l	Sequence number of tree of species *j* in stratum *i*; dimensionless
0.001	Conversion factor from kilogram to tonne (1 t = 10^3 kg)
i	Index for strata
j	Index for species

The estimate of the carbon stock change in the baseline deadwood and litter pools is obtained directly from equations (B.8) and (B.9), respectively.

For the choice of methods 1 or 2 above, there is no priority in terms of transparency and conservativeness. The choice should mainly depend on the availability of parameters. V_{ij} and $I_{v,ij}$ shall be estimated on the basis of the number of trees and national/local growth curve/table that usually can be obtained from national/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.

Parameters D_j, $BEF_{1,j}$, $BEF_{2,j}$, CF_j, $R1_j$ and R_j shall be chosen from data sources 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 (that is, with similar shape/form, and from the same species family,e.g., evergreen coniferous, or deciduous broadleaved) can be used, with the data source priority as listed for species-specific information. If ranges of values for BEF, $R1_j$, R_j and D_2 are available, the values used for the estimation of baseline removals should be chosen in a way resulting in a conservative estimate of baseline annual carbon stock change due to biomass growth of living trees. Note that trees under the baseline scenario are trees outside of a forest, and BEFs for such isolated trees are generally higher than for forest trees. If BEF_2 for trees outside forests are unavailable then, to be conservative, the BEF_2 applicable to forest trees shall be enlarged by 30% in order to approximate the BEF_2 for such isolated trees.

Table C: **Data needed for ex ante estimation**

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
A_i	ha	Area of stratum *i*		Project design and stratification
$B_{DW,S,ij}$	t d.m. ha^{-1}	Steady-state biomass stock in the deadwood pool for species *j* in stratum *i*		Regional or national inventory, or peer-reviewed publications or official reports relevant to the project area, or IPCC default data
$B_{LI,S,ij}$	t d.m. ha^{-1}	Steady-state biomass stock in the litter pool for species *j* in stratum *i*		Regional or national inventory, or peer-reviewed publications or official reports relevant to the project area, or IPCC default data
$BEF_{1,j}$	Dimensionless	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total aboveground tree biomass increment for species *j*;		IPCC default, national inventory, literature
$BEF_{2,j}$	Dimensionless	Biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j*;		IPCC Guidelines, IPCC GPG- LULUCF, national inventory, local survey, literature
CF	t C (t d.m.)$^{-1}$	Average carbon fraction of dead wood or litter biomass (IPCC default 0.5)		IPCC default, national inventory, literature
CF_j	t C (t d.m.)$^{-1}$	Carbon fraction of dry matter for species *j* or species group type *j*		IPCC default, national inventory, literature
D_j	t. d.m. m^{-3}	Basic wood density for species *j* or species group type *j*;		Most updated GPG-LULUCF, IPCC 2006 Guidelines, national GHG inventory, local survey

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$f_j(DBH,H)$	kg d.m. tree^{-1}	Allometric equation for species j linking diameter at breast height (*DBH*) and possibly tree height (*H*) to aboveground biomass of living trees	Most updated	National GHG inventory, literature, IPCC, local data
$I_{V,ij,t}$	m^3 ha^{-1} yr^{-1}	Average annual increment in merchantable volume of species j in stratum i, for year *t*		IPCC default, national inventory, local data, literature
N_{ij}	Dimensionless	Number of trees of species *j* in stratum *i*		Sampling survey
R_j	Dimensionless	Root-shoot ratio appropriate for biomass stock, for species *j*	Most updated	National GHG inventory, literature, IPCC, local data
$R1_j$	Dimensionless	Root-shoot ratio appropriate to increments for species *j*	Most updated	National GHG inventory, literature, IPCC, local data
T_S	yrs	Time taken for the deadwood or litter biomass pools to reach a steady state (IPCC default: 20 years)		Regional or national inventory, or peer-reviewed publications or official reports relevant to the project area, or IPCC default data
$V_{tree,ij,t}$	m^3 ha^{-1}	Merchantable volume of stratum *i*, species *j*, at time *t*		Estimated based on national or local yield table or growth curve

7. Ex ante actual net GHG removals by sinks

In choosing key parameters and making critical 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 overestimation of actual net GHG removals by sinks should be applied.

Verifiable changes in carbon stocks in the carbon pools

The estimation of average annual carbon stock change in aboveground woody biomass, belowground woody biomass, deadwood and litter pools between two monitoring events shall be performed on the lowest level of stratification and summed accordingly over the entire project area.

$$\Delta C_t = \sum_{i=1}^{M_{PS}} (\Delta C_{DW,i,t} + \Delta C_{LI,i,t} + \Delta C_{AB,i,t} + \Delta C_{BB,i,t}) * 44/12) \quad \textbf{(B.15)}$$

where:

ΔC_t	Total changes in carbon stock in carbon pools for year t; t CO_2-e yr^{-1}
$\Delta C_{AB\ i,t}$	Changes in carbon stock in aboveground biomass of trees and permanent non-tree vegetation for stratum *i,* for year *t*; t C yr^{-1}
$\Delta C_{BB,i,t}$	Changes in carbon stock in belowground biomass of trees and permanent non-tree vegetation for stratum *i,* for year *t*; t C yr^{-1}
$\Delta C_{DW,i,t}$	Annual carbon stock change in the deadwood carbon pool for stratum *i*, for year *t*; t C yr^{-1}
$\Delta C_{LI,i,t}$	Annual carbon stock change in the litter carbon pool for stratum *i*, for year *t*; t C yr^{-1}
44/12	Ratio of molecular weights of CO_2 and carbon; t CO_2 t^{-1} C
i	1, 2, 3, … M_{PS} strata in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

a.1 Calculation of average annual carbon stock change biomass of living trees and permanent non-tree vegetation[8]

$$\Delta C_{AB,i,t} = (C_{AB,i,t2} - C_{AB,i,t1})/ T \quad \textbf{(B.16)}$$

$$\Delta C_{BB,i,t} = (C_{BB,i,t2} - C_{BB,i,t1})/ T \quad \textbf{(B.17)}$$

$$C_{AB,i,t} = C_{AB\_tree,i,t} + C_{AB\_pnon\text{-}tree,i,t} \quad \textbf{(B.18)}$$

$$C_{BB,i,t} = C_{BB\_tree,i,t} + C_{BB\_pnon\text{-}tree,i,t} \quad \textbf{(B.19)}$$

where:

$\Delta C_{AB,i,t}$	Average annual changes in carbon stock in aboveground biomass of trees and permanent non-tree vegetation for stratum *i,* for year t; *t* C yr^{-1}
$\Delta C_{BB,i,t}$	Average annual changes in carbon stock in belowground biomass of trees and permanent non-tree vegetation for stratum *i,* for year *t*; t C yr^{-1}
$C_{AB,i,t2}$	Carbon stock in aboveground biomass of trees and permanent non-tree vegetation for stratum *i*, calculated at time t2; t C
$C_{AB,i,t1}$	Carbon stock in aboveground biomass of trees and permanent non-tree vegetation for stratum *i*, calculated at time t1; t C
$C_{BB,i,t2}$	Carbon stock in belowground biomass of trees and permanent non-tree vegetation for stratum *i*, calculated at time t2; t C
$C_{BB,i,t1}$	Carbon stock in belowground biomass of trees and permanent non-tree vegetation for stratum *i*, calculated at time t1; t C

[8] Refers to equation 3.2.3 in GPG-LULUCF

$C_{AB\_tree,i,t}$	Carbon stock in aboveground biomass of trees for stratum *i,* at time *t*; t C
$C_{AB\_pnon\text{-}tree,i,t}$	Carbon stock in aboveground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*; t C
$C_{BB\_tree,i,t}$	Carbon stock in belowground biomass of trees for stratum *i,* at time *t*; t C
$C_{BB\_pnon\text{-}tree,i,t}$	Carbon stock in belowground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*; t C
T	Number of years between time t2 and t1; yr
i	Index for strata
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

a.1.1 Planted trees

The biomass expansion factors (BEF) method is used to estimate the carbon stock in aboveground and belowground biomass of living trees[9] that were planted within the A/R CDM project (pre-project existing trees shall not be included in the estimations):

$$C_{AB\_tree,i,t} = \sum_{j=1}^{S_{PS}} C_{AB\_tree,ij,t} \quad \textbf{(B.20)}$$

$$C_{AB\_tree,ij,t} = A_i * V_{tree,ij,t} * D_j * BEF_{2,j} * CF_j \quad \textbf{(B.21)}$$

$$C_{BB\_tree,ij,t} = C_{AB\_tree,ij,t} * R_j \quad \textbf{(B.22)}$$

$$C_{BB\_tree,i,t} = \sum_{j=1}^{S_{PS}} C_{BB\_tree,ij,t} \quad \textbf{(B.23)}$$

where

$C_{AB\_tree,i,t}$	Carbon stock in aboveground biomass of trees for stratum *i,* at time *t*; t C
$C_{BB\_tree,i,t}$	Carbon stock in belowground biomass of trees for stratum *i,* at time *t*; t C
$C_{AB\_tree,ij,t}$	Carbon stock in aboveground biomass of tree species *j* in stratum *i,* at time *t*; t C
$C_{BB\_tree,ij,t}$	Carbon stock in belowground biomass of trees species j in stratum *i,* at time *t*; t C
A_i	Area of stratum *i*; ha
$V_{tree\_ij,t}$	Mean merchantable/standing volume for stratum *i*, and species *j* at time *t*; m^3 ha^{-1}
D_j	Basic wood density for species *j*; t d.m. m^{-3}
$BEF_{2,j}$	Biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j*; dimensionless

[9] GPG-LULUCF Equation 3.2.3

CF_j	Carbon fraction of dry matter for species or type *j* ; t C (t d.m.)$^{-1}$
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; ; dimensionless
i	Index for strata
j	*1, 2, 3, …* S_{PS} tree species in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

a.1.2 Planted permanent non-tree vegetation[10]

$$C_{AB\_pnon-tree,ij,t} = \sum_{l_{pnon-tree}=1}^{N_{pnon-tree,ij}} f_j(DB_{i,l_{pnon-tree},t}, H_{i,l_{pnon-tree},t}, CA_{i,l_{pnon-tree},t}) * CF_p \quad \textbf{(B.24)}$$

$$C_{BB\_pnon-tree,ij,t} = C_{AB\_pnon-tree,ij,t} * R_{p,j} \quad \textbf{(B.25)}$$

$$C_{AB\_pnon-tree,i,t} = \sum_{j=1}^{S_{PS}} C_{AB\_pnon-tree,ij,t} \quad \textbf{(B.26)}$$

$$C_{BB\_pnon-tree,i,t} = \sum_{j=1}^{S_{PS}} C_{BB\_pnon-tree,ij,t} \quad \textbf{(B.27)}$$

where:

$C_{AB\_pnon-tree,ij,t}$	Carbon stock in aboveground biomass of permanent non-tree vegetation of species *j* in stratum *i*, at time t; t C
$C_{BB\_pnon-tree,ij,t}$	Carbon stock in belowground biomass of permanent non-tree vegetation of species *j* in stratum *i*, at time t; t C
CF_p	Carbon fraction of permanent non-tree vegetation; t C (t d.m.)$^{-1}$
$N_{pnon-tree,ij}$	Number of shrubs or permanent non-tree vegetation of species *j* in stratum *i*; dimensionless
$l_{pnon-tree}$	Sequence number of permanent non-tree vegetation for species *j* in stratum *i*; dimensionless
$R_{p,j}$	Root-shoot ratio of permanent non-tree vegetation species *j*; dimensionless
f(DB, H, CA)	An allometric equation linking aboveground biomass of shrubs or permanent non-tree vegetation to one or more of the variables diameter at base (*DB*), shrub height (*H*) and crown area/diameter (*CA*); t d.m. tree^{-1}

[10] For this methodology, permanent non-tree vegetation includes perennial crops–such as cocoa, coffee, oil palm, coconut, bananas–and woody vegetation (shrubs) that falls below the thresholds to be considered trees, and is not expected to exceed those thresholds at a later time.

$C_{AB\_pnon\text{-}tree,i,t}$ Carbon stock in aboveground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*; t C

$C_{BB\_pnon\text{-}tree,i,t}$ Carbon stock in belowground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*; t C

i Index for strata

j *1, 2, 3, …* S_{PS} species in the project scenario

t *1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

The changes of diameter at base (*DB*), shrub height (*H*), crown area/diameter (*CA*) and number of stems (*NS*) due to forage harvest and regrowth within each harvest cycle may be obtained from literature, or local yield tables for planted permanent non-tree vegetation, or surveys on similar permanent non-tree vegetation.

If there are no allometric equations available, or it is impossible to estimate the biomass of planted permanent non-tree vegetation, the carbon stock change in living biomass of planted permanent non-tree vegetation may be conservatively assumed to be zero.

a.2. Changes in deadwood carbon stock

There are several options for estimating changes in the deadwood carbon stock for the purpose of ex ante estimation:

(i) As a conservative assumption, or if fuelwood gathering is expected, it can be assumed than changes are zero; or

(ii) If there is no fuelwood gathering, a simple approach to estimation is to use the approach based on default data given in Section 6 above. If that approach is used, the value for T_S to be used in equation B.8) shall be the longer of either 20 years (the IPCC default), or a value justified from regional or national inventory, or the duration of the project—whichever is the longer; or

(iii) Change in deadwood pool $\Delta C_{DW,ij,t}$ is estimated using one of following two methods that can be chosen based on the availability of data.

Method 1 (Carbon gain-loss method)

$$\Delta C_{DW,i,t} = \sum_{j=1}^{S_{PS}} \Delta C_{DW,ij,t} \qquad \textbf{(B.28)}$$

$$\Delta C_{DW,ij,t} = \Delta C_{DW\_mlb,ij,t} + \Delta C_{DW\_hr,ij,t} - \Delta C_{DW\_fw,ij,t} - \Delta C_{DW\_desc,ij,t} \qquad \textbf{(B.29)}$$

where:

$\Delta C_{DW,i,t}$ Annual carbon stock change in the deadwood carbon pool for stratum *i*, for year *t*; t C yr^{-1}

$\Delta C_{DW,ij,t}$ Annual carbon stock change in the deadwood carbon pool of species j in stratum i, time *t*; t C yr^{-1}

$\Delta C_{DW\_mlb,ij,t}$	Annual increase of carbon stock in the deadwood carbon pool due to mortality of the living biomass of trees of species j in stratum i, time *t*; t C yr^{-1}
$\Delta C_{DW\_hr,ij,t}$	Annual increase of carbon stock in the deadwood carbon pool due to harvesting residues not collected of species j in stratum i, time *t*; t C yr^{-1}
$\Delta C_{DW\_fw,ij,t}$	Annual decrease of carbon stock in the deadwood carbon pool due to harvesting of deadwood of species j in stratum i, time *t*; t C yr^{-1}
$\Delta C_{DW\_desc,ij,t}$	Annual decrease of carbon stock in the deadwood carbon pool due to deadwood decomposition of species j in stratum i, time *t*; t C yr^{-1}
i	Index for strata
j	*1, 2, 3, …* S_{PS} species in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

The following equations shall be used:

$$\Delta C_{DW\_mlb,ij,t} = V_{ij,t} * Mf_{ij,t} * Dw_j * BEF_{2,j} * CF * A_i \quad \textbf{(B.30)}$$

$$\Delta C_{DW\_hr,ij,t} = H_{ij,t} * Hf_{ij,t} * Dw_j * BEF_{2,j} * CF * A_i \quad \textbf{(B.31)}$$

$$\Delta C_{DW\_fw,ij,t} = Fwf_{ij,t} * \Delta C_{DW,ij,t-1} \quad \textbf{(B.32)}$$

$$\Delta C_{DW\_desc,ij,t} = DC * \Delta C_{DW,ij,t-1} \quad \textbf{(B.33)}$$

$$\Delta C_{DW,\ ij,\ t=0} = 0 \quad \textbf{(B.34)}$$

where:

$\Delta C_{DW\_mlb,ij,t}$	Annual increase of carbon stock in the deadwood carbon pool due to mortality of the living biomass of trees of species j in stratum i, time *t*; t C yr^{-1}
$V_{ij,t}$	Mean merchantable volume of stratum *i*, species *j*, at time *t*; m^3 ha^{-1}
$Mf_{ij,t}$	Mortality factor, i.e., the fraction of $V_{ij,t}$ dying at time *t*; dimensionless
Dw_j	Intermediate[11] deadwood density for species *j*; t d.m. m^{-3} merchantable volume
$BEF_{2,j}$	Biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j*; dimensionless
CF	Average carbon fraction of dead wood or litter biomass (IPCC default 0.5); t C (t d.m.)$^{-1}$

[11] Each deadwood piece should be assigned to one of three density states – sound, intermediate, and rotten (Warren, W.G. and Olsen, P.F. 1964. A line transects technique for assessing logging waste. *Forest Science* 10:267-276). In absence of ex-ante data, intermediate densities should be assumed.

A_i	Area of stratum *i*; ha
$H_{ij,t}$	Average annually harvested merchantable volume of species j in stratum i, time *t*; m^3 ha^{-1} yr^{-1}
$\Delta C_{DW\_hr,ij,t}$	Annual increase of carbon stock in the deadwood carbon pool due to harvesting residues not collected of species j in stratum i, time *t*; t CO_2-e yr^{-1}
$Hf_{ij,t}$	Fraction of annually harvested merchantable volume not extracted and left on the ground as harvesting residue of species j in stratum i, time *t*; dimensionless
$\Delta C_{DW\_fw,ij,t}$	Annual decrease of carbon stock in the deadwood carbon pool due to harvesting of deadwood of species j in stratum i, time *t*; t CO_2-e yr^{-1}
$Fwf_{ij,t}$	Fraction of annually harvested deadwood carbon stock harvested as fuel wood of species j in stratum i, time *t*; dimensionless
$C_{DW,ij,t1}$	Carbon stock in the deadwood carbon pool in stratum *i*, species *j*, time t_1 (*t* minus 1 year); t C
$\Delta C_{DW\_desc,ij,t}$	Annual decrease of carbon stock in the deadwood carbon pool due to deadwood decomposition of species j in stratum i, time *t*; t CO_2-e yr^{-1}
DC	Decomposition rate (% carbon stock in total deadwood stock decomposed annually); dimensionless
44/12	Ratio of molecular weights of CO_2 and C; dimensionless
i	Index for strata
j	*1, 2, 3, …* S_{PS} species in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Project proponents shall make conservative estimates of the parameters used in Equations B.29 to B.32.

Method 2 (stock change method)

$$\Delta C_{DW,i,t} = \sum_{j=1}^{S_{PS}} \Delta C_{DW,ij,t} \quad \textbf{(B.35)}$$

$$\Delta C_{DW,ij,t} = (C_{DW,\,ij,t2} - C_{DW,\,ij,t1})/T \quad \textbf{(B.36)}$$

where:

$\Delta C_{DW,i,t}$	Annual carbon stock change in the deadwood carbon pool for stratum *i*, for year *t*; t C yr^{-1}
$\Delta C_{DW,ij,t}$	Annual carbon stock change in the deadwood carbon pool of species j in stratum i, time *t*; t C yr^{-1}
$C_{DW,ij,t2}$	Total carbon stock in deadwood of species j in stratum i, calculated at time t_2; t C
$C_{DW,ij,t1}$	Total carbon stock in deadwood of species j in stratum i, calculated at time t_1; t C
T	Number of years between times t_2 and t_1 ($T = t_2 - t_1$); yr

i	Index for strata
j	*1, 2, 3, …* S_{PS} species in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

If there are no data adequate to support *ex ante* estimation of changes in the deadwood carbon stock then the changes may be conservatively assumed to be zero.

a.3. Changes in litter carbon stocks

There are several options for estimating changes in the litter carbon stock for ex ante estimation:

(i) As a conservative assumption, or if fuelwood gathering is expected, it can be assumed than changes are zero; or

(ii) If there is no fuelwood gathering, or it is restricted to the deadwood pool only, a simple approach to estimation of the change in the litter pool is to use the approach based on default data given in Section 6 above. If that approach is used, the value for T_S to be used in equation B.9 shall be the longer of either 20 years (the IPCC default), or a value justified from regional or national inventory, or the duration of the project - whichever is the longer; or

(iii) Changes in litter[12] carbon stocks $\Delta C_{LI,\,ij,t}$ are estimated using one of following two methods that can be chosen based on the availability of data.

Method 1 (Carbon gain-loss method)

$$\Delta C_{LI,i,t} = \sum_{j=1}^{Sps} \Delta C_{LI,ij,t} \qquad \textbf{(B.37)}$$

$$\Delta C_{LI,ij,t} = \Delta C_{LI\_mlb,ij,t} + \Delta C_{LI\_hr,ij,t} - \Delta C_{LI\_fw,ij,t} - \Delta C_{LI\_desc,ij,t} \qquad \textbf{(B.38)}$$

where:

$\Delta C_{LI,i,t}$	Annual carbon stock change in the litter carbon pool for stratum *i*, for year *t*; t C yr^{-1}
$\Delta C_{LI,ij,t}$	Annual carbon stock change in the litter carbon pool of species j in stratum i, time *t*; t C yr^{-1}
$\Delta C_{LI\_mlb,ij,t}$	Annual increase of carbon stock in the litter carbon pool due to mortality of the living biomass of trees of species j in stratum i, time *t*; t C yr^{-1}
$\Delta C_{LI\_hr,ij,t}$	Annual increase of carbon stock in the litter carbon pool due to harvesting residues not collected of species j in stratum i, time *t*; t C yr
$\Delta C_{LI\_fw,ij,t}$	Annual decrease of carbon stock in the litter carbon pool due to harvesting of litter of species j in stratum i, time *t*; t C yr^{-1}

[12] Litter includes all non-living biomass with a diameter less than a minimum diameter chosen by the country, in various states of decomposition, above the mineral or organic soil. Refer to Table 3.1.2 in GPG LULUCF.

$\Delta C_{LI\_desc,ij,t}$	Annual decrease of carbon stock in the litter carbon pool due to litter decomposition of species j in stratum i, time *t*; t C yr^{-1}
i	Index for strata
j	*1, 2, 3, … S_{PS}* species in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Method 2 (stock change method)

$$\Delta C_{LI,i,t} = \sum_{j=1}^{S_{PS}} \Delta C_{LI,ij,t} \quad \textbf{(B.39)}$$

$$\Delta C_{LI,ij,t} = (C_{LI,ij,t2} - C_{LI,ij,t1})/T \quad \textbf{(B.40)}$$

where:

$\Delta C_{LI\ i,t}$	Annual carbon stock change in the litter carbon pool for stratum *i*, for year *t*; t C yr^{-1}
$\Delta C_{LI,ij,t}$	Annual carbon stock change in the litter carbon pool of species j in stratum i, time *t*; t C yr^{-1}
$C_{LI,ij,t2}$	Total carbon stock in litter of species j in stratum i, calculated at time t_2; t C
$C_{LI,ij,t1}$	Total carbon stock in litter of species j in stratum i, calculated at time t_1; t C
T	Number of years between times t_2 and t_1 $(T = t_2 - t_1)$; yr
i	Index for strata
j	*1, 2, 3, … S_{PS}* species in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

If there are no data adequate to support *ex ante* estimation of changes in the litter carbon stock then the changes may be conservatively assumed to be zero.

a.3. Determining parameters and data for estimation of GHG removals by sinks

Data required to estimate *ex ante* GHG removals by sinks may include: above-ground biomass or biomass increment of woody species, and values for such parameters as the carbon fraction (*CF*), root-shoot ratio (*R*), wood density (*D*), and biomass expansion factors (*BEF*s). This information can be obtained by a combination of:

- Destructive harvest of vegetation in sample plots (see Section III.5 for details):
    - Above-ground biomass: destructive harvest within the appropriate strata identified in Section II.2.2, and depicted in Table 1, can be used to determine current and climax above-ground biomass. The maximum age of destructively harvested species in regenerating strata, and minimum age of destructively harvested species in climax strata, should be determined by growth-ring counting to provide a direct and conservative estimate of t_{cv-c}. If shrubs are being harvested, below-ground biomass could also be determined relatively easily, to provide a direct estimate of the root-shoot ratio (for which limited published data exist);

- o Above-ground biomass increment: an average value for this parameter can be calculated from the dry above-ground biomass of woody species divided by the species age (as determined from counting of growth rings from a basal stem section).

- Destructive harvest of individual trees or shrubs (see Section III.5 for details):
  - o Above-ground biomass: allometric equations and/or BEFs can be developed to convert simply measured parameters such as stem diameter and height to above-ground woody biomass. If shrubs are being harvested, below-ground biomass could also be determined relatively easily, to provide a direct estimate of the root-shoot ratio (for which limited published data exist);
  - o Above-ground biomass increment: allometric equations and/or BEFs developed from destructive harvest can be used in repeat measurements to estimate above-ground mean biomass increment. Alternatively, mean increment can be determined from a single biomass estimate if the age of the woody species is known or can be determined from stem core samples, or from counting of growth rings. If shrubs are being harvested, below-ground biomass could also be determined relatively easily, to provide a direct estimate of the root-shoot ratio (for which limited published data exist).

- Making use of data from available studies, chosen with the following priority:

(i) Existing local species-specific data from peer-reviewed studies or official reports; or

(ii) Regional/national species-specific data (e.g., from regional/national forest inventory); or

(iii) Species-specific data from neighbouring countries with similar climatic conditions. In the case of a large country that encompasses very different biome types, option (iii) might be preferable to option (ii) if project conditions differ substantially from those reported in national data; or

(iv) Global species-specific data (e.g., from the GPG-LULUCF).

If making use of existing data, note that:

(a) If species-specific information is not available, information for similar species—that is, with similar shape/form, and from the same species family (e.g., evergreen coniferous, or deciduous broadleaved)—can be used, with the data source priority as listed above for species-specific information.

(b) If using existing growth models to predict biomass, or to predict parameters (e.g., diameter at breast height, height) for use in existing allometric equations, the growth models must be valid for the age(s) of the woody species present in the project area. If using existing yield curves, these must be similarly valid.

(c) Note that trees under the baseline scenario are trees outside of a forest, and BEFs for such isolated trees are generally higher than for forest trees. If there are no data on BEFs of trees outside of a forest, then increasing BEFs of forest species by 30% is considered a conservative default.

(a) Emissions from project activity

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]:

- 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 GHGs from biomass burning during forest fires;
- Direct N_2O emissions caused by nitrogen fertilization application;
- Emissions of GHGs from combustion of fossil fuels for site preparation, thinning and logging;
- An increase in GHG emissions if there are more grazing animals in the project than in the baseline

GHG emissions caused by animals allowed to graze within the project boundary are not attributable to the A/R CDM project activity as long as the main reason for existence of these animals is not the project activity (e.g., animals serving for transportation or wood harvest/collection purposes).

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

$$GHG_E = E_{biomass\ loss} + E_{non-CO2,BiomassBurn} + E_{fertilizer} + E_{FuelBurn} + E_{livestock} \quad \textbf{(B.41)}$$

where:

GHG_E	GHG emissions resulting from implementation of the A/R project activity within the project boundary; t CO_2-e yr^{-1}
$E_{biomass\ loss}$	CO_2 emissions from a decrease in carbon stock in living biomass; t CO_2-e yr^{-1}
$E_{non\text{-}CO2,\ BiomassBurn}$	Non-CO_2 emissions from burning of biomass, if this is to be used; t CO_2-e yr^{-1}
$E_{fertilizer}$	Direct N_2O emissions that result from application of nitrogenous fertilizer; t CO_2-e yr^{-1}
$E_{FuelBurn}$	CO_2 emissions from combustion of fossil fuels; t CO_2-e yr^{-1}
$E_{livestock}$	Increase in GHG emissions due to an increase above baseline levels of the population of livestock in the project area; t CO_2-e yr^{-1}

b.1 Calculation of the decrease in carbon stock in biomass of existing biomass

It is assumed that all non-tree vegetation as well as all deadwood and litter within the project area will be oxidized instantaneously at the start of the project due to site preparation 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 resulting GHG emission shall be accounted only once at the start of the

[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.

project activity. The decrease in the carbon stock in the non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation is calculated as:

$$E_{biomass\ loss} = \sum_{i=1}^{M_{PS}} B_{pre,i} * A_i * CF_{pre} * 44/12 \qquad \textbf{(B.42)}$$

where:

$E_{biomass\ loss}$	Decrease in the carbon stock in the non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation in the year of site preparation; t CO_2-e
A_i	Area of stratum *i*; ha
$B_{pre,i}$	Average pre-existing stock of pre-project biomass in the non-tree living biomass (aboveground and belowground), deadwood and litter carbon pools on land of a proposed A/R CDM project activity for baseline stratum *i*; t d.m. ha^{-1}
CF_{pre}	Mean carbon fraction of dry biomass in pre-existing vegetation; t C $(t\ d.m.)^{-1}$
44/12	Ratio of molecular weights of CO_2 and carbon; t CO_2-e t^{-1} C
i	1, 2, 3, ... M_{PS} strata in the project scenario

b.2 Calculation of emissions from biomass burning

If biomass is burned (e.g. during forest fires) then the CO_2 emissions from aboveground biomass will always be accounted in those sections of the methodology that deal with biomass loss while this section provides an approach for estimation of non-CO_2 emissions from burning of aboveground biomass.

Based on the GPG-LULUCF[14], non-CO_2 emissions from biomass burning can be calculated as:

$$E_{non-CO2,BiomassBurn} = E_{BiomassBurn,N2O} + E_{BiomassBurn,CH4} \qquad \textbf{(B.43)}$$

where:

$E_{non-CO2,BiomassBurn}$	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 burning of biomass; t CO_2-e yr^{-1}

and:

$$E_{BiomassBurn,N2O} = E_{BiomassBurn,C} * \left({}^{N}\!/_{C}\ ratio \right) * ER_{N2O} * {}^{44}\!/_{28} * GWP_{N2O} \qquad \textbf{(B.44)}$$

$$E_{BiomassBurn,CH4} = E_{BiomassBurn,C} * ER_{CH4} * {}^{16}\!/_{12} * GWP_{CH4} \qquad \textbf{(B.45)}$$

[14] Refers to equation 3.2.20 in GPG for LULUCF

where:

$E_{BiomassBurn,C}$ C loss in aboveground biomass due to burning of biomass; t C yr^{-1}

N/C ratio Nitrogen-carbon ratio (IPCC default: 0.01); dimensionless

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 (IPCC default = 310, valid for the first commitment period); kg CO_2-e kg^{-1} N_2O

GWP_{CH4} Global warming potential for CH_4 (IPCC default = 21, valid for the first commitment period); kg CO_2-e kg^{-1} CH_4

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:

$$E_{BiomassBurn,C} = \sum_{i=1}^{M_{PS}} A_{burn,i} * B_{AB,i} * CE * CF_{av} \quad \textbf{(B.46)}$$

where:

$E_{BiomassBurn,C}$ Loss of carbon stock in aboveground biomass during burning; t C yr^{-1}

$A_{burn,\,i}$ Area of stratum *i* subject to burning; ha yr^{-1}

$B_{AB,i}$ Average aboveground biomass before burning for stratum *i*; t d.m. ha^{-1}

CE Average combustion efficiency for aboveground biomass (IPCC default: 0.5); dimensionless

CF_{av} Average carbon fraction of dry biomass in aboveground biomass (IPCC default: 0.5); t C $(t\ d.m)^{-1}$

i *1, 2, 3, …* M_{PS} strata in the project scenario

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.

b.3 Calculation of nitrous oxide emissions from nitrogen fertilization practices

Annual emissions from application of nitrogenous fertiliser within the project boundary, $E_{fertilizer}$, are estimated using the latest version of the following methodological tool approved by the CDM Executive Board: *Estimation of direct nitrous oxide emission from nitrogen fertilisation*[15]

b.4 GHG emissions from burning of fossil fuel

Annual emissions from combustion of fossil fuels within the project boundary for year *t*, $E_{FuelBurn}$ are estimated using the latest version of the following methodological tool approved by the CDM Executive Board: *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*[16]

b.5 Emissions from an increase in livestock population

If the population of grazing animals within the project boundary increases above baseline levels due to project silvopastoral activities, increased GHG emissions due to enteric digestion (as applicable), and manure management, shall be estimated. Estimation is based on IPCC default methodology, using simple emission factors expressed on a per-head livestock basis. As per an applicability condition of this methodology, manure remains in the field, and no manure management or gathering practices are permitted. Under these conditions, the increase in GHG emissions due to an increase in the livestock population above baseline levels is given by (assumed constant with time for *ex ante* estimates):

$$E_{livestock} = \sum_{LT=1}^{n} \left(Pop_{\mathrm{Proj,LT}} - Pop_{\mathrm{BSL,LT}}\right) * \left(\left(EF_{Enteric,\mathrm{CH4,LT}} + EF_{Manure,\mathrm{CH4,LT}}\right) * \mathrm{GWP}_{\mathrm{CH4}} + EF_{Manure,\mathrm{N2O,LT}} * GWP_{\mathrm{N2O}}\right) \quad \textbf{(B.47)}$$

where:

$E_{livestock}$	Increase in annual GHG emissions due to an increase above baseline levels of the population of livestock in the project area; t CO_2-e yr^{-1}
$Pop_{Proj,\ LT}$	Population of livestock type *LT* in the project area; head
$Pop_{BSL,\ T}$	Population of livestock type *LT* in the baseline; head
$EF_{Enteric,\ CH4,L\ T}$	Emission factor for enteric methane production for livestock type *LT*; kg CH_4 $head^{-1}$ yr^{-1}
$EF_{Manure,\ CH4,\ LT}$	Emission factor for methane production from manure for livestock type *LT*; kg CH_4 $head^{-1}$ yr^{-1}
$EF_{Manure,\ N2O,\ LT}$	Emission factor for nitrous oxide production from manure for livestock type *LT*; kg N_2O $head^{-1}$ yr^{-1}
GWP_{CH4}	Global warming potential for CH_4 (IPCC default = 21, valid for the first commitment period); kg CO_2-e kg^{-1} CH_4

[15] CDM Executive Board Meeting Report EB33, Annex 16: *Estimation of direct nitrous oxide emission from nitrogen fertilisation.*

[16] CDM Executive Board Meeting Report EB33, Annex 14: *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities.*

GWP_{N2O}	Global warming potential for N_2O (IPCC default = 310, valid for the first commitment period); kg CO_2-e kg^{-1} N_2O
LT	Livestock type; *1 … n* (dimensionless)

Estimates of $Pop_{BSL,T}$ should be developed by a sampled census in the proposed project area at the start of the project, or from local or regional statistics of livestock density (head ha^{-1}). If this information is not available, the value of $Pop_{BSL,T}$ may be conservatively set to zero. Estimates of $Pop_{Proj,T}$ should be based on the project plan, as recorded in the CDM-AR-PDD, that should include estimates of the number of animals the project is designed to support. If $Pop_{Proj,T} \leq Pop_{BSL,T}$, then $E_{livestock} = 0$.

Emission factors can be obtained from regional or national GHG inventory. Alternatively, IPCC default data may be used for $EF_{Enteric,\ CH4,\ T}$, and $EF_{Manure,\ CH4,\ T}$ —taken from Tables 10.10 and 10.11, and Tables 10.14 and 10.15, respectively of AFOLU (IPCC 2006).

A value for $EF_{Manure,\ N20,\ T}$ can be simply estimated from (based on equations 10.30 and 11.1; AFOLU, IPCC 2006).

$$EF_{Manure,\mathrm{N2O,T}} = N_{\mathrm{rate(T)}} * \frac{TAM_{\mathrm{LT}}}{1000} * 365 * EF_{3,\mathrm{T}} \quad \textbf{(B.48)}$$

where:

$EF_{Manure,\ N2O,\ LT}$	Emission factor for enteric methane production for livestock type L*T*; kg N_2O $head^{-1}$ yr^{-1}
$N_{rate(LT)}$	Excretion rate for livestock type *LT*; kg N (1000 kg animal mass)$^{-1}$ day^{-1}
TAM_{LT}	Typical animal mass for livestock type *LT*; kg $head^{-1}$
$EF_{3,\ LT}$	Emission factor for N_2O emissions from dung and urine deposited on pasture; kg N_2O-N (kg N input)$^{-1}$. IPCC default: 0.02 for cattle (dairy, non-dairy, buffalo and pigs), and 0.01 for all other animals (Table 11.1; AFOLU, IPCC 2006.
1000	Conversion factor: kg to tonnes
365	Conversion factor: days to years

Default values for $N_{rate(LT)}$ can be obtained from Table 10.19 (AFOLU, IPCC 2006), and together with project-based estimates of TAM_{LT} and IPCC default values for EF_{3LT}, used to calculate $EF_{Manure,\ N2O,\ LT}$.

(b) Actual Net GHG removals by sinks

The actual net GHG removals by sinks of the project activity are calculated as the difference between changes in carbon stocks of the different pools and the emissions by sources:

$$C_{ACTUAL,t} = \Delta C_t - GHG_E \quad \textbf{(B.49)}$$

where:

$C_{ACTUAL,t}$	Actual Net GHG removals by sinks of the project activity in year *t;* t CO_2-e

ΔC_t	Total changes in carbon stock in carbon pools, for year *t*; t CO_2 yr^{-1}
GHG_E	GHG emissions resulting from implementation of the A/R project activity within the project boundary; t CO_2-e yr^{-1}
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity.

8. Leakage

In choosing key parameters and making critical 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 underestimation of leakage emissions should be applied.

Under applicability conditions of this methodology, the potential leakage emissions attributable to the proposed A/R project activity are those from fossil fuel combustion and collection of wood from non-renewable sources to be used for fencing of the project area. The emissions sources included in or excluded from leakage are listed in the Table D.

Total leakage emissions are thus given by:

$$LE_t = LE_{FuelBurn,t} + LE_{WP,t} \quad \textbf{(B.50)}$$

where:

LE_t	Total estimated leakage due to the project in year *t*; t CO_2-e
$LE_{FuelBurn,t}$	Leakage emissions from combustion of fossil fuels, in year *t*; t CO_2 yr^{-1}
$LE_{WP,t}$	Estimated leakage from fence activity due to the project in year *t*; t CO_2-e
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Table D: Emissions sources included in or excluded from leakage

Sources	Gas	Included/excluded	Justification/Explanation of Choice
Wood for fencing from a non-renewable source	CO_2	Included	Could be a potential major source if not controlled by project participants.
	CH_4	Excluded	Potential emission is negligibly small
	N_2O	Excluded	Potential emission is negligibly small
Combustion of fossil fuels	CO_2	Included	Could be significant.
	CH_4	Excluded	Potential emission is negligibly small
	N_2O	Excluded	Potential emission is negligibly small

GHG emissions related to fossil fuel combustion

Annual emissions from combustion of fossil fuels outside the project boundary but attributable to project activities, $LE_{FuelBurn,t}$, are estimated using the latest version of the following methodological tool approved by the CDM Executive Board: *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*[17]

[17] CDM Executive Board Meeting Report EB33, Annex 14: *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities.*

GHG emissions related to collection of wood from a non-renewable sources

GHG emissions related to collection of wood from nonrenewable sources (mainly for fencing purposes) is estimated on the basis of the assumption that both collected wood and supporting below-ground biomass are subject to instant oxidation, as shown in the following equation:

$$LE_{WP,t} = \sum_{i=1}^{M_{PS}} \sum_{j=1}^{S_{BL}} \left[\frac{LM_{i,t}}{dp_i} * Vp * (1+Wp) * D_j * CEF_j * (1+R_j) * CF_j \right] * 44/12 \quad \textbf{(B.51)}$$

where:

$LE_{WP,t}$	Estimated leakage from fencing due to the project in year t; t CO_2-e
$LM_{i,t}$	Linear meters for fencing in stratum i in year t; m ha^{-1}
dp_i	D between wood posts in fences for stratum i; m
Vp	Average volume of each wood post for fences; m^3
Wp	Waste fraction of unsustainable logging to extract wood posts; percentage
D_j	Basic wood density for species j; t d.m. m^{-3}
CEF_j	Crown expansion factor: the ratio of crown and stem biomass to stem biomass for tree species j; dimensionless
R_j	Root-shoot ratio appropriate for biomass stock, for species j; ; dimensionless
CF_j	Carbon fraction of dry matter for tree species j; $t\ C\ (t\ d.m.)^{-1}$
$44/12$	Carbon to CO_2 conversion factor; dimensionless
j	1, 2, 3, ... S_{BL} baseline tree species
i	*1, 2, 3, ...* M_{PS} strata in the project scenario
t	*1, 2, 3, ...* t years elapsed since the start of the A/R CDM project activity.

Note: In accordance with the guidance provided by the Executive Board, "If obtaining timber for fencing outside the project boundary, only the gathered volume of wood that is non-renewable shall be considered as an emission by sources if forests are not significantly degraded due to this activity. However, if supply of fencing timber involves deforestation outside the project boundary, or forest degradation, effects on all carbon pools will be considered."

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:

$$C_{AR\text{-}CDM,,t} = C_{ACTUAL,t} - C_{BSL,t} - LE_t \quad \textbf{(B.52)}$$

where:

$C_{AR\text{-}CDM,,t}$	Net anthropogenic greenhouse gas removals by sinks in year t; t CO_2-e
$C_{ACTUAL,t}$	Actual net GHG removals by sinks of the project activity in year t; t CO_2-e

$C_{BSL,t}$	Baseline net GHG removals by sinks summed over all strata projected in year *t*; t CO_2-e
LE_t	Estimated leakage of the project in year *t*; t CO_2-e
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity.

10. 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 from annually-integrated data provided 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-e;
- Carbon stocks for the baseline scenario at the time of verification $C_B(t_v)$; t CO_2-e;
- Project emissions for year *t*, GHG_t; t CO_2-e;
- Leakage emissions for year *t*, LE_t; t CO_2-e;
- Year of verification, t_v; yr;
- Time span between two verifications, κ; yrs.

11. Uncertainties

To help reduce uncertainties in the accounting of emissions and removals**,** this methodology uses whenever possible the proven methods from the GPG-LULUCF, GPG 2000, and the IPCC 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 one of the following:

- Data from well-referenced peer-reviewed literature or other well-established published sources[18];
- 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;
- 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

[18] 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.

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 not more than 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 overestimation of ex ante net anthropogenic GHG removals by sinks should be selected.

12. Data needed for ex ante estimations

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$\Delta C_{AB,i,t}$	t C yr^{-1}	Changes in carbon stock in aboveground biomass of trees and permanent non-tree vegetation for stratum *i*, for year *t*		Estimated for stratum
$\Delta C_{BB,i,t}$	t C yr^{-1}	Changes in carbon stock in belowground biomass of trees and permanent non-tree vegetation for stratum *i*, for year *t*		Estimated on stratum
$\Delta C_{G,ij,t}$	t CO_2-e yr^{-1}	Annual increase in carbon due to biomass growth of living trees of species *j* in stratum *i*, for year *t*		Estimated per stratum per species
$\Delta C_{ij,BSL,t}$	t CO_2-e yr^{-1}	Baseline average annual carbon stock change due to biomass growth of living trees of species *j* in stratum *i* for year *t*		Estimated per stratum per species
$\Delta C_{L,ij,t}$	t CO_2-e yr^{-1}	Annual decrease in carbon due to biomass loss of living trees for stratum *i*, species , *j*, for year *t*		Estimated per stratum per species
ΔC_t	t CO_2-e yr^{-1}	Total changes in carbon stock in carbon pools for year *t*		Calculated
$\Delta C_{DW,i,t}$	t C yr^{-1}	Annual carbon stock change in the deadwood carbon pool for stratum *i*, for year *t*		Estimated for stratum

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$\Delta C_{DW,ij,t}$	t C yr^{-1}	Annual carbon stock change in the deadwood carbon pool of species *j* in stratum *i*, for year *t*		Estimated on stratum and species basis
$\Delta C_{DW\_desc,ij,t}$	t C yr^{-1}	Annual decrease of carbon stock in the deadwood carbon pool due to deadwood decomposition of species *j* in stratum *i*, time *t*		Estimated per stratum per species
$\Delta C_{LI\_desc,ij,t}$	t C yr^{-1}	Annual decrease of carbon stock in the litter carbon pool due to litter decomposition of species *j* in stratum *i*, time *t*		Estimated ex ante, monitored ex post
$\Delta C_{DW,BSL,ij,t}$	t CO_2-e yr^{-1}	Baseline annual carbon stock change in the deadwood carbon pool of species *j* in stratum *i*, time *t*		Estimated per stratum per species
$\Delta C_{DW\_fw,ij,t}$	t C yr^{-1}	Annual decrease of carbon stock in the deadwood carbon pool due to harvesting of deadwood of species *j* in stratum *i*, time *t*		Estimated ex ante, monitored ex post
$\Delta C_{DW\_hr,ij,t}$	t C yr^{-1}	Annual increase of carbon stock in the deadwood carbon pool due to harvesting residues not collected of species *j* in stratum *i*, time *t*		Estimated ex ante, monitored ex post
$\Delta C_{G,DW,ij,t}$	t CO_2-e ha^{-1} yr^{-1}	Annual input of carbon stock to the deadwood pool for species *j* in stratum *i*, for year *t*		
$\Delta C_{G,LI,ij,t}$	t CO_2-e ha^{-1} yr^{-1}	Annual input of carbon stock to the litter pool for species *j* in stratum *i*, for year *t*		

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$\Delta C_{L,DW,ij,t}$	t CO_2-e ha^{-1} yr^{-1}	Annual loss of carbon stock in the deadwood pool for species *j* in stratum *i*, for year *t*		
$\Delta C_{L,LI,ij,t}$	t CO_2-e ha^{-1} yr^{-1}	Annual loss of carbon stock in the litter pool for species *j* in stratum *i*, for year *t*		
$\Delta C_{LI\_hr,ij,t}$	t C yr^{-1}	Annual increase of carbon stock in the litter carbon pool due to harvesting residues not collected of species *j* in stratum *i*, time *t*		Estimated ex ante, monitored ex post
$\Delta C_{LI,i,t}$	t C yr^{-1}	Annual carbon stock change in the litter carbon pool for stratum *i*, for year *t*		Estimated for stratum
$\Delta C_{LI,ij,t}$	t C yr^{-1}	Annual carbon stock change in the litter carbon pool of species *j* in stratum *i*, time *t*		Estimated on stratum and species basis
$\Delta C_{LI,BSL,ij,t}$	t CO_2-e yr^{-1}	Baseline annual carbon stock change in the litter carbon pool of species *j* in stratum *i*, time *t*		Estimated per stratum per species
$\Delta C_{DW\_mlb,ij,t}$	t C yr^{-1}	Annual increase of carbon stock in the deadwood carbon pool due to mortality of the living biomass of trees of species *j* in stratum *i*, time *t*		Estimated ex ante, monitored ex post
$\Delta C_{LI\_mlb,ij,t}$	t C yr^{-1}	Annual increase of carbon stock in the litter carbon pool due to mortality of the living biomass of trees of species *j* in stratum *i*, time t		Calculated
$\Delta C_{LI\_fw,ij,t}$	t C yr^{-1}	Annual decrease of carbon stock in the litter carbon pool due to harvesting of litter of species *j* in stratum *i*, time *t*		Estimated ex ante Monitored ex post

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
A_i	ha	Area of stratum *i*		Project design and stratification
$A_{burn,\ i}$	ha yr^{-1}	Area of stratum *i* subject to burning		Estimated per stratum
$B_{AB,i}$	t d.m. ha^{-1}	Average aboveground biomass before burning for stratum *i*		Estimated per stratum per species, IPCC default, national inventory, literature
$B_{DW,S,ij}$	t d.m. ha^{-1}	Steady-state biomass stock in the deadwood pool for species *j* in stratum *i*		
$B_{LI,S,ij}$	t d.m. ha^{-1}	Steady-state biomass stock in the litter pool for species *j* in stratum *i*		
$BEF_{1,j}$	Dimensionless	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total aboveground tree biomass increment for species *j*		IPCC default, national inventory, literatures
$BEF_{2,j}$	Dimensionless	Biomass expansion factor for conversion of tree merchantable volume to aboveground tree biomass for species j		IPCC Guidelines, IPCC GPG- LULUCF, national inventory, local survey, literature.
$B_{pre,i,}$	t d.m. ha^{-1}	Average pre-existing stock of pre-project biomass in the non-tree living biomass (aboveground and belowground), deadwood and litter carbon pools on land of a proposed A/R CDM project activity for baseline stratum *i*		Local survey
$C_{ACTUAL,t}$	t CO_2-e	Actual net GHG removals by sinks of the project activity in year *t*		Calculated
$C_{AR\text{-}CDM,t}$	t CO_2-e	Net anthropogenic greenhouse gas removals by sinks in year *t*		Calculated

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$C_{ij,t}$	t C	Total carbon stock in living biomass of trees of species *j* in stratum *i*, calculated at time *t*		Estimated per stratum per species
$C_{ij,t1}$	t C	Total carbon stock in living biomass of trees of species *j* in stratum *i*, calculated at time t1		Estimated per stratum per species
$C_{ij,t2}$	t C	Total carbon stock in living biomass of trees of species *j* in stratum *i*, calculated at time t2		Estimated per stratum per species
$C_{AB\_pnon\text{-}tree,i,t}$	t C	Carbon stock in aboveground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*		Estimated for stratum
$C_{AB\_pnon\text{-}tree,ij,t}$	t C	Carbon stock in aboveground biomass of planted permanent non-tree vegetation of species *j* in stratum *i*, at time t		Estimated on stratum and species basis
$C_{AB\_tree,i,t}$	t C	Carbon stock in aboveground biomass of trees for stratum *i,* at time *t*		Estimated on stratum
$C_{AB\_tree,ij,t}$	t C	Carbon stock in aboveground biomass of tree species *j* in stratum *i,* at time *t*,		Estimated on stratum and species basis
$C_{AB\ i,t}$	t C	Carbon stock in aboveground woody biomass for stratum *i*, calculated at time *t*		Calculated
$C_{AB\ i,t2}$	t C	Carbon stock in aboveground woody biomass for stratum *i*, calculated at time t_2		Calculated
$C_{AB,\ i,t1}$	t C	Carbon stock in aboveground woody biomass for stratum *i*, calculated at time t_1		Calculated
$C_{BB,i,t}$	t C	Carbon stock in belowground woody biomass for stratum *i*, calculated at time *t*		Calculated

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$C_{BB,i,t2}$	t C	Carbon stock in belowground woody biomass for stratum *i*, calculated at time t_2		Calculated
$C_{BB,i,t1}$	t C	Carbon stock in belowground woody biomass for stratum *i*, calculated at time t_1		Calculated
$C_{BB\_pnon\text{-}tree,i,t}$	t C	Carbon stock in belowground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*		Estimated per stratum
$C_{BB\_pnon\text{-}tree,ij,t}$	t C	Carbon stock in belowground biomass of planted permanent non-tree vegetation of species *j* in stratum *i*, at time *t*		Estimated on stratum and species basis
$C_{BB\_tree,i,t}$	t C	Carbon stock in belowground biomass of trees for stratum *i,* at time *t*		Estimated for stratum
$C_{BB\_tree,ij,t}$	t C	Carbon stock in belowground biomass of trees species *j* in stratum *i,* at time *t*		Estimated on stratum and species basis
$C_{BSL,i,t}$	t CO_2-e yr^{-1}	Sum of the changes in carbon stocks in the baseline for year *t*		Calculated
$C_{BSL,t}$	t CO_2	Baseline net GHG removals by sinks summed over strata projected in year t		Calculated
$C_{DW,ij,t1}$	t CO_2-e	Carbon stock in the deadwood carbon pool in stratum *i*, species *j*, time t = t_1		Estimated on stratum and species basis
$C_{DW,ij,t2}$	t CO_2-e	Carbon stock in the deadwood carbon pool in stratum *i*, species *j*, time t = t_2		Estimated on stratum and species basis
CF_j	t C (t d.m.)$^{-1}$	Carbon fraction of dry matter for species or type *j*		IPCC default, national inventory, literature
CF_p	t C (t d.m.)$^{-1}$	Carbon fraction of permanent non-tree vegetation	Most updated	National GHG inventory, literature, IPCC

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
CF_{pre}	t C (t d.m.)$^{-1}$	Carbon fraction of dry biomass in pre-existing vegetation	Most recent	IPCC Guidelines, GPG-LULUCF, national GHG inventory, local survey
CEF_j	Dimensionless	Crown expansion factor: the ratio of crown and stem biomass to stem biomass for tree species *j*		IPCC Guidelines, GPG-LULUCF, national GHG inventory, local survey
$C_{LI,ij,t1}$	t C	Total carbon stock in litter of species *j* in stratum *i*, calculated at time $t = t_1$		Calculated
$C_{LI,ij,t2}$	t C	Total carbon stock in litter of species j in stratum i, calculated at time $t = t_2$		Calculated
CE	Dimensionless	Average combustion efficiency for aboveground biomass	Default	IPCC 2006 Guidelines, national GHG inventory
CF	t C (t d.m.)$^{-1}$	Average carbon fraction of dead wood or litter biomass; (IPCC default 0.5)	Default	IPCC default, national inventory, literature
CF_{av}	t C (t d.m)$^{-1}$	Average carbon fraction of dry biomass in aboveground biomass; (IPCC default 0.5)	Default	IPCC default, national inventory, literature
Costs and revenues of land uses	US$	Baseline alternatives identification	Most recent date	Local statistics, published data, and/or survey
DC	Dimensionless	Decomposition rate (% carbon stock in total deadwood stock decomposed annually);		GPG-LULUCF, national and local forestry inventory, preferably investigated ex post
D_j	t d.m. m^{-3}	Basic wood density for species *j*		Most updated GPG-LULUCF, IPCC 2006 Guidelines, national GHG inventory, local survey
dp_i	m	Distance between wood posts in fences for stratum *i*		Project design

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
Dw_j	t d.m. m^{-3} merchantable volume	Intermediate deadwood density for species *j*		GPG-LULUCF, national and local forestry inventory, preferably investigated ex post
$E_{biomassloss}$	t CO_2-e yr^{-1}	CO_2 emissions from a decrease in carbon stock in living biomass		Calculated
$E_{non\text{-}CO2, BiomassBurn}$	t CO_2-e yr^{-1}	non-CO_2 emissions from burning of biomass if this is to be used		Calculated
$E_{BiomassBurn,\ N2O}$	t CO_2-e yr^{-1}	N_2O emissions from biomass as a result of burning of biomass		Calculated
$E_{BiomassBurn,\ CH4}$	t CO_2-e yr^{-1}	CH_4 emissions from biomass as a result of burning of biomass;		calculated
$E_{BiomassBurn,C}$	t C yr^{-1}	C loss in aboveground biomass due to burning of biomass		Calculated
ER_{N2O}	Value	Emission ratio for N_2O	Global default	IPCC 2006 Guidelines for National Inventories
ER_{CH4}	Value	Emission ratio for CH_4	Global default	IPCC 2006 Guidelines for National Inventories
$E_{fertilizer}$	t CO_2-e yr^{-1}	Direct N_2O emissions that result from application of nitrogenous fertilizer		Calculated
$E_{FuelBurn}$	t CO_2-e	GHG emissions related from combustion of fossil fuels		Calculated
$E_{livestock}$	t CO_2-e yr^{-1}	Increase in annual GHG emissions due to an increase above baseline levels of the population of livestock in the project area		Calculated
$EF_{Enteric,\ CH4,L\ T}$	kg CH_4 $head^{-1}$ yr^{-1}	Emission factor for enteric methane production for livestock type *LT*		

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$EF_{Manure,\ CH4,\ LT}$	kg CH_4 head^{-1} yr^{-1}	Emission factor for methane production from manure for livestock type *LT*		
$EF_{Manure,\ N2O,\ LT}$	kg N_2O head^{-1} yr^{-1}	Emission factor for nitrous oxide production from manure for livestock type *LT*		Regional or national GHG inventory. Alternatively, IPCC default data may be used
$EF_{3,\ LT}$	kg N_2O-N (kg N input)$^{-1}$.	Emission factor for N_2O emissions from dung and urine deposited on pasture IPCC default: 0.02 for cattle (dairy, non-dairy, buffalo and pigs), and 0.01 for all other animals (Table 11.1; AFOLU, IPCC 2006.		Regional or national GHG inventory. Alternatively, IPCC default data may be used
f_j *(DBH,CA)*	t d.m. tree^{-1}	Allometric equation linking aboveground biomass of shrubs or permanent non-tree vegetation to one or more of the variables diameter at base (*DB*), shrub height (*H*) and crown area/diameter (*CA*)	Most updated	National GHG inventory, literature, IPCC
f_j*(DBH,H)*	kg d.m. tree^{-1}	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly tree height (*H*) to aboveground biomass of living trees		Local survey, literature
$Fwf_{ij,t}$	Dimensionless	Fraction of annually harvested deadwood carbon stock harvested as fuel wood of species j in stratum i, time *t*		Estimated to measured ex ante, measured ex post
GHG_E	t CO_2-e yr^{-1}	GHG emissions resulting from implementation of the A/R project activity within the project boundary		Calculated

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$G_{TOTAL,ij,t}$	t d.m. ha^{-1} yr^{-1}	Annual increment of total dry biomass of living trees for stratum *i* species *j*		Estimated per stratum per species
$G_{w,ij,t}$	t d.m. ha^{-1} yr^{-1}	Average annual aboveground dry biomass increment of living trees of species j in stratum i, for year *t*		Estimated per stratum per species
GWP_{CH4}	kg CO_2-e kg^{-1} CH_4	100-year global global warming Potential for methane	Global default	IPCC 2006 Guidelines for National Inventories
GWP_{N2O}:	kg CO_2-e kg^{-1} N_2O	100-year global warming potential for N_2O	Global default	IPCC 2006 Guidelines for National Inventories
$Hf_{ij,t}$	Dimensionless	Fraction of annually harvested merchantable volume not extracted and left on the ground as harvesting residue of species j in stratum i, time *t*		Estimated ex ante
$H_{ij,t}$	m^3 ha^{-1} yr^{-1}	Average annually harvested merchantable volume of species j in stratum i, time *t*		Estimated ex ante
Historical land use/cover data		Determining baseline alternatives Demonstrating eligibility of land	Earliest possible up to now	Publications, national or regional forestry inventory
i	Dimensionless	Index for strata		
$I_{V,ij,t}$	m^3 ha^{-1} yr^{-1}	Average annual increment in merchantable volume of species j in stratum i, for year *t*		IPCC default, national inventory, literatures
j	Dimensionless	Index for species		
$l_{pnon-tree}$	Dimensionless	Sequence number of permanent non-tree vegetation for species *j* in stratum *i*		
l	Dimensionless	Sequence number of tree of species *j* in stratum *i*		

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
Land use/cover map		Demonstrating eligibility of land, stratifying land area	Around 1990 and most recent date	Satellite images, aerial photographs, land cover maps, satellite imagery, and aerial photos. Source will have a minimum resolution to map the national forest area definition threshold.
LE_t	t CO_2-e	Total estimated leakage due to the project in year *t*		Calculated
$LE_{FuelBurn,\ t}$	t CO_2 yr^{-1}	Leakage emissions from combustion of fossil fuels, in year *t*		Calculated
$LE_{WP,t}$	t CO_2-e	Estimated leakage from fence activity due to project in year *t*		Calculated
LM_{it}	m ha^{-1}	Linear meters for fencing in stratum *i* in year *t*		Project design
LT	Dimensionless	Livestock type; *1 … n*		
M_{PS}		Strata in project scenario		
M_{BL}	Dimensionless	Strata in baseline		
$Mf_{ij,t}$	Dimensionless	Mortality factor, i.e., fraction of $V_{ij,t}$ dying at time *t*		Estimated
N/C ratio	Dimensionless	Nitrogen–carbon ratio; dimensionless		IPCC
N_{ij}	Number	Number of trees of species *j* in stratum *i*		Sampling survey
$N_{pnon\text{--}tree,ij}$	Number	Number of shrubs or permanent non-tree vegetation of species *j* in stratum *i*; (dimensionless)		Sampling survey
$N_{rate(LT)}$	kg N (1000 kg animal $mass)^{-1}$ day^{-1}	Excretion rate for livestock type *LT*		
$Pop_{Proj,\ LT}$	Head	Population of livestock type *LT* in the project area		Sampling survey
$Pop_{BSL,\ T}$	Head	Population of livestock type *LT* in the baseline		Sampled census in the proposed project area at the start of the project, or from local or regional statistics of livestock density

Data/ Parameter	Unit	Description	Vintage	Data sources and geographic scale
$R1_j$	Dimensionless	Root-shoot ratio appropriate to increments for species *j*		Most updated GPG-LULUCF, IPCC 2006 Guidelines, national GHG inventory, local survey, per species
R_j	Dimensionless	Root-shoot ratio appropriate for biomass stock, for species *j* ;		National GHG inventory, literature, IPCC, local data
$R_{p,j}$	Dimensionless	Root-shoot ratio of permanent non-tree vegetation species *j*	Most updated	National GHG inventory, literature, IPCC
S_{BL}	Dimensionless	Baseline tree species		
Satellite image		Demonstrating eligibility of land, stratifying land area	1989/1990 and most recent date	Satellite images providers will have a minimum resolution to map the national forest area definition threshold
Soil map		Stratifying land area	Most recent date	Local government and institutional agencies
t	yr	Years elapsed since the start of the A/R CDM project activity		
T	yr	Number of years between times t_2 and t_1 ($T = t_2 - t_1$)		
TAM_{LT}	kg $head^{-1}$	Typical animal mass for livestock type *LT*		
T_S	yr	Time taken for the deadwood or litter biomass pools to reach a steady state (IPCC default: 20 years)		
$V_{ij,t}$	m^3 ha^{-1}	Merchantable volume of trees in stratum *i*, species *j* at time *t*		Estimated based on national or local yield table or growth curve
Vp	m^3	Average volume of each wood post for fences		Project design
$V_{tree,ij,t}$	m^3 ha^{-1}	Mbean merchantable/standing volume for stratum *i*, and species *j* at time *t*		Estimated per stratum per species based on local or national growth curve, yield table
Wp	Percentage	Waste fraction of unsustainable logging to extract wood posts	Most recent date	Local statistics, published data and/or survey

Default parameters

Carbon fraction of biomass (dry matter) $CF_m = CF_{non\text{-}tree} = CF_{dw} = 0.5$ t C (t d.m.)$^{-1}$

Source: IPCC Good Practice Guidance for LULUCF (IPCC, 2003, p. 3.25)

Carbon fraction to mass of litter (dry matter) ratio $CF_{rn} = 0.37$ t C (t d.m.)$^{-1}$

Source: IPCC Good Practice Guidance for LULUCF (IPCC, 2003, p. 3.35)

References for data availability of some factors:

Coarse crown ratio and coarse root ratio:

Rodríguez Jimenez, L. (1988) – Consideraciones sobre la biomasa, composición química y dinámica del bosque pluvial tropical de Colinas Bajas, Bajo Calima, Buenaventura, Colombia.

Grimm, U. and Fassbender, H.W. (1981) – Ciclos bioquímicos en un ecosistema forestal de los Andes Occidentales de Venezuela. I. Inventario de las reservas orgánicas y minerales (N, P, K, Ca, Mg, Mn, Fe, Al, Na). Turrialba 31(1): 27-37.

Ovington, J.D. and Olson J.S. (1970) – Biomass and chemical content of El Verde lower Montane Rain Forest plants. In: T.H. Odum and P.R.F. Odum (eds.) A Tropical Rain Forest. Atomic Energy Comission, Virginia, USA

Litterfall rate:

Alder, D. and Montenegro, F. (1999) - A yield model for *Cordia alliodora* plantations in Ecuador. International Forestry Review, 1(4): 242-250.

Trees, Version 1.0a (2002) – Árboles tropicales y subtropicales de uso múltiple. Forestry database program by A. Vallejo and F. Zapata, Medellín, Colombia.

Coarse and Fine necromass decomposition rate:

Songwe, N. C., Okali, D.U.U. and Fasehun, F.E. (1995) - Litter decomposition and nutrient release in a tropical rainforest, Sourthern Bakundu Forest Reserve, Cameroon. Journal of Tropical Ecology 11: 333-350.

Fine and coarse necromass respiration:

Wilson, C. (1998) – Modelling carbon sequestration in Forests: A tool for joint implementation project investors. MSc Thesis, Imperial College, London.

Section III: Monitoring methodology description

1. Monitoring project implementation

To allow for the monitoring of the project implementation, data shall be collected and recorded to confirm the information provided in the project design document (PDD), especially to establish that:

(a) The geographic position of the project falls within the project boundary as described in the PDD and this position is accurately and precisely recorded for all parcels; and

(b) Applicability conditions of the methodology are met; and

(c) 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 geographic position of the project:

- 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 all candidate areas have been forested, check that all land areas are within the designed project 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 reconfirm applicability conditions:

- Information in peer-reviewed publications or official reports can be used to justify that the applicability conditions are still valid; or
- Time sequential historical photographs, satellite images, maps, or other datasets can be used to provide evidence that applicability conditions are still valid - including quantifying the degraded or degrading state of lands, occurrence 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 still 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 that the project lands will continue to provide the same amount of goods and services after the project commences.

(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 minimize soil erosion in those circumstances in which site preparation or planting involves soil disturbance;
- Through monitoring and (internal) audits ensure that the SOPs are being implemented.

(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;
- Through monitoring and (internal) audits ensure that the SOPs are being implemented.

The monitoring comprises the following elements as part of the QA/QP procedures (see also Section 11.1):

1. Design of standard operating procedures (SOPs) for project activities
2. Recording of information and consistency checks
3. Consolidation and archiving

(a) Design of standard operating procedures (SOPs) for project activities

Project participants shall develop forest management plans as SOPs for each project activity. A plan will include at least:

(a) Technical description of the system: list of tree and non-tree species, planting density, expected wood outputs, location, etc.

(b) Main activities to be performed within the crediting period, particularly: site preparation, planting, pruning, thinnings, and/or harvesting

(c) Actions to be taken as a consequence of forest fires, pests, and plagues; and reporting requirements for project participants

(d) Measures to prevent leakages and/or prevent or mitigate significant environmental or social impacts

(e) Expected inputs in terms of material and labor

A complete set of specific forest management plans for each forestry system shall be available for verification.

(b) Recording and crosschecking

Project participants shall establish recording and crosschecking procedures in order to:

1. Measure the area of each planted site with GPS (LULUCF IPCC 2003 p. 492f) during technical field visits or other methods to geographically locate it and determine its size.
2. Define recording and crosschecking responsibilities and corresponding formats for small landholders, technical experts, community leaders, public/private organizations, and the executing institution.
3. Establish procedures for reporting risk events (fires, pests, etc.).

Reports of all on-site inspections and other reporting formats will be available for verification. These reports may be complemented with recent satellite imagery, aerial photographs, or photographs of planted sites.

(c) Consolidation and archiving

Project participants will consolidate and archive relevant activity data for calculation of actual net GHG removals by sinks, including:

(a) Area planted for each stratum and project activity

(b) Main forest intervention executed (e.g., thinnings and clearings)

(c) Amount of synthetic fertilizer applied

(d) Amount of manure fertilizer applied

(e) Linear meters of fencing

(f) Amount of wood and non-wood products harvested

The implementation of other relevant measures must be cross-checked in order to prevent leakages and/or prevent or mitigate significant environmental or social impacts.

The consolidated information will be documented in a transparent manner and will be available for verification.

2. Stratification and sampling design

(a) Stratification

If the project activity or area is not homogeneous with regard to carbon stocks , 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[19] 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:

(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 actual net GHG removals by sinks:

(a) Using appropriate ex post stratification approach taken from any approved methodology; 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 design

The approved tool "Calculation of the number of sample plots for measurements within A/R CDM project activities" will be used for defining the sampling design for collection of field data in this methodology.

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

Determination of *ex post* baseline net GHG removals by sinks is not required by this methodology.

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

The required data are presented in Table C.

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

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:

$$\Delta C_{ACTUAL,t} = \sum_{i=1}^{M_{PS}} \Delta C_{i,t} - GHG_{E,t} \qquad \textbf{(M.1)}$$

where:

$\Delta C_{ACTUAL,t}$	Actual net GHG removals by sinks for year *t*; t CO_2-e yr^{-1}
$\Delta C_{i,t}$	Verifiable changes in the carbon stock of living biomass resulting from implementation of the A/R activity for stratum *i* in year *t*; t CO_2-e yr^{-1}
$GHG_{E,t}$	Increase in GHG emissions by the sources within the project boundary resulting from implementation of the A/R project activity in year *t*; t CO_2-e yr^{-1}
i	*1, 2, 3, …* M_{PS} strata in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

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 underestimate, rather than overestimate, net GHG removals by sinks.

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

The estimation of average annual carbon stock change in aboveground woody biomass, belowground woody biomass, deadwood and litter pools between two monitoring events shall be performed on the lowest level of stratification and summed accordingly over the entire project area.

$$\Delta C_{i,t} = (\Delta C_{DW,i,t} + \Delta C_{LI,i,t} + \Delta C_{tree,i,t} + \Delta C_{pnon-tree,i,t}) * 44/12 \qquad \textbf{(M.2)}$$

where:

$\Delta C_{i,t}$	Verifiable changes in the carbon stock of living biomass resulting from implementation of the A/R activity for stratum *i* in year *t*; t CO_2-e yr^{-1}
$\Delta C_{tree,i,t}$	Changes in carbon stock in biomass of trees for stratum *i* for year *t;* t C yr^{-1} .
$\Delta C_{pnon-tree,i,t}$	Changes in carbon stock in biomass of permanent non-tree vegetation for stratum *i* for year *t* ; t C yr^{-1}
$\Delta C_{DW,i,t}$	Changes in carbon stock in the deadwood carbon pool for stratum *i* for year *t* ; t C yr^{-1} .

$\Delta C_{LI,i,t}$	Changes in carbon stock change in the litter carbon pool for stratum *i* for year *t* ; t C yr^{-1}
44/12	Ratio of molecular weights of CO_2 and carbon; t CO_2 t^{-1} C
i	*1, 2, 3, … M_{PS}* strata in the project scenario
t	*1, 2, 3, …* *t* years elapsed since the start of the A/R CDM project activity

a.1 Calculation of average annual carbon stock change in living woody biomass[20]

$$\Delta Ctree_{i,t} = (C_{treei,t2} - C_{treei,t1})/ T \quad \textbf{(M.3)}$$

$$\Delta C_{pnon\text{-}tre,i,t} = (C_{pnon\text{-}treei,t2} - C_{pnon\text{-}treei,t1})/ T \quad \textbf{(M.4)}$$

$$C_{tree,i,t} = C_{AB\_tree,i,t} + C_{BB\_tree,i,t} \quad \textbf{(M.5)}$$

$$C_{pnon\text{-}tree,i,t} = C_{AB\_pnon\text{-}tree,i,t} + C_{BB\_pnon\text{-}tree,i,t} \quad \textbf{(M.6)}$$

where:

$\Delta C_{tree,i,t}$	Changes in carbon stock in biomass of trees for stratum *i* for year *t;* t C yr^{-1}
$\Delta C_{pnon\text{-}tree,i,t}$	Changes in carbon stock in biomass of permanent non-tree vegetation for stratum *i* for year *t*; t C yr^{-1}
$C_{tree,i,t2}$	Carbon stock in biomass of trees for stratum *i*, calculated at time t_2; t C
$C_{tree,i,t1}$	Carbon stock in biomass of trees for stratum *i*, calculated at time t_1; t C
$C_{pnon\text{-}tree,i,t2}$	Carbon stock in biomass of permanent non-tree vegetation for stratum *i*, calculated at time t_2; t C
$C_{pnon\text{-}tree,i,t1}$	Carbon stock in biomass of permanent non-tree vegetation for stratum *i*, calculated at time t_1; t C
$C_{AB\_tree,i,t}$	Carbon stock in aboveground biomass of trees for stratum *i,* at time *t*; t C
$C_{AB\_pnon\text{-}tree,i,t}$	Carbon stock in aboveground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*; t C
$C_{BB\_tree,i,t}$	Carbon stock in belowground biomass of trees for stratum *i,* at time *t,* t C
$C_{BB\_pnon\text{-}tree,i,t}$	Carbon stock in belowground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*; t C
T	Number of years between time t2 and t1; dimensionless
i	*1, 2, 3, … M_{PS}* strata in the project scenario
t	*1, 2, 3, …* *t* years elapsed since the start of the A/R CDM project activity

a.1.1 Planted trees

[20] Refers to equation 3.2.3 in GPG-LULUCF

The mean carbon stock per unit area in aboveground and belowground biomass resulting from the A/R activity is estimated from field measurements at the permanent sample plots. Any trees that existed at the time of project commenced and that fall within the sample plot perimeter shall be marked and excluded from the measurements. The mean carbon stock resulting from the A/R activity can be estimated using one of the two methods: the biomass bxpansion factors (BEF) method, or the allometric equations method.

BEF Method

Step 1: Measure the diameter at breast height *(DBH* at 1.3 m aboveground), 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 or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate), expressed as volume . 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 selected 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: Converting the volume of the commercial component of trees into carbon stock in aboveground biomass and belowground biomass via basic wood density, BEF root-shoot ratio and carbon fraction, given by:

$$C_{AB\_tree,l,ij,sp,t} = V_{l,ij,sp,t} * D_j * BEF_{2,j} * CF_j \qquad \textbf{(M.7)}$$

$$C_{BB\_tree,l,ij,sp,t} = C_{AB\_tree,l,ij,sp,t} * R_j \qquad \textbf{(M.8)}$$

where:

$C_{AB\_tree,l,ij,sp,t}$	Carbon stock in aboveground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t* , t C tree^{-1}

$C_{BB\_tree,l,ij,sp,t}$	Carbon stock in belowground biomass of tree *l* of species *j* in plot *sp*at time *t* , t C $tree^{-1}$
$V_{l,ij,sp,t}$	Merchantable volume of tree *l* of species *j* in plot *sp* in stratum *i* at time *t* , m^3 $tree^{-1}$
D_j	basic wood density of species *j* ; t d.m. m^{-3}
$BEF_{2,j}$	Biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j*; dimensionless
CF_j	Carbon fraction of biomass for tree species *j*; t C (tonne d.m.)$^{-1}$ (IPCC default value = 0.5 t C (tonne d.m.)$^{-1}$)
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless.
l	sequence number of trees on plot s*p*

The total, i.e aboveground biomass and belowground biomass, of tree *l* of species *j* in plot *sp* in stratum *i* at time *t* is given by:

$$C_{AB\_tree,l,ij,sp,t} + C_{BB\_tree,l,ij,sp,t} = C_{AB\_tree,l,ij,sp,t} * (1 + R_j) \quad \textbf{(M.9)}$$

where:

$C_{AB\_tree,l,ij,sp,t}$	Carbon stock in aboveground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t* , t C $tree^{-1}$
$C_{BB\_tree,l,ij,sp,t}$	Carbon stock in belowground biomass of tree *l* of species *j* in plot *sp*at time *t* , t C $tree^{-1}$
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless.

Step 5: Calculation of the plot level carbon stock in aboveground and belowground biomass of living trees is performed in the following sub-steps:

Summation of carbon stock in aboveground and belowground biomass over all trees of species *j* present in plot *sp* in stratum *i* at time *t*:

$$C_{AB\_tree,ij,sp,t} + C_{BB\_tree,ij,sp,t} = \sum_{l=1}^{N_{ij,sp,t}} C_{AB\_tree,l,ij,sp,t} * (1 + R_j) \quad \textbf{(M.10)}$$

where:

$C_{AB\_tree,ij,sp,t}$	Carbon stock in aboveground biomass of trees of species *j* on plot *sp* of stratum *i* at time *t*, t C
$C_{BB\_tree,ij,sp,t}$	Carbon stock in belowground biomass of trees of species *j* on plot *sp* of stratum *i* at time *t*, t C
$C_{AB\_tree,l,ij,sp,t}$	Carbon stock in aboveground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*, t C $tree^{-1}$
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless

$N_{ij,sp,t}$	Number of trees of species *j* on plot s*p* of stratum *i* at time *t*
l	Sequence number of trees on plot s*p*

Summation of carbon stock in aboveground and belowground biomass of trees over species *j* present in plot *sp* in stratum *i* at time *t*:

$$C_{AB\_tree,i,sp,t} + C_{BB\_tree,i,sp,t} = \sum_{j=1}^{S_{PS}} (C_{AB\_tree,ij,sp,t} + C_{BB\_tree,ij,sp,t}) \quad \textbf{(M.11)}$$

where:

$C_{AB\_tree,ij,sp,t}$	Carbon stock in aboveground biomass of trees of species *j* on plot *sp* of stratum *i* at time *t*, t C
$C_{BB\_tree,ij,sp,t}$	Carbon stock in belowground biomass of trees of species *j* on plot *sp* of stratum *i* at time *t*, t C
$C_{AB\_tree,i,sp,t}$	Carbon stock in aboveground biomass of trees on plot *sp* of stratum *i* at time *t*, t C
$C_{BB\_tree,i,sp,t}$	Carbon stock in belowground biomass of trees on plot *sp* of stratum *i* at time *t*, t C
j	*1, 2, 3, ...* S_{PS} tree species in the project scenario

Step 6: Calculation of the mean carbon stock in above and belowground biomass for each stratum:

$$C_{AB\_tree,\,i,t} + C_{BB\_tree,i,t} = \frac{A_i}{\sum A_{sp}} (\sum_{p=1}^{P_i} (C_{AB\_tree,i,sp,t} + C_{BB\_tree,i,sp,t}) \quad \textbf{(M.12)}$$

where**:**

$C_{AB\_tree,i,t}$	Carbon stock in aboveground biomass of trees in stratum *i,* at time *t*; t C
$C_{BB\_tree,i,t}$	Carbon stock in belowground biomass of trees in stratum *i,* at time *t*; t C
$C_{AB\_tree,i,sp,t}$	Carbon stock in aboveground biomass of trees on plot *sp* of stratum *i* at time *t*, tonnes C
$C_{BB\_tree,i,sp,t}$	Carbon stock in belowground biomass of trees on plot *sp* of stratum *i* at time *t*, tonnes C
P_i	Number of plots in stratum *i*
$\sum A_{sp}$	Total area of all sample plots *in* stratum *i* ; ha
A_i	Area of stratum *i*; ha

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 within each permanent sample plot.

Step 2: Choose or establish an appropriate allometric equation.

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 underestimate rather than overestimate the biomass) - 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 aboveground biomass in sample plot per unit of area using selected or developed allometric equations applied to the tree measurements made in Step 1.

$$C_{AB\_tree,ij,sp,t} = \frac{\sum_{l=1}^{N_{j,sp}} f_j(DBH_{ijlt}, H_{ijlt}) * CF_j}{A_{sp}} \qquad \textbf{(M.13)}$$

where:

$C_{AB\_tree,ij,sp,t}$	Carbon stock in aboveground biomass of tree species *j* stratum *i*, sample plot *sp* at time *t*; t C ha^{-1}
A_{sp}	Area of sample plot *sp*; ha
CF_j	Carbon fraction of dry matter for species or type *j*; t C (t d.m.)$^{-1}$
$f_j(DBH, H)$	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly tree height (*H*) to aboveground biomass of living trees; t d.m. tree^{-1}
i	*1, 2, 3, …* M_{PS} strata in the project scenario
j	*1, 2, 3, ...* S_{PS} tree species in the project scenario
l	*1, 2, 3…*$N_{j,sp}$ sequence number of individual trees of species *j* in sample plot *sp*
sp	Index for sample plots
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Step 4: Estimate the carbon stock in belowground biomass using root-shoot ratios .

$$C_{BB\_tree,ij,sp,t} = C_{AB\_tree,ij,sp,t} * R_j \qquad \textbf{(M.14)}$$

where:

$C_{BB\_tree,ij,sp,t}$	Carbon stock in belowground biomass of tree species *j* stratum *i*, sample plot *sp* at time *t*; t C ha^{-1}
$C_{AB\_tree,ij,sp,t}$	Carbon stock in aboveground biomass of tree species *j* stratum *i*, sample plot *sp* at time *t*; t C ha^{-1}
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless
i	*1, 2, 3, …* M_{PS} strata in the project scenario
j	*1, 2, 3, ...* S_{PS} tree species in the project scenario
sp	Index for sample plots
t	*1, 2, 3, ... t* years elapsed since the start of the A/R CDM project activity

Step 5: Calculate the carbon stock in the aboveground ($C_{ABtree,ij,t}$) and belowground ($C_{BBtree,ij,t}$) biomass of each tree species for each stratum based on the average value of the plots and the area of the stratum.

Step 6: Sum up the carbon stocks over the species to obtain the carbon stock per stratum

$$C_{AB\_tree,i,t} = \sum_{j=1}^{S_{PS}} C_{AB\_tree,ij,t} \tag{M.15}$$

$$C_{BB\_tree,i,t} = \sum_{j=1}^{S_{PS}} C_{BB\_tree,ij,t} \tag{M.16}$$

where:

$C_{AB\_tree,i,t}$	Carbon stock in aboveground biomass of trees for stratum *i,* at time *t*; t C
$C_{BB\_tree,i,t}$	Carbon stock in belowground biomass of trees for stratum *i,* at time *t;* t C
$C_{AB\_tree,ij,t}$	Carbon stock in aboveground biomass of tree species *j* in stratum *i,* at time *t*; t C
$C_{BB\_tree,ij,t}$	Carbon stock in belowground biomass of trees species *j* in stratum *i,* at time *t;* t C
i	*1, 2, 3, …* M_{PS} strata in the project scenario
j	*1, 2, 3, ...* S_{PS} tree species in the project scenario
t	*1, 2, 3, ... t* years elapsed since the start of the A/R CDM project activity

a.1.2 Planted permanent non-tree vegetation[21]

For permanent non-tree vegetation, aboveground biomass will be estimated using the allometric method.

Allometric method

[21] For this methodology, permanent non-tree vegetation includes perennial crops–such as cocoa, coffee, oil palm, coconut, bananas–and woody vegetation (shrubs) that falls below the thresholds to be considered trees, and is not expected to exceed those thresholds at a later time.

Step 1: Select one or more of the following variables to be included in the equation: diameter at base (DB), shrub height (*H*) and crown area/diameter (*CA*).

Step 2: Choose or establish an appropriate allometric equation.

The allometric equations used should preferably be locally-derived and species-specific. When more generic allometric equations are selected from existing ones, it is necessary to verify their applicability by destructive harvesting. This is carried out within the project area but outside the sample plots, by cutting and weighing samples in subplots adjacent to but outside of the permanent plot. For a few non-trees of different sizes, a mixed subsample should be selected to determine dry-oven weight and for estimating carbon stock. If the biomass of the harvested non-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 underestimate rather than overestimate the biomass) - 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 non-tree vegetation, representing different size classes, is destructively harvested, and total biomass per unit of non-tree vegetation determined. The volume of non-tree vegetation to be destructively harvested and measured depends on the range of size classes and number of species - the greater the heterogeneity the greater volume is 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 diameter at base (*DB*), height (*H*) and crown area/diameter (*CA*) (see the guidance provided in Chapter 4.3, GPG LULUCF). If there are no allometric equations available, or it is impossible to estimate the biomass of planted permanent non-tree vegetation, the carbon stock change in living biomass of planted permanent non-tree vegetation can be assumed to be zero.

Step 3: Estimate carbon stock in aboveground biomass per unit of area using selected or developed allometric equations applied to the non-tree tree measurements made in Step 1 (the equation below assumes that the unit of non-tree vegetation is the individual plant but other units, e.g. area of crown cover, are possible).

$$C_{AB\_pnon-tree,ij,sp,t} = \frac{\sum_{l=1}^{N_{j,sp}} f_j(DB_{i,l,t}, H_{i,l,t}, CA_{i,l,t}) * CF_p}{A_{sp}} \qquad \textbf{(M.17)}$$

where:

$C_{AB\_pnon-tree,ij,sp,t}$	Carbon stock in aboveground biomass of permanent non-tree vegetation of species *j* in stratum *i,* sample plot *sp* at time *t*; t C ha^{-1}
A_{sp}	Area of sample plot; hectare; ha
CF_p	Carbon fraction of permanent non-tree vegetation; t C (t d.m.)$^{-1}$
f(DB, H, CA)	An allometric equation linking aboveground biomass of shrubs or permanent non-tree vegetation to one or more of the variables diameter at base (*DB*), shrub height (*H*) and crown area/diameter (*CA*); t d.m. tree^{-1}
i	*1, 2, 3, …* M_{PS} strata in the project scenario
j	*1, 2, 3, ...* S_{PS} tree species in the project scenario

l	$1, 2, 3 \ldots N_{j,sp}$ sequence number of individuals plants of non-tree species j in sample plot sp
sp	Index for sample plots
t	$1, 2, 3, \ldots t$ years elapsed since the start of the A/R CDM project activity

Step 4: Estimate the carbon stock in belowground biomass using root-shoot ratios. The root-shoot ratios used should preferably be locally-derived and species- (or group of species)- specific. If default ratios are not available then root-shoot ratios will be estimated by a procedure similar to that for allometric equations, i.e. subsamples of roots and rhizomes at depths of 0.3 to 0.4 m from subplots outside of but adjacent to the main tree plot will be taken and a mixed subsample should be selected to determine dry-oven weight.

$$C_{BB\_pnon\text{-}tree,ij,sp,t} = C_{AB\_pnon\text{-}tree,ij,sp,t} * R_{p,j} \quad \textbf{(M.18)}$$

where:

$C_{AB\_pnon\text{-}tree,ij,sp,t}$	Carbon stock in aboveground biomass of permanent non-tree vegetation for stratum i, non-tree species j, sample plot sp at time t; t C ha^{-1}
$C_{BB\_pnon\text{-}tree,ij,sp,t}$	Carbon stock in belowground biomass of permanent non-tree vegetation for stratum i, non-tree species j, sample plot sp at time t; t C ha^{-1}
$R_{p,j}$	Root-shoot ratio of permanent non-tree vegetation species j
i	$1, 2, 3, \ldots M_{PS}$ strata in the project scenario
j	$1, 2, 3, \ldots S_{PS}$ tree species in the project scenario
sp	Index for sample plots
t	$1, 2, 3, \ldots t$ years elapsed since the start of the A/R CDM project activity

If root-shoot ratios of permanent non-tree vegetation by species are not available, the carbon stock change in belowground biomass of planted permanent non-tree vegetation can be assumed to be zero.

Step 5: Calculate the carbon stock in the aboveground and belowground biomass of the permanent non-tree vegetation for each species in each stratum based on the average value of the plots and the area of the stratum.

Step 6: Sum up the carbon stocks in the species to obtain the carbon stock per stratum

$$C_{AB\_pnon-tree,i,t} = \sum_{j=1}^{S_{PS}} C_{AB\_pnon-tree,ij,t} \quad \textbf{(M.19)}$$

$$C_{BB\_pnon-tree,i,t} = \sum_{j=1}^{S_{PS}} C_{BB\_pnon-tree,ij,t} \quad \textbf{(M.20)}$$

where:

$C_{AB\_pnon\text{-}tree,i,t}$	Carbon stock in aboveground biomass of permanent non-tree vegetation for stratum *i*, at time *t*; t C
$C_{BB\_pnon\text{-}tree,i,t}$	Carbon stock in belowground biomass of permanent non-tree vegetation for stratum *i*, at time *t*; t C
$C_{AB\_pnon\text{-}tree,ij,t}$	Carbon stock in aboveground biomass of permanent non-tree vegetation for stratum *i* species *j*, at time *t*; t C
$C_{BB\_pnon\text{-}tree,ij,t}$	Carbon stock in belowground biomass of permanent non-tree vegetation of species *j* in stratum *i* at time *t*; t C
i	*1, 2, 3, …* M_{PS} strata in the project scenario
j	*1, 2, 3, ...* S_{PS} tree species in the project scenario
t	*1, 2, 3, ... t* years elapsed since the start of the A/R CDM project activity

a.2 Deadwood (coarse necromass)

Deadwood observed in the field comprises two components – *standing deadwood* and *lying dead wood*. Considering the differences in two components, different sampling and estimation procedures should be used to calculate the changes in deadwood biomass of the two components.

In addition to the standing and the lying deadwood components that are observable in the field, deadwood also occurs below the ground. The belowground deadwood has different rates of decomposition in comparison to the decomposition rates of standing and lying deadwood. The belowground deadwood of the project is expected to contribute to the increases in carbon stocks. Therefore, non-accounting of this component is considered conservative under this methodology.

$$\Delta C_{DW,i,t} = (C_{DW,i,m2} - C_{DW,i,m1}) / T_{DW} \qquad \textbf{(M.21)}$$

where:

$\Delta C_{DW,i,t}$	Average annual change in the carbon stock of deadwood in stratum *i* at time *t;* t C
$C_{DW,i,m2}$	Carbon stock of deadwood in stratum *i* at monitoring event m_2; t C
$C_{DW,i,m1}$	Carbon stock of deadwood in stratum *i* at monitoring event m_1; t C
T_{DW}	Monitoring interval for dead wood $T_{DW} = m_2 - m_1$ (where m_2 and m_1 are the two most recent monitoring events); yr

$$C_{DW,i,m} = C_{SDW,i,m} + C_{LDW,i,m} \qquad \textbf{(M.22)}$$

where:

$C_{DW,i,m}$	Carbon stock of deadwood biomass in stratum *i* at monitoring event *m;* t C
$C_{SDW,i,m}$	Carbon stock of standing deadwood in stratum *i* at monitoring event *m*; t.C

$C_{LDW,i,m}$ Carbon stock of lying deadwood in stratum *i,* at monitoring event *m*; t. C

The methods to be followed in the measurement of the standing deadwood and the lying deadwood biomass are outlined below.

a.2.1 Standing dead wood

Step 1: Standing dead trees shall be measured using the same criteria and monitoring frequency used for measuring live trees. The decomposed portion that corresponds to the original living biomass is discounted.

Step 2: The decomposition class of the dead tree and the diameter at breast height shall be recorded and the standing dead wood is categorized under the following four decomposition classes.

1. Tree with branches and twigs that resembles a live tree (except for leaves)
2. Tree with no twigs but with persistent small and large branches
3. Tree with large branches only
4. Bole only, no branches

Step 3: Biomass should be estimated using the allometric equation for live trees in the decomposition class 1. When the bole is in decomposition classes 2, 3 or 4, it is recommended to limit the estimate of the biomass to the main trunk of the tree.

Step 4: The volume of deadwood is converted to biomass using the appropriate dead wood density class. If the top of the standing dead tree is missing, the height of the remaining stem is measured and the top diameter is estimated as the ratio of the top diameter to the basal diameter.

Step 5: The amount of biomass is summed over all the species to obtain the total standing dead wood for the stratum.

Step 6 The carbon stock of the standing deadwood in the stratum is calculated using the following equation:

$$C_{SDW,i,m} = B_{SDW,i,m} * CF_{DW} \quad \textbf{(M.23)}$$

where:

$C_{SDW,i,m}$ Carbon stock of standing deadwood in stratum *i* at monitoring event *m;* t C

$B_{SDW,i,m}$ Biomass of standing deadwood in stratum *i,* at monitoring event *m*; t d.m.

CF_{DW} Carbon fraction of deadwood, t C (t d.m.)$^{-1}$

a.2.2 Lying dead wood

The lying dead wood pool is highly variable in young stands and it increases as the stands grow. If there is negligible amount of lying dead wood observed in the early stages of a stand, its monitoring could be taken up in the second or subsequent monitoring periods. The information on the occurrence of lying deadwood can be assessed from the plot surveys.

Step 1: Lying deadwood should be sampled using the line intersect method (Harmon and Sexton, 1996)[22]. Two 50-meter lines are established bisecting each plot and the diameters of the lying dead wood (≥ 5 cm diameter) intersecting the lines are measured.

Step 2: The dead wood is assigned to one of the three density states (sound, intermediate, and rotten).

Step 3: Volume of lying deadwood per unit area is calculated using the following equation (IPCC 2003, Eq. 4.3.2):

$$V_{iq,sp,t} = \frac{\pi^2 \times \sum_{m=1}^{M} Dm_{iq,sp,t}^2}{8 \times L_{i,sp}} \qquad \textbf{(M.24)}$$

where:

$V_{iq,sp,t}$	Total volume of lying deadwood of density class *q* for plot *sp* in stratum *i* in year *t*; $m^3\ ha^{-1}$
$Dm_{iq,sp,t}$	Diameter of the piece *m* of necromass of density class *q*, intersected by the transect in plot *sp* in stratum *i* in year *t*; cm.
$L_{i,sp}$	Length of the transect for determining lying deadwood of plot *sp* in stratum *i*; m.
q	Index for density class.
sp	Index for sample plots
i	*1, 2, 3, …* M_{PS} strata in the project scenario
m	*1,2,3, … .M*pieces of necromass
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity.

The following is the equation for calculating the carbon stock in deadwood pool for the *sp* plot:

$$C_{LDW,i,sp,t} = \left(\sum_{q=1}^{Q} V_{iq,sp,t} * \rho_q \right) \times CF_{DW} \qquad \textbf{(M.25)}$$

where:

$C_{LDW,i,sp,t}$	Carbon stock in lying deadwood pool for plot *sp* in stratum *i* in year *t;* t C ha^{-1}
$V_{iq,sp,t}$	Total volume of lying deadwood of density class *q* for plot *sp* in stratum *i* at year *t;* $m^3\ ha^{-1}$
ρ_q	Density of density class *q* of deadwood; t d.m. m^{-3}
CF_{DW}	Carbon fraction of deadwood; t C (t d.m.)$^{-1}$
q	Index for density classes
Q	Total number of density classes

22 Harmon, M. E. and J. Sexton. (1996) Guidelines for Measurements of Woody Detritus in Forest Ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

sp	Index for sample plots
i	*1, 2, 3, …* M_{PS} strata in the project scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Step 4: Calculate the carbon stock in the lying deadwood ($C_{LDWi,m}$) for each stratum based on the average value of the plots and the area of the stratum.

a.3 Litter (fine necromass)

Litter includes all dead biomass of less than 10-cm diameter and dead leaves, twigs, dry grass, and small branches. The litter accumulation is a function of annual amount of litter fall minus the annual rate of decomposition. During early stages of stand development, litter increases rapidly and stabilizes during the later part of the stand. Therefore, litter samples shall be collected at the same time of the year in order to account for natural and anthropogenic influences on the litter accumulation and to eliminate seasonal effects.

Step 1: Litter shall be sampled using a 30-cm radius circular frame. The frame is placed at four locations within the sample plot.

Step 2: At each location, all litter (leaves, fruits, small wood, etc.) falling inside the frame shall be collected and the litter from four locations is mixed to get a representative sample for measuring the wet weight of the biomass.

Step 3: A subsample of litter is taken, oven dried and weighed to determine the dry weight. The dry to wet weight ratio of the subsample is calculated.

Step 4: To estimate the dry litter biomass in tonnes per ha, the wet litter biomass for the sample plots is multiplied by the ratio calculated in the step 3 and an expansion factor for the plot size to calculate the litter biomass per ha (10,000 m^2/ (4 * area of sampling frame in m^2)).

$$B_{LI,i,sp,m} = 2.5 * B_{LI\_wet,i,sp,m} * \frac{MP_L}{a_{i,sp}} \quad \textbf{(M.26)}$$

where:

$B_{LI,i,sp,m}$	Biomass of dry litter for plot *sp* in stratum *i* at monitor time *;* t d.m. ha^{-1}
$B_{LI\_wet,i,sp,m}$	Humid weight (field) of the litter in plot *sp* of stratum *i*; kg m^{-2}
MP_{LI}	Dry-to-wet weight ratio of the litter (dry weight/wet weight)
$a_{i,sp}$	Area of sampling frame; m^2

Step 5: Calculate the biomass of the litter ($B_{LI,i,m}$ in t. d.m.) for each stratum based on the average value of the plots and the area of the stratum.

Step 6: The average annual change in the carbon stock of litter from the data at two monitoring intervals shall be calculated. As recommended in the Good Practice Guidance on LULUCF (Chapter 3.2, p 3.35), the dry mass of litter is converted into carbon using 0.370 t C (t d.m.)$^{-1}$ as default value[23] instead of the default carbon fraction (0.5 t C (t d.m.)$^{-1}$) used for biomass.

$$\Delta C_{LI,i,t} = [(B_{LI,i,m2} - B_{LI,i,m1}) / T_L] * CF_{LI} \quad \textbf{(M.27)}$$

where:

$\Delta C_{LI,i,t}$	Changes in carbon stock change in the litter carbon pool for stratum *i* for year *t*; t C yr^{-1}
$B_{LI,i,m2}$	Biomass of litter in stratum *i* at monitoring event m_2; t d.m.
$B_{LI,i,m1}$	Biomass of litter in stratum *i* at monitoring event m_1; t d.m.
T_L	Monitoring interval for litter $T_L = m_2 - m_1$; yr
CF_{LI}	Carbon fraction of litter; t C (t d.m.)$^{-1}$

(b) Increase in GHG emissions by the sources within the project boundary resulting from implementation of the A/R project activity

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

$$GHG_{E,t} = E_{FuelBurn,t} + E_{biomass\ loss,t} + E_{non-CO2,BiomassBurn,t} + E_{fertilizer,t} + E_{livestock,t} \quad \textbf{(M.28)}$$

where:

$GHG_{E,t}$	Increase in GHG emissions resulting from implementation of the A/R project activity in year *t*; t CO_2-e yr^{-1}
$E_{FuelBurn,t}$	Increase in GHG emission as a result of burning of fossil fuels in year *t*; t CO_2-e yr^{-1}
$E_{biomass\ loss,t}$	Oxidation of the pre-project aboveground biomass of permanent non-tree vegetation in year *t*; t CO_2-e yr^{-1}
$E_{non-CO2,BiomassBurn,t}$	Increase in non-CO_2 emissions as a result of burning of biomass in year *t*; t CO_2-e yr^{-1}
$E_{fertilizer,t}$	Direct N_2O emissions as a result of fertilizer application in year *t*; t CO_2-e yr^{-1}
$E_{livestock,t}$	Increase in GHG emissions due to an increase above baseline levels of the population of livestock in the project area, in year *t*; t CO_2-e yr^{-1}

Note that the biomass loss and biomass burning components of eqn. M.27 may involve different biomass stocks.

23 Smith and Heath, 2002

b.1 GHG emissions from burning of fossil fuel

To estimate the increase in GHG emissions related to fossil fuel combustion ($E_{FuelBurn,t}$) from vehicles (mobile sources, such as trucks, tractors, etc.) and mechanical equipment (e.g., portable equipment such as chain saws and steady equipment such as, water pumps) required by the A/R CDM project activity, project participants shall use the latest version of A/R methodological tool approved by the CDM Executive Board: *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*[24]

b.2 Decrease in carbon stock in aboveground biomass of pre-project permanent non-tree vegetation biomass

It is assumed that all non-tree vegetation as well as all deadwood and litter within the project area will be oxidized instantaneously at the start of the project due to site preparation due to competition from planted trees. This is a conservative assumption because there will likely be some non-tree vegetation regrowth in the project scenario The resulting GHG emission shall be accounted only once at the start of the project activity. The decrease in the carbon stock in the non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation is calculated as:

$$E_{biomass\ loss} = \sum_{i=1}^{M_{PS}} B_{pre,i} * A_i * CF_{pre} * 44/12 \qquad \textbf{(M.29)}$$

where:

$E_{biomass\ loss}$	Decrease in the carbon stock in the non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation in the year of site preparation; t CO_2-e
A_i	Area of stratum *i*; ha
$B_{pre,i}$	Average pre-existing stock of pre-project biomass in the non-tree living biomass (aboveground and belowground), deadwood and litter carbon pools on land of a proposed A/R CDM project activity for baseline stratum *i*; t d.m. ha^{-1}
CF_{pre}	Mean carbon fraction of dry biomass in pre-existing vegetation; t C $(t\ d.m.)^{-1}$
44/12	Ratio of molecular weights of CO_2 and carbon; t CO_2-e t^{-1} C)
i	*1, 2, 3, … M_{PS}* strata in the project scenario (ex post)

Average pre-existing stock of pre-project biomass in the non-tree living biomass (aboveground and belowground), deadwood and litter carbon pools on land of a proposed A/R CDM project activity shall be measured/estimated using methods described above in this section.

b.3 Non-CO_2 GHG emissions from biomass burning

Estimate the non-CO_2 emissions of wildfires after the project commences based on the aboveground biomass of both trees that existed at the time the project started[25], and living and dead tree biomass

[24] CDM Executive Board Meeting Report EB33, Annex 14: *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities.*

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

resulting from the A/R activity. This will have been determined as part of Section III.5. above if at least one cycle of monitoring has been completed, or if not can be obtained from ex ante estimates.

$$E_{BiomassBurn,C} = \sum_{i=1}^{n_{st}} \sum_{j=1}^{n_{sp}} A_{burn,i} * B_{AB,ij} * CE * CF_j \qquad \textbf{(M.30)}$$

where:

$E_{BiomassBurn,C}$	Loss of carbon stock in aboveground living and dead biomass due to biomass burning; t C yr^{-1}
$A_{burn,i}$	Area of biomass burning for stratum *i*; ha yr^{-1}
$B_{AB,ij}$	Average aboveground stock of living and dead tree 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	Combustion efficiency; dimensionless
CF_j	Carbon fraction of dry matter for species or type *j* (IPCC default = 0.5 shall be considered as a conservative approximation); t C (t d.m.)$^{-1}$
i	*1, 2, 3, … M_{PS}* strata in the project scenario
j	*1, 2, 3, ... S_{PS}* tree species in the project scenario

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 non-CO_2 GHG emissions from biomass burning are estimated using the following calculations which are based on the revised IPCC 1996 Guidelines for LULUCF, and the GPG- LULUCF:

$$E_{non-CO_2,BiomassBurn,t} = E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \qquad \textbf{(M.31)}$$

where:

$E_{non\text{-}CO2,BiomassBurn,t}$	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:

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,C} * \left(N/_{C}\,ratio\right) * ER_{N_2O} * 44/28 * GWP_{N_2O} \qquad \textbf{(M.32)}$$

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,C} * ER_{CH_4} * 16/12 * GWP_{CH_4} \qquad \textbf{(M.33)}$$

where[26]:

$E_{BiomassBurn,\ N2O}$	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}
$E_{BiomassBurn,C}$	Loss of carbon stock in aboveground living biomass, deadwood and litter due to biomass burning; t C yr^{-1}
N/C ratio	Nitrogen–carbon ratio (IPCC default: 0.01); dimensionless
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 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.

b.4 Nitrous oxide emissions from nitrogen fertilization practices

To estimate N_2O emissions from fertilizers ($E_{fertilizer,t}$) project participants shall use the latest version of A/R Methodology tool approved by the CDM Executive Board: *Estimation of direct nitrous oxide emissions from nitrogen fertilization*[27]

b.5 Emissions from an increase in livestock population

If the population of grazing animals within the project boundary increases above baseline levels due to project silvopastoral activities, increased GHG emissions due to enteric digestion (as applicable), and manure management, shall be estimated. Estimation is based on IPCC default methodology, using simple emission factors expressed on a per-head livestock basis. As per an applicability condition of the project, manure remains in the field, and no manure management or gathering practices are permitted.

To estimate the increase in emissions:

1. Conduct a census of, or estimate from regional or national statistics, the number (*Pop*) and type (L*T*) of livestock grazing within the proposed project boundary prior to the start of the project, $Pop_{BSL,T}$
2. Determine, and monitor annually during the project, the number and type of animals grazing within the project boundary, $Pop_{Proj,LT}$.

---

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

[27] CDM Executive Board Meeting Report EB33, Annex 16: *Estimation of direct nitrous oxide emission from nitrogen fertilisation.*

3. Use equations (B.47)–(B.48) in Section II.7.b.5 to estimate the annual increase in livestock emissions, $E_{livestock}$. If $Pop_{Proj,LT} \leq Pop_{BSL,T}$, then $E_{livestock} = 0$.

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.

Data to be collected or used in order to monitor the verifiable changes in carbon stock in carbon pools

ID number	Data variable	Data Unit	Data source	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Propor-tion of data to be monitored	Comment
6.1.1 - 1	Actual net GHG removals by sinks in year *t* ($\Delta C_{ACTUAL,t}$)	t CO_2-e yr^{-1}		c	Every 5 years	100%	
6.1.1 - 2	Area of stratum *i* (A_i)	ha	On-site measure-ment or remote sensing	m	Every 5 years	100%	
6.1.1 - 3	Area of implementation of the project activity in stratum *i* in year *t*	ha	On-site measure-ment or remote sensing	m	Every 5 years	100%	
6.1.1 - 4	Area of sample plot (A_{sp})	ha	Predefined	Predefined	S. comment	S. comment	Remeasured for quality control
6.1.1 - 5	Area of sampling frame ($a_{i,sp}$)	m^2	Predefined	Predefined			
6.1.1 - 6	Basic wood density of species *j* (D_j)	t d.m. m^{-3}	Default value				
6.1.1 - 7	Biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j* ($BEF_{2,j}$)	Dimensionless	Default value	e			
6.1.1 - 8	Biomass of standing deadwood in stratum *i*, at monitoring event *m* ($B_{SDWi,m}$)	t d.m	Plot measure-ments	c	Every 5 years	Total area though sample plots	
6.1.1 – 9	Biomass of dry litter for plot *sp* in stratum *i* at monitor time *m* ($B_{LI,i,sp,m}$)	t d.m. ha^{-1}	Plot measure-ments	c	Every 5 years	Total area though sample plots	

ID number	Data variable	Data Unit	Data source	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
6.1.1 – 10	Biomass of dry litter in stratum *i* at monitoring event *m* ($B_{LI,i,m}$)	t d.m.	Plot measurements	c	Every 5 years	Total area though sample plots	
6.1.1 – 11	Carbon fraction of dry matter for tree species *j* (CF_j)	t C (tonne d.m.)$^{-1}$	Default value	e			IPCC default value = 0.5 t C (tonne d.m.)$^{-1}$
6.1.1 – 12	Carbon fraction of permanent non-tree vegetation (CF_p)	t C (t d.m.)$^{-1}$	Default value	e			
6.1.1 – 13	Carbon fraction of deadwood (CF_{DW})	t C (t d.m.)$^{-1}$	Default value	e			
6.1.1 – 14	Carbon fraction of litter (CF_{LI})	t C (t d.m.)$^{-1}$	Default value	e			
6.1.1 – 15	Carbon stock in biomass of trees for stratum *i*, calculated at time *t* ($C_{tree,i,t}$)	t C	Plot measurements	c	Every 5 years	Total area though sample plots	
6.1.1 – 16	Carbon stock in biomass of permanent non-tree vegetation for stratum *i*, calculated at time *t* ($C_{pnon\text{-}tree,i,t}$)	t C	Plot measurements	c	Every 5 years	Total area though sample plots	
6.1.1 – 17	Carbon stock in aboveground biomass of trees for stratum *i*, at time *t* ($C_{AB\_tree,i,t}$)	t C	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 18	Carbon stock in aboveground biomass of permanent non-tree vegetation for stratum *i* species *j*, at time *t* ($C_{AB\_pnon\text{-}tree,ij,t}$)	t C	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 19	Carbon stock in aboveground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t* ($C_{AB\_tree,l,ij,sp,t}$)	t C tree^{-1}	Plot measurements	c	Every 5 years	Total area of plot for trees	

ID number	Data variable	Data Unit	Data source	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
6.1.1 – 20	Carbon stock in aboveground biomass of planted permanent non-tree vegetation for stratum *i*, at time *t* ($C_{AB\_pnon\text{-}tree,i,t}$)	t C	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 21	Carbon stock in belowground biomass of trees for stratum *i*, at time *t* ($C_{BB\_tree,i,t}$)	t C	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 22	Carbon stock in belowground biomass of trees of species *j* on plot *sp* of stratum *i* at time *t* ($C_{BB\_tree,ij,sp,t}$)	t C	Plot measurements	c	Every 5 years	Total area of plot for trees	
6.1.1 – 23	Carbon stock in aboveground biomass of trees on plot *sp* of stratum *i* at time *t* ($C_{AB\_tree,i,sp,t}$)	t C					
6.1.1 – 24	Carbon stock in belowground biomass of trees on plot *sp* of stratum *i* at time *t* ($C_{BB\_tree,i,sp,t}$)	t C	Plot measurements	c	Every 5 years	Total area of plot for trees	
6.1.1 – 25	Carbon stock in belowground biomass of tree *l* of species *j* in plot *sp* at time *t* ($C_{BB\_tree,l,ij,sp,t}$)	t C $tree^{-1}$	Plot measurements	c	Every 5 years	Total area of plot for trees	
6.1.1 – 26	Carbon stock in belowground biomass of planted permanent non-tree vegetation for stratum *i*, at time *t* ($C_{BB\_pnon\text{-}tree,i,t}$)	t C	Plot measurements	c	Every 5 years	Total area through sample plots	

ID number	Data variable	Data Unit	Data source	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Propor-tion of data to be monitored	Comment
6.1.1 – 27	Carbon stock in belowground biomass of permanent non-tree vegetation of species *j* in stratum *i* at time *t* ($C_{BB\_pnon\text{-}tree,ij,t}$)	t C	Plot measure-ments	c	Every 5 years	Total area through sample plots	
6.1.1 - 28	Carbon stock in aboveground biomass of tree species *j* in stratum *i,* at time *t* ($C_{AB\_tree,ij,t}$)	t C	Plot measure-ments	c	Every 5 years	Total area of plot for trees	
6.1.1 – 29	Carbon stock in belowground biomass of trees species *j* in stratum *i,* at time *t* ($C_{BB\_tree,ij,t}$)	t C	Plot measure-ments	c	Every 5 years	Total area through sample plots	
6.1.1 – 30	Carbon stock in aboveground biomass of tree species *j* stratum *i*, sample plot *sp* at time *t* ($C_{AB\_tree,ij,sp,t}$)	t C ha^{-1}	Plot measure-ments	c	Every 5 years	Total area through sample plots	
6.1.1 – 31	Carbon stock in belowground biomass of tree species *j* stratum *i*, sample plot *sp* at time *t* ($C_{BB\_tree,ij,sp,t}$)	t C ha^{-1}	Plot measure-ments	c	Every 5 years	Total area through sample plots	
6.1.1 – 32	Carbon stock in aboveground biomass of permanent non-tree vegetation of species j in stratum i, sample plot *sp* at time *t* ($C_{AB\_pnon\text{-}tree,ij,sp,t}$)	t C ha^{-1}	Plot measure-ments	c	Every 5 years	Total area through sample plots	

ID number	Data variable	Data Unit	Data source	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
6.1.1 – 33	Carbon stock in belowground biomass of permanent non-tree vegetation for stratum *i*, non-tree species *j*, sample plot *sp* at time t ($C_{BB\_pnon\text{-}tree,ij,sp,t}$)	t C ha^{-1}	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 34	Carbon stock of deadwood in stratum *i* at monitoring event m ($C_{DWi,m}$)	t C	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 35	Carbon stock of standing deadwood in stratum *i* at monitoring event *m* ($C_{SDW,i,m}$)	t C	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 36	Carbon stock of lying deadwood in stratum *i,* at monitoring event *m* ($C_{LDW,i,m}$)	t C	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 37	Carbon stock in lying deadwood pool for plot *sp* in stratum *i* in year *t* ($C_{LDW,i,sp,t}$)	t C ha^{-1}	Plot measurements	c	Every 5 years	Total area of plot for trees	
6.1.1 – 38	Changes in carbon stock inbiomass of trees for stratum *i* for year *t* ($\Delta C_{tree,i,t}$)	t C yr^{-1}	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 39	Changes in carbon stock in biomass of permanent non-tree vegetation for stratum *i* for year *t* ($\Delta C_{pnon\text{-}tree,i,t}$)	t C yr^{-1}	Plot measurements	c	Every 5 years	Total area of plot for trees	
6.1.1 - 40	Changes in carbon stock in the deadwood carbon pool for stratum *i* for year *t* ($\Delta C_{DW\,i,t}$)	t C yr^{-1}	Plot measurements	c	Every 5 years	Total area through sample plots	

ID number	Data variable	Data Unit	Data source	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
6.1.1 – 41	Changes in carbon stock change in the litter carbon pool for stratum *i* for year *t* ($\Delta C_{LI,\ i,t}$)	t C yr^{-1}	Plot measurements	c	Every 5 years	Total area through sample plots	
6.1.1 – 42	Density of density class *q* of deadwood (ρ_q)	t d.m. m^{-3}	Parameter measurement	m	Once	To meet predefined tolerable error	
6.1.1 – 43	Diameter at breast height of tree *l* of species *j* of stratum *i* at time *t* ($DBH_{i,j,l,t}$)	cm	Plot measurements	m	Every 5 years	100% of trees above threshold in sample plots	
6.1.1 – 44	Diameter at breast height of standing dead wood piece *l* of species *j* of stratum *i* at time *t*	cm	Plot measurements	m	Every 5 years	100% of standing deadwood in sample plots	
6.1.1 – 45	Diameter of the piece *m* of necromass of density class *q*, intersected by the transect in plot *sp* in stratum *i* in year *t* ($Dm_{iq,sp,t}$)	cm	Plot measurements	m	Every 5 years	100% of lying deadwood above threshold in sample plots	
6.1.1 – 46	Dry weight (laboratory) of the subsample of litter in plot *sp* of stratum *i*	kg	Plot measurements	m	Every 5 years	100%	
6.1.1 – 47	Dry-to-wet weight ratio of the litter (MP_{LI})	%	Plot measurements	c	Every 5 years		Ratio of 6.1.1-38 and 6.1.1-42
6.1.1 – 48	Height of tree *l* of species *j* of stratum *i* at time *t* ($H_{i,j,l,t}$)	m	Plot measurements	m	Every 5 years	100% of trees above threshold in sample plots	

ID number	Data variable	Data Unit	Data source	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Propor-tion of data to be monitored	Comment
6.1.1 – 49	Height of standing dead wood pice *l* of species *j* of stratum *i* at time *t* ($H_{i,j,l,t}$)	m	Plot measurements	m	Every 5 years	100% of standing deadwood in sample plots	
6.1.1 – 50	Humid weight (field) of the litter in plot *sp* of stratum *I* ($B_{LI\_wet,i,sp,m}$)	kg m^{-2}	Plot measurements	m	Every 5 years	100%	
6.1.1 – 51	Increase in GHG emissions by the sources within the project boundary resulting from implementation of the A/R project activity in year *t* ($GHG_{E,t}$)	t CO_2-e yr^{-1}		c			
6.1.1 – 52	Length of the transect for determining lying deadwood of plot *sp* in stratum *i* ($L_{i,sp}$)	m	Predefined	Predefined			
6.1.1 – 53							
6.1.1 – 54	Merchantable volume of tree *l* of species *j* in plot *sp* in stratum *i* at time *t* ($V_{l,ij,sp,t}$)	m^3 $tree^{-1}$	Plot measurements	e	Every 5 years	100%	
6.1.1 – 55	Monitoring interval for dead wood (T_{DW}) $T_{DW} = m_2 - m_1$ (where m_2 and m_1 are the two most recent monitoring events)	yr					
6.1.1 – 56	Monitoring interval for litter (T_L)	yr					
6.1.1 – 57	Root-shoot ratio appropriate for biomass stock, for species *j* (R_j)	Dimensionless	Default value	e	Every 5 years	100%	
6.1.1 – 58	Root-shoot ratio of permanent non-tree vegetation species *j* ($R_{p,j}$)	Dimensionless	Default value	e	Every 5 years	100%	

ID number	Data variable	Data Unit	Data source	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Propor-tion of data to be monitored	Comment
6.1.1 – 59	Verifiable changes in the carbon stock of living biomass resulting from implementation of the A/R activity for stratum *i* in year *t* ($\Delta C_{i,t}$)	t CO_2-e yr^{-1}	Plot measurements	c	Every 5 years	100%	
6.1.1 – 60	Total volume of lying deadwood of density class *q* for plot *sp* in stratum *i* in year *t* ($V_{iq,sp,t}$)	m^3 ha^{-1}	Plot measurements	c	Every 5 years	100%	

Data to be collected or used in order to monitor GHG emissions by sources

ID number	Data variable	Data unit	Source of data	Measured (m) Calcu-lated (c) or Estimated (e)	Recording frequency	Propor-tion of data to be monitored	Comment
6.1.2 – 1	Area of stratum *i* (A_i)	ha					
6.1.2 – 2	Average pre-existing stock of pre-project biomass in the non-tree living biomass (aboveground and belowground), deadwood and litter carbon pools on land of a proposed A/R CDM project activity for baseline stratum *i* ($B_{pre,i}$)	t d.m. ha^{-1}					
6.1.2 – 3	Area of stratum *i* subject to burning ($A_{burn,i}$)	t C yr^{-1}	On-site measure-ment or remote sensing	m		100%	

ID number	Data variable	Data unit	Source of data	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
6.1.2 – 4	Average aboveground stock of living and dead biomass resulting from the A/R activity, plus that in trees that existed within the project boundary at the time the project commenced, for stratum *i* species *j* ($B_{AB,ij}$)	t d.m. ha^{-1}	Plot measurements	c		Total area of plot for trees	
6.1.2 –5	Carbon fraction of dry biomass for tree species *j* (CF_j)	t C (t d.m.)$^{-1}$.	Default value	e			
6.1.2 –6	Combustion efficiency (*CE*)	Dimensionless	Default value	e			
6.1.2 –7	Direct N_2O emissions as a result of fertilizer application in year *t* (($E_{fertilizer,t}$))	t CO_2-e yr^{-1}	Measurements	c	Every 5 years		
6.1.2 –8	Increase in GHG emissions resulting from implementation of the A/R project activity in year *t* ($GHG_{E,t}$)	t CO_2-e yr^{-1}	Measurements	c	Every 5 years		
6.1.2 –9	Increase in GHG emission as a result of burning of fossil fuels in year *t* ($E_{FuelBurn,t}$)	t CO_2-e yr^{-1}	Measurements	c	Every 5 years		
6.1.2 –10	Emission factor for enteric methane production for livestock type *LT* ($EF_{Enteric,\ CH4,LT}$)	kg CH_4 $head^{-1}$ yr^{-1}	Default value	e			
6.1.2 –11	Emission factor for methane production from manure for livestock type *LT* ($EF_{Manure,\ CH4,\ LT}$)	kg CH_4 $head^{-1}$ yr^{-1}	Default value	e			

ID number	Data variable	Data unit	Source of data	Measured (m) Calcu-lated (c) or Estimated (e)	Recording frequency	Propor-tion of data to be monitored	Comment
6.1.2 –12	Emission factor for nitrous oxide production from manure for livestock type *LT* ($EF_{Manure, N2O, LT}$)	kg N_2O head^{-1} yr^{-1}	Default value	e			
	Emission factor for N_2O emissions from dung and urine deposited on pasture ($EF_{3, LT}$)	kg N_2O -N (kg N input)$^{-1}$	Default value				
6.1.2 –13	Increase in GHG emissions due to an increase above baseline levels of the population of livestock in the project area, in year *t* ($E_{livestock, t}$)	t CO_2-e yr^{-1}	Measurements	c	Every 5 years		
6.1.2 –14	Increase in non-CO_2 emissions as a result of burning of biomass in year *t* ($E_{non\text{-}CO2,BiomassBurn,t}$)	t CO_2-e yr^{-1}	Measurements	c	Every 5 years		
6.1.2 –15	Livestock type; *1 … n* (*LT*)	dimensionless					
6.1.2 –16	Loss of carbon stock in aboveground biomass of non-tree vegetation due to biomass burning in year *t* ($E_{BiomassBurn,C}$)	t C yr^{-1}	Plot measurements	c	Every 5 years		
6.1.2 –17	Mean carbon fraction of dry biomass in pre-existing vegetation (CF_{pre})	t C (t d.m.)$^{-1}$	Default value	e			
6.1.2 –18	Oxidation of the pre-project aboveground biomass of permanent non-tree vegetation in year *t* ($E_{biomass\ loss,t}$)	t CO_2-e yr^{-1}	Measurements	c	Every 5 years		

ID number	Data variable	Data unit	Source of data	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
6.1.2 –19	Population of livestock type *LT* in the project area ($Pop_{Proj, LT}$)	head	Measurements	m	Every 5 years		
6.1.2 –20	N_2O emission from biomass burning ($E_{BiomassBurn, N2O}$)	t CO_2-e yr^{-1}	Measurements	c	Every 5 years		
6.1.2 –21	CH_4 emission from biomass burning ($E_{BiomassBurn, CH4}$)	t CO_2-e yr^{-1}	Measurements	c	Every 5 years		

7. Leakage

Under applicability conditions of this methodology, the potential leakage emissions attributable to the proposed A/R project activity are those from fossil fuel combustion and collection of wood from non-renewable sources to be used for fencing of the project area. Total leakage emissions are thus given by:

$$LE_t = LE_{FuelBurn,t} + LE_{WP,t} \quad \textbf{(M.34)}$$

where:

LE_t Total estimated leakage due to the project in year *t*; t CO_2-e

$LE_{FuelBurn, t}$ Leakage emissions from combustion of fossil fuels, in year *t*; t CO_2 yr^{-1}

$LE_{WP,t}$ Estimated leakage from fence activity due to the project in year *t*; t CO_2-e

t *1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Annual emissions from combustion of fossil fuels outside the project boundary but attributable to project activities, $LE_{FuelBurn, t}$, are estimated using the latest version of the following A/R methodological tool approved by the CDM Executive Board: *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*[28]

Project participants can prevent leakage from the use of wood for fencing by archiving evidence to support the fact that wood for fences comes from a sustainable source. If a project fails to prevent leakage from deforestation for fencing, project participants will subtract the estimated emissions calculated using as activity data the linear length of fencing implemented, as follows:

$$LE_{WP,t} = \left[\sum_{i=1}^{I} \frac{LM_{it}}{dp_i} * Vp * (1+Wp) * D_j * CEF_j * (1+R_j) * CF_j \right] * 44/12 \quad \text{(M.35)}$$

[28] CDM Executive Board Meeting Report EB33, Annex 14: *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities.*

where:

$LE_{WP,t}$	Estimated leakage from fence activity due to the project in year *t*; t CO_2-e
$LM_{i,t}$	Linear meters for fencing in stratum *i* in year *t*; m ha^{-1}
dp_i	Distance between wood posts in fences for stratum *i*; m
Vp	Average volume of each wood post for fences; m^3
Wp	Waste fraction of unsustainable logging to extract wood posts; percentage
D_j	Basic wood density for tree species *j*; t m^{-3}
CEF_j	Crown expansion factor : the ratio of crown and stem biomass to stem biomass for tree species *j*; dimensionless
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; ; dimensionless
CF_j	Carbon fraction of biomass for tree species *j; t C (t d.m.)$^{-1}$*
44/12	Carbon to CO_2 conversion factor; t CO_2 t^{-1} C).
i	Index for stratum.
I	Total number of strata.
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity.

Data to be collected and archived for leakage

ID number	Data variable	Data unit	Source of data	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
7.1 – 1	Average volume of each wood post for fences (*Vp*)	m^3	Parameter measurement	e	Once	To meet predefined tolerable error	Only if project does not prevent leakage
7.1 – 2	Basic wood density for tree species *j* (D_j)	t m^{-3}					
7.1 – 3	Carbon fraction of biomass for tree species *j* (CF_j)	t C (t d.m.)$^{-1}$	Parameter measurement	e	Once	To meet predefined tolerable error	
7.1 – 4	Crown expansion factor: the ratio of crown and stem biomass to stem biomass for tree species *j* (CEF_j)	Dimensionless					

ID number	Data variable	Data unit	Source of data	Measured (m) Calculated (c) or Estimated (e)	Recording frequency	Proportion of data to be monitored	Comment
7.1 – 5	Distance between wood posts in fences in stratum *i* (dp_j)	m	On-site visits	e	Once	To meet predefined tolerable error	Only if project does not prevent leakage
7.1 – 6	Land use of areas prior to the implementation of the project activity		On-site visits	Verified	Once	100%	
7.1 – 7	Leakage emissions from combustion of fossil fuels, in year *t* ($LE_{FuelBurn,t}$)	$t\ CO_2\ yr^{-1}$	Parameter measurement	e	Once	To meet predefined tolerable error	Only if project does not prevent leakage
7.1 – 8	Leakage from fence activity due to the project until year *t* ($LE_{WP,t}$)	$t\ CO_2$	On-site visit	c	Annually	100%	Only if project does not prevent leakage
7.1 – 9	Property rights of parcels		Legal titles and agree-ments with landholders	Verified	Once	100%	
7.1 – 10	Linear meters for fencing in stratum *i* in year *t* ($LM_{i,t}$)	$m\ ha^{-1}$	On-site visits	e	Once	100%	Only if project does not prevent leakage
7.1 – 11	Root-shoot ratio appropriate for biomass stock, for species *j* (R_j)	*Dimensionless*					
7.1 – 12	Total estimated leakage due to the project in year *t* (LE_t)	$t\ CO_2$-e	Parameter measurement	e	Once	To meet predefined tolerable error	Only if project does not prevent leakage
7.1 – 13	Waste fraction of unsustainable logging to extract wood posts (*Wp*)	Fraction	Parameter measurement	e	Once	To meet predefined tolerable error	Only if project does not prevent leakage

8. 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:

$$C_{AR\_CDMt} = \Delta C_{ACTUALt} - \Delta C_{BSLt} - LE_t \quad \textbf{(M.36)}$$

where:

$C_{AR\_CDM,t}$	Net anthropogenic GHG removals by sinks for year t; t CO_2-e yr^{-1}
$\Delta C_{ACTUAL,t}$	Actual net GHG removals by sinks for year t; t CO_2-e yr^{-1}
$\Delta C_{BSL,t}$	Baseline net GHG removals by sinks for year t; t CO_2-e yr^{-1}
LE_t	Leakage for year t; t CO_2-e yr^{-1}

9. 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 from annually-integrated data provided 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-e;
- Carbon stocks for the baseline scenario at the time of verification $C_B(t_v)$; t CO_2-e;
- Project emissions for year *t*, GHG_t; t CO_2-e;
- Leakage emissions for year *t*, LE_t; t CO_2-e;
- Year of verification, t_v; yr;
- Time span between two verifications, κ; yrs.

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[29];

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

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 underestimate, rather than overestimate, net GHG removals by sinks.

Section IV: Lists of variables, acronyms and references

1. List of variables used in equations:

Variable	SI Unit	Description
$\Delta C_{AB,i,t}$	t C yr^{-1}	Changes in carbon stock in aboveground biomass of trees and permanent non-tree vegetation for stratum *i,* for year *t*
$\Delta C_{BB,i,t}$	t C yr^{-1}	Changes in carbon stock in belowground biomass of trees and permanent non-tree vegetation for stratum *i,* for year *t*
$\Delta C_{pnon\text{-}tree,i,t}$	t C yr^{-1}	Changes in carbon stock in biomass of permanent non-tree vegetation for stratum *i* for year *t*
$\Delta C_{ACTUAL,t}$	t CO_2-e yr^{-1}	Actual net GHG removals by sinks of the project activity in year *t*
$\Delta C_{tree,i,t}$	t C yr^{-1}	Changes in carbon stock in biomass of trees for stratum *i* for year *t*
$\Delta C_{G,ij,t}$	t CO_2 yr^{-1}	Annual increase in carbon due to biomass growth of living trees of species j in stratum i, for year *t*
$\Delta C_{G,DW,ij,t}$	t CO_2-e ha^{-1} yr^{-1}	Annual input of carbon stock to the deadwood pool for species *j* in stratum *i*, for year *t*
$\Delta C_{G,LI,ij,t}$	t CO_2-e ha^{-1} yr^{-1}	Annual input of carbon stock to the litter pool for species *j* in stratum *i*, for year *t*
$\Delta C_{L,DW,ij,t}$	t CO_2-e ha^{-1} yr^{-1}	Annual loss of carbon stock in the deadwood pool for species *j* in stratum *i*, for year *t*
$\Delta C_{i,t}$	t CO_2-e yr^{-1}	Verifiable changes in the carbon stock of living biomass resulting from implementation of the A/R activity for stratum *i* in year *t*

Variable	SI Unit	Description
$\Delta C_{ij,BSL,t}$	t CO_2-e yr^{-1}	Baseline average annual carbon stock change due to biomass growth of living trees of species j in stratum i for year *t*
$\Delta C_{L,LI,ij,t}$	t CO_2-e ha^{-1} yr^{-1}	annual loss of carbon stock in the litter pool for species *j* in stratum *i*, for year *t*
$\Delta CLI\ i,t$	t C yr^{-1}	Annual carbon stock change in the litter carbon pool for stratum *i*, for year *t*
$\Delta C_{L,ij,t}$	t CO_2 yr^{-1}	Annual decrease in carbon due to biomass loss of living trees for stratum *i*, species , *j,* for year *t*
ΔC_t	t CO_2-e yr^{-1}	Total changes in carbon stock in carbon pools for year *t*
$\Delta C_{DW\_desc,ij,t}$	t C yr^{-1}	Annual decrease of carbon stock in the deadwood carbon pool due to deadwood decomposition of species *j* in stratum *i*, time *t*
$\Delta C_{LI\_desc,ij,t}$	t C yr^{-1}	Annual decrease of carbon stock in the litter carbon pool due to litter decomposition of species *j* in stratum *i*, time *t*
$\Delta CDW,\ i,t$	t C yr^{-1}	Annual carbon stock change in the deadwood carbon pool for stratum *i*, for year *t*
$\Delta C_{DW,\ ij,t}$	t C yr^{-1}	Annual carbon stock change in the deadwood carbon pool of species *j* in stratum *i*, time *t*
$\Delta CDW,BSL,\ ij,t$	t CO_2-e yr^{-1}	Baseline annual carbon stock change in the deadwood carbon pool of species *j* in stratum *i*, for year *t*
$\Delta C_{DW\_fw,ij,t}$	t C yr^{-1}	Annual decrease of carbon stock in the deadwood carbon pool due to harvesting of deadwood of species *j* in stratum *i*, time *t*
$\Delta CLI_{\_fw,ij,t}$	t C yr^{-1}	Annual decrease of carbon stock in the litter carbon pool due to harvesting of litter of species *j* in stratum *i*, time *t*
$\Delta C_{DW\_hr,ij,t}$	t C yr^{-1}	Annual increase of carbon stock in the deadwood carbon pool due to harvesting residues not collected of species *j* in stratum *i*, time *t*
$\Delta C_{LI\_hr,ij,t}$	t C yr^{-1}	Annual increase of carbon stock in the litter carbon pool due to harvesting residues not collected of species *j* in stratum *i*, time *t*
$\Delta CLI,\ i,t$	t C yr^{-1}	Annual carbon stock change in the litter carbon pool for stratum *i*, for year *t*
$\Delta C_{LI\ ij,t}$	t C yr^{-1}	Annual carbon stock change in the litter carbon pool of species *j* in stratum *i*, time *t*
$\Delta CLI,BSL,\ ij,t$	t CO_2-e yr^{-1}	Baseline annual carbon stock change in the litter carbon pool of species *j* in stratum *i*, for year *t*
$\Delta C_{DW\_mlb,ij,t}$	t C yr^{-1}	Annual increase of carbon stock in the deadwood carbon pool due to mortality of the living biomass of trees of species *j* in stratum *i*, time *t*

Variable	SI Unit	Description
$\Delta C_{LI\_mlb,ij,t}$	$t\ C\ yr^{-1}$	Annual increase of carbon stock in the litter carbon pool due to mortality of the living biomass of trees of species *j* in stratum *i*, time *t*
44/12	$t\ CO_2\ t^{-1}\ C$	Ratio of molecular weights of CO_2 and carbon
$A_{burn,i}$	$ha\ yr^{-1}$	Area of stratum *i* subject to burning
A_i	ha	Area of stratum *i*
A_{ij}	ha	Area of stratum *i* species *j*.
A_{sp}	ha	Area of sample plot
$a_{i,sp}$	m^2	Area of sampling frame
$B_{AB,i}$	$t\ d.m.\ ha^{-1}$	Average aboveground biomass before burning for stratum *i*
$B_{AB,ij}$	$t\ d.m.\ ha^{-1}$	Average aboveground stock of living and dead biomass resulting from the A/R activity, plus that in trees that existed within the project boundary at the time the project commenced, for stratum *i* species *j*
$B_{DW,S,ij}$	$t\ d.m.\ ha^{-1}$	Steady-state biomass stock in the deadwood pool for species *j* in stratum *i*
$BEF_{1,j}$	Dimensionless	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total aboveground tree biomass increment for species *j*
$BEF_{2,j}$	Dimensionless	Biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j*
$EF_{3,\ T}$	kg N_2O-N (kg N input)$^{-1}$	Emission factor for N_2O emissions from dung and urine deposited on pasture; . IPCC default: 0.02 for cattle (dairy, non-dairy, buffalo and pigs), and 0.01 for all other animals (Table 11.1; AFOLU, IPCC 2006).
$B_{LI,\ i,m}$	t d.m.	Biomass of litter in stratum *i* at monitoring event *m*
$B_{LI,\ i,sp,m}$	$t\ d.m.\ ha^{-1}$	Biomass of dry litter for plot *sp* in stratum *i* at monitor time
$B_{LI,S,ij}$	$t\ d.m.\ ha^{-1}$	Steady-state biomass stock in the litter pool for species *j* in stratum
$B_{LI\_wet\ i,sp,m}$	$kg\ m^{-2}$	Humid weight (field) of the litter in plot *sp* of stratum *i*
$B_{SDW,i,m}$	t d.m.	Biomass of standing deadwood in stratum *i,* at monitoring event *m*
Bpre,i	$t\ d.m.\ ha^{-1}$	Average pre-existing stock of pre-project biomass in the non-tree living biomass (aboveground and belowground), deadwood and litter carbon pools on land of a proposed A/R CDM project activity for baseline stratum *i*

Variable	SI Unit	Description
$C_{ij,t}$	t C	Total carbon stock in living biomass of trees of species j in stratum i, calculated at time *t*
$C_{ACTUAL,t}$	t CO_2-e	Actual Net GHG removals by sinks of the project activity in year *t*
$C_{pnon\text{-}tree,i,t}$	t C	Carbon stock in biomass of permanent non-tree vegetation for stratum *i*, calculated at time *t*
$C_{AB\ i,t}$	t C	Carbon stock in aboveground woody biomass for stratum *i*, calculated at time *t*
$C_{AB\_pnon\text{-}tree,i,t}$	t C	Carbon stock in aboveground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*
$C_{AB\_pnon\text{-}tree,ij,t}$	t C	Carbon stock in aboveground biomass of permanent non-tree vegetation of species *j* in stratum *i*, at time t
$C_{AB\_pnon\text{-}tree,ij,sp,t}$	t C ha^{-1}	Carbon stock in aboveground biomass of permanent non-tree vegetation of species *j* in stratum *i,* sample plot *sp* at time *t*
$C_{AB\_tree,i,t}$	t C	Carbon stock in aboveground biomass of trees for stratum *i,* at time *t*
$C_{AB\_tree,ij,t}$	t C	Carbon stock in aboveground tree biomass of species *j* in stratum *i*, at time *t*
$C_{AB\_tree,ij,sp,t}$	t C ha^{-1}	Carbon stock in aboveground biomass of tree species *j* stratum *i*, sample plot *sp* at time *t*
$C_{AB,ij,t}$	t C	Carbon stock in aboveground tree biomass of species *j* in stratum *i*, at time *t*
$C_{AB\_tree,ij,sp,t}$	t C	Carbon stock in aboveground biomass of trees of species *j* on plot *sp* of stratum *i* at time *t*
$C_{BB\_tree,ij,sp,t}$	t C	Carbon stock in belowground biomass of trees of species *j* on plot *sp* of stratum *i* at time *t*
$C_{AB\_tree,l,ij,sp,t}$	t C $tree^{-1}$	carbon stock in aboveground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*
$C_{BB\_tree,l,ij,sp,t}$	t C $tree^{-1}$	carbon stock in belowground biomass of tree *l* of species *j* in plot *sp*at time *t*
$C_{AB\_tree,i,sp,t}$	t C	Carbon stock in aboveground biomass of trees on plot *sp* of stratum *i* at time *t*
$C_{BB\_tree,i,sp,t}$	t C	Carbon stock in belowground biomass of trees on plot *sp* of stratum *i* at time *t*
$C_{AR\text{-}CDM,,t}$	t CO_2-e	Net anthropogenic greenhouse gas removals by sinks in year *t*
$C_{BB,i,t}$	t C	Carbon stock in belowground woody biomass for stratum *i*, calculated at time *t*
$C_{BB,ij,t}$	t C	Carbon stock in belowground tree biomass of species *j* in stratum *i*, at time *t*
$C_{tree,i,t}$	t C	Carbon stock in biomass of trees for stratum *i*, calculated at time *t*
$C_{BB\_tree,i,t}$	t C	Carbon stock in belowground biomass of trees for stratum *i,* at time *t,*

Variable	SI Unit	Description
$C_{BB\_pnontree,ij,sp,t}$	$t\ C\ ha^{-1}$	Carbon stock in belowground biomass of permanent non-tree vegetation of species *j* stratum *i*, sample plot *sp* at time *t*
$C_{BB\_tree,ij,t}$	t C	Carbon stock in belowground tree biomass of species j in stratum i, at time *t*
$C_{BB\_pnon\text{-}tree,i,t}$	t C	Carbon stock in belowground biomass of planted permanent non-tree vegetation for stratum *i,* at time *t*
$C_{BB\_pnon\text{-}tree,ij,t}$	t C	Carbon stock in belowground biomass of permanent non-tree vegetation of species *j* in stratum *i*, at time t
$C_{BSL,t}$	$t\ CO_2\text{-}e\ yr^{-1}$	Sum of the changes in carbon stocks in the baseline for year *t*
$C_{BSL,i,t}$	$t\ CO_2\text{-}e\ yr^{-1}$	Sum of the changes in carbon stocks in the baseline for year *t*
$C_{LDW,i,sp,t}$	$t\ C\ ha^{-1}$	Carbon stock in lying deadwood pool for plot *sp* in stratum *i* in year *t*
$C_{SDW,i,m}$	t C	Carbon stock of standing deadwood in stratum *i* at monitoring event *m*
$C_{LDW,i,m}$	t C	Carbon stock of lying deadwood in stratum *i,* at monitoring event *m*
$C_{DW,i,m}$	t C	Carbon stock of deadwood in stratum *i* at monitoring event *m*
CDW,ij,t	t C	Carbon stock in the deadwood carbon pool in stratum *i*, species *j*, time *t*
CE		Average combustion efficiency for aboveground biomass (IPCC default: 0.5)
CEF_j		Crown expansion factor: the ratio of crown and stem biomass to stem biomass for tree species *j*
CF_{av}	$t\ C\ (t\ d.m)^{-1}$	Average carbon fraction of dry biomass in aboveground biomass; (IPCC default 0.5)
CF_{DW}	$t\ C\ (t\ d.m.)^{-1}$	Carbon fraction of biomass for deadwood
CF	$t\ C\ (t\ d.m.)^{-1}$	Average carbon fraction of dead wood or litter biomass; (IPCC default 0.5)
CF_j	$t\ C\ (t\ d.m.)^{-1}$	Carbon fraction of dry matter for species or type *j*
CF_{LI}	$t\ C\ (t\ d.m.)^{-1}$	Carbon fraction of litter
CF_p	$t\ C\ (t\ d.m.)^{-1}$	Carbon fraction of permanent non-tree vegetation
CF_{pre}	$t\ C\ (t\ d.m.)^{-1}$	Mean carbon fraction of dry biomass in pre-existing vegetation
$C_{LI\ ij,t}$	t C	Total carbon stock in litter of species *j* in stratum *i,* calculated at time *t*
$DBH_{i,j,l,t}$	cm	Diameter at breast height of tree *l* of species *j* of stratum *i* at time *t*
DC	Dimensionless	Decomposition rate (% carbon stock in total deadwood stock decomposed annually)
D_j	$t\ d.m.\ m^{-3}$	Basic wood density for species *j*

Variable	SI Unit	Description
$Dm_{iq,sp,t}$	cm	Diameter of the piece *m* of necromass of density class *q*, intersected by the transect in plot *sp* in stratum *i* in year *t*
dp_i	m	Distance between wood posts in fences for stratum *i*
Dw_j	t d.m. m^{-3} merchantable volume	Intermediate deadwood density for species *j*
$E_{BiomassBurn,C}$	t C yr^{-1}	C loss in aboveground biomass due to burning of biomass
$E_{BiomassBurn,\ N2O}$	t CO_2-e yr^{-1}	N_2O emissions from biomass as a result of burning of biomass
$E_{BiomassBurn,\ CH4}$	t CO_2-e yr^{-1}	CH_4 emissions from biomass as a result of burning of biomass
$E_{biomass\ loss}$	t CO_2 yr^{-1}	CO_2 emissions from a decrease in carbon stock in living biomass
$E_{fertilizer,t}$	t CO_2-e / year	Direct N_2O emissions that result from application of nitrogenous fertilizer
$E_{FuelBurn}$	t CO_2-e yr^{-1}	CO_2 emissions from combustion of fossil fuels
$E_{livestock}$	t CO_2-e yr^{-1}	Increase in GHG emissions due to an increase above baseline levels of the population of livestock in the project area
$E_{non\text{-}CO2,\ BiomassBurn}$	t CO_2-e yr^{-1}	Non-CO_2 emissions from burning of biomass
$EF_{Enteric,\ CH4,\ LT}$	kg CH_4 $head^{-1}$ yr^{-1}	Emission factor for enteric methane production for livestock type *LT*
$EF_{Manure,\ CH4,\ LT}$	kg CH_4 $head^{-1}$ yr^{-1}	Emission factor for methane production from manure for livestock type *LT*
$EF_{Manure,\ N2O,\ LT}$	kg N_2O $head^{-1}$ yr^{-1}	Emission factor for nitrous oxide production from manure for livestock type *LT*
$EF_{3,\ LT}$	kg N_2O-N (kg N $input)^{-1}$.	Emission factor for N_2O emissions from dung and urine deposited on pasture
ER_{N2O}	Value	Emission ratio for N_2O
ER_{CH4}	Value	Emission ratio for CH_4
f(DB, H, CA)	t d.m. ha^{-1}	Allometric equation linking aboveground biomass of shrubs or permanent non-tree vegetation to one or more of the variables diameter at base (*DB*), shrub height (*H*) and crown area/diameter (*CA*)
$f_j(DBH,H)$	kg d.m. $tree^{-1}$	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly tree height (*H*) to aboveground biomass of living trees
$Fwf_{ij,t}$	Dimensionless	Fraction of annually harvested deadwood carbon stock harvested as fuel wood of species j in stratum i, time *t*
$GHG_{E,t}$	t CO_2-e yr^{-1}	GHG emissions resulting from implementation of the A/R project activity within the project boundary in year *t*

Variable	SI Unit	Description
$G_{TOTAL,ij,,t}$	t d.m. ha^{-1} yr^{-1}	Annual increment of total dry biomass of living trees for stratum *i* species *j*, for year *t*
$G_{w,ij,t}$	t d.m. ha^{-1} yr^{-1}	Average annual aboveground dry biomass increment of living trees of species j in stratum i, for year *t*
$H_{i,j,l,t}$	m	Height of tree *l* of species *j* of stratum *i* at time *t*
$Hf_{ij,t}$	Dimensionless	Fraction of annually harvested merchantable volume not extracted and left on the ground as harvesting residue of species j in stratum i, time *t*
$H_{ij,t}$	m^3 ha^{-1} yr^{-1}	Average annually harvested merchantable volume of species j in stratum i, time *t*
$I_{V,ij,t}$	m^3 ha^{-1} yr^{-1}	Average annual increment in merchantable volume of species j in stratum i, for year *t*
$lCERs_t$	t CO_2	lCERs issued at time of verification
LE_t	t CO_2	Total estimated leakage due to the project in year *t*
$LE_{FuelBurn,\ t}$	t CO_2 yr^1	leakage emissions from combustion of fossil fuels, in year *t*
$LE_{WP,t}$	t CO_2-e	Estimated leakage from fence activity due to the project in year *t*
$L_{i,sp}$	m	Length of the transect of plot *sp* in stratum *i*
LT	dimensionless	Livestock type; *1 … n*
$LM_{i,t}$	m ha^{-1}	Linear meters for fencing in stratum *i* in year *t*
$Mf_{ij,t}$	Dimensionless	Mortality factor, i.e., fraction of $V_{ij,t}$ dying at time *t*
MP_{LI}		Dry-to-wet weight ratio of the litter (dry weight/wet weight)
M_{BL}	Dimensionless	Strata in baseline
M_{PS}	Dimensionless	Strata in project scenario
N/C ratio	dimensionless	Nitrogen–carbon ratio (IPCC default: 0.01)
N_{ij}		Number of trees of species *j* in stratum *i*
$N_{ij,sp,t}$		Number of trees of species *j* on plot s*p* of stratum *i* at time *t*
$N_{pnon\text{-}tree,ij}$		Number of shrubs or permanent non-tree vegetation of species *j* in stratum *i*
$N_{rate(LT)}$	kg N (1000 kg animal mass)$^{-1}$ day^{-1}	Excretion rate for livestock type *LT*
$Pop_{Proj,\ LT}$	Head	Population of livestock type *LT* in the project area
$Pop_{BSL,\ LT}$	Head	Population of livestock type *LT* in the baseline
$R1_j$	Dimensionless	Root-shoot ratio appropriate to increments for species *j*
R_j	Dimensionless	Root-shoot ratio appropriate for biomass stock, for species *j*
$R_{p,j}$	Dimensionless	Root-shoot ratio of permanent non-tree vegetation species *j*
T		Number of years between times t_2 and t_1 ($T = t_2 - t_1$)
TAM_{LT}	kg $head^{-1}$	Typical animal mass for livestock type *LT*

Variable	SI Unit	Description
T_S	Yrs	Time taken for the deadwood or litter biomass pools to reach a steady state (IPCC default: 20 years)
T_{DW}	Yr	Monitoring interval for dead wood $T_{DW} = m_2 - m_1$ (where m_2 and m_1 are the two most recent monitoring events)
T_L	Yr	Monitoring interval for litter $T_L = m_2 - m_1$
$V_{ij,t}$	$m^3\ ha^{-1}$	Merchantable volume of stratum *i*, species *j*, at time *t*
$V_{l,ij,sp,t}$	$m^3\ tree^{-1}$	Merchantable volume of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*
Vp	m^3	Average volume of each wood post for fences
$V_{iq,sp,t}$	$m^3\ ha^{-1}$	Total volume of lying deadwood of density class *q* for plot *sp* in stratum *i* in year *t*
$V_{tree,ij,t}$	$m^3\ ha^{-1}$	Mean merchantable/standing volume for stratum *i*, and species *j* at time *t*
Wp	Dimensionless	Waste fraction of unsustainable logging to extract wood posts
ρ_q	$t\ d.m.\ m^{-3}$	Density of density class *q* of deadwood.

2. List of acronyms used in the methodologies:

Acronym	Description
A/R	Afforestation and reforestation
CDM	Clean Development Mechanism
d.m.	dry matter
EB	Executive Board
GHG	Greenhouse gases
GIS	Geographic information system
GPS	Global positioning system
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change and Forestry
SOP	Standard operating procedures

3. References:

Alder, D. and Montenegro, F. (1999) - A yield model for *Cordia alliodora* plantations in Ecuador. International Forestry Review, 1(4): 242-250.

Brown, S. (1997): *Estimating biomass and biomass change of tropical forests: a primer*. FAO Forestry Paper (FAO). 0258-6150, no. 134, 2nd ed., Food and Agriculture Organization (FAO), Rome (Italy).

Cochran, W.G. (1977): *Sampling techniques*. John Wiley and Sons, New York.

Grimm, U. and Fassbender, H.W. (1981) – Ciclos bioquímicos en un ecosistema forestal de los Andes

Occidentales de Venezuela. I. Inventario de las reservas orgánicas y minerales (N, P, K, Ca, Mg, Mn, Fe, Al, Na). Turrialba 31(1): 27-37.

Harmon, M.E. y Sexton, J. (1996): *Guidelines for measurements of wood detritus in forest ecosystems*. US LTER Network Office, US LTER Publication No.2, University of Washington, Seattle/WA.

IPCC (1997): Revised 1996 IPCC guidelines for national greenhouse gas inventories; Volume 1: Reporting Instructions, http://www.ipcc-nggip.iges.or.jp/public/gl/invs4.htm

IPCC (2001): *Climate change 2001: the scientific basis*. Cambridge University Press, Cambridge.

IPCC (2003): *Good practice guidance for land use, land-use change and forestry*. Institute for Global Environmental Strategies (IGES), Hayama.

MacDicken, K.G. (1997): *A guide to monitoring carbon storage in forestry and agroforestry projects*. Winrock International Institute for Agricultural Development, Arlington/VA.

Márquez, L., Roy, A. y Castellano, E. (2000): Elementos técnicos para inventarios de carbono. Fundación Solar, Guatemala, http://www.capas.org/PDF/Climate%20change/245ManualCarbon.pdf.

Ovington, J.D. and Olson J.S. (1970) – Biomass and chemical content of El Verde lower Montane Rain Forest plants. In: T.H. Odum and P.R.F. Odum (eds.) A Tropical Rain Forest. Atomic Energy Comission, Virginia, USA

Rodríguez Jimenez, L. (1988) – Consideraciones sobre la biomasa, composición química y dinámica del bosque pluvial tropical de Colinas Bajas, Bajo Calima, Buenaventura, Colombia.

Songwe, N. C., Okali, D.U.U. and Fasehun, F.E. (1995) - Litter decomposition and nutrient release in a tropical rainforest, Sourthern Bakundu Forest Reserve, Cameroon. Journal of Tropical Ecology 11: 333-350.

Trees, Version 1.0a (2002) – Árboles tropicales y subtropicales de uso múltiple. Forestry database program by A. Vallejo and F. Zapata, Medellín, Colombia.

UNAC (2002): *Inventario forestal; Modelo d*e financiación alternativo para el manejo sostenible de los bosques en los *Valles de San Nicolás*. Universidad Nacional de Colombia (UNAC); Departamento de Ciencias Forestales, Medellín.

Vine, E. y Sathaye, J. (1997): *The monitoring, evaluation, reporting, and verification of climate change mitigation projects: discussion of issues and methodologies and review of existing protocols and guidelines*. Lawrence Berkeley National Laboratory, Berkeley.

Vine, E., Sathaye, J. y Makundi, W. (1999): *Guidelines for the monitoring, evaluation, reporting, verification, and certification of forestry projects for climate change mitigation*. Contract No. DE-AC03-76SF00098, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley/CA.

Wilson, C. (1998) – Modelling carbon sequestration in Forests: A tool for joint implementation project investors. MSc Thesis, Imperial College, London.

- - - - -

History of the document

Version	Date	Nature of revision
01	EB35, Annex 14 19 October 2007	Initial adoption