Consolidated afforestation and reforestation baseline and monitoring methodology AR-ACM0001

"Afforestation and reforestation of degraded land"

I. SOURCE, DEFINITIONS AND APPLICABILITY

1. Sources

This methodology is based on elements from the following methodologies:

- AR-AM0003 "Afforestation and reforestation of degraded land through tree planting, assisted natural regeneration and control of animal grazing", whose baseline study, monitoring and verification plan and project design document were prepared by the General Directorate for Forests and Pastures and the International Bank for Reconstruction and Development as Trustee of the BioCarbon Fund.
- AR-NM0032-rev "Restoration of degraded soils under grassland through afforestation and reforestation", whose baseline study, monitoring and verification plan and project design document were prepared by Factor CO_2 Integral Services.

For more information regarding the source methodologies and their consideration by the Executive Board please refer to http://cdm.unfccc.int/goto/ARappmeth.

This methodology also refers to the latest approved versions of the following tools:

- Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM Project Activities;
- Combined tool to identify the baseline scenario and demonstrate the additionality in A/R CDM project activities;
- Estimation of GHG emissions related to fossil fuel combustion in A/R project activities;
- Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of a A/R CDM project activity;
- Estimation of direct nitrous oxide emission from nitrogen fertilization;
- Estimation of GHG emissions related to displacement of grazing activities in A/R CDM project activity;
- Procedure to determine when accounting of the soil organic carbon pool may be conservatively neglected in A/R CDM project activities;
- Calculation of the number of sample plots for measurements within A/R CDM project activities;
- Tool for testing significance of GHG emissions in A/R CDM project activities.

All the above-mentioned tools are available at: http://cdm.unfccc.int/Reference/Guidclarif/.

2. 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".

3. Definitions

This methodology does not use any methodology specific definitions.

4. Applicability

This methodology is applicable to afforestation and reforestation CDM project activities that are implemented on degraded lands.

The conditions under which the methodology is applicable are:

- The A/R CDM project activity is implemented on degraded lands, which are expected to remain degraded or to continue to degrade in the absence of the project, and hence the land cannot be expected to revert to a non-degraded state without human intervention;
- Encroachment of natural tree vegetation that leads to the establishment of forests according to the host country definition of forest for CDM purposes is not expected to occur;
- Flooding irrigation is not part of the project activity;
- If project activities are implemented on organic soils, drainage is not allowed and not more than 10% of the project area may be disturbed as result of soil preparation for planting;
- Nitrogen-fixing trees used in the A/R CDM project activity account for less than 10% of the total forest crown area, so greenhouse gas emissions from denitrification can therefore be neglected.

Evidence that lands are degraded or degrading may comprise credible information on at least one of the following:

- National or international land classification data or peer-reviewed studies that categorise lands in the project boundary as degraded or degrading, or that categorise as degraded or degrading similar lands in the country in which the project is located (similar biophysical, climatic, and land-use conditions); or
- Soil erosion is present and no actions aimed at decreasing it have been imposed in the recent past; or
- Recent anthropogenic activities present in the project area are a known cause of on-going loss of soil and / or vegetation cover on similar lands elsewhere; or
- Topsoil has been at least partly lost due to past anthropogenic influences or natural impacts—e.g. droughts, rains, floods or changes in the soil water table—and no actions are being taken to restore the topsoil; or
- Loss of vegetation cover is ongoing due to past anthropogenic influences other than sustainable harvesting activities or natural impacts—e.g. droughts, rains, floods or changes in the soil water table—and no actions are being taken to restore the topsoil; or

- Other evidence that transparently demonstrates that project lands are in a degraded or degrading state.

Credible sources of information may include, but are not limited to:

- Peer-reviewed publications or official reports or other sources of credible qualitative or quantitative evidence; or
- Satellite images or maps or photographs or other datasets that allow degradation processes to be identified.

II. BASELINE METHODOLOGY PROCEDURE

1. Project boundary and eligibility of land

The "project boundary" geographically delineates the afforestation or reforestation project activity under the control of the project participants. The A/R CDM project activity may contain more than one discrete area of land. At the time the PDD is validated, the following shall be defined:

- Each discrete area of land shall have a unique geographical identification;
- The project participants shall describe legal title to the land, rights of access to the sequestered carbon, current land tenure, and land use for each discrete area of land;
- The project participants shall justify, that during the crediting period, each discrete area of land is expected to be subject to an afforestation or reforestation project activity under the control of the project participants.

It shall be demonstrated that each discrete area of land to be included in the boundary is eligible for an A/R CDM project activity. Project Participants shall apply the latest version of the Procedures to Demonstrate the Eligibility of Lands for Afforestation and Reforestation CDM Project Activities as approved by the Executive Board.

The carbon pools included in or excluded from the project boundary are shown in Table 1.

Table 1: Selected carbon pools

Carbon pools	Selected (Yes or No)	Justification / Explanation of choice
Above-ground biomass	Yes	Major carbon pool subjected to the project activity. This methodology covers both tree and non-tree biomass.
Below-ground biomass	Yes	Below-ground biomass stock is expected to increase due to the implementation of the A/R CDM project activity.

Carbon pools	**Selected (Yes or No)**	**Justification / Explanation of choice**
Dead wood	Yes (alternatively No)	This stock may increase (when compared to baseline) due to implementation of the project activity. The methodology provides an approach for accounting for this pool, but it allows also for exclusion of the dead wood carbon pool if transparent and verifiable information can be provided that carbon stocks in dead wood in the baseline scenario can be expected to decrease more or increase less, relative to the project scenario.
Litter	Yes (alternatively No)	This stock may increase (when compared to baseline) due to implementation of the project activity. The methodology provides an approach for accounting for this pool, but it also allows for exclusion of the litter carbon pool if transparent and verifiable information can be provided that carbon stocks in litter in the baseline scenario can be expected to decrease more or increase less, relative to the project scenario.
Soil organic carbon	Yes (alternatively No)	SOC may increase (when compared to baseline) due to implementation of the A/R CDM project activity. The methodology provides an approach for accounting for this pool, but it also allows for exclusion of the soil organic carbon pool if transparent and verifiable information can be provided that carbon stocks in the soil organic matter pool in the baseline scenario can be expected to decrease more or increase less in the absence of the project activity, relative to the project scenario. The latter condition is obeyed when the latest version of the "Procedure to determine when accounting of the soil organic carbon pool may be conservatively neglected in A/R CDM project activities" allows for conservative neglecting of accounting of the soil organic carbon pool in areas of land of the A/R CDM project activity.

The emissions sources included in or excluded from the project boundary are shown in Table 2. Any one of these sources can be neglected, i.e. accounted as zero, if the application of the most recent version of the “Tool for testing significance of GHG emissions in A/R CDM project activities” leads to the conclusion that the emission source is insignificant.

Table 2: Emissions sources included in the project boundary

Sources	Gas	Included/ excluded	Justification/Explanation of choice
Combustion of fossil fuels	CO_2	Included	Main gas of this source
	CH_4	Excluded	Potential emissions are negligibly small
	N_2O	Excluded	Potential emissions are negligibly small
Use of fertilizers	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Main gas for this source.
Burning of biomass	CO_2	Excluded	However, carbon stock decreases due to burning are accounted as a carbon stock change
	CH_4	Included	Non-CO_2 gas emitted from biomass burning
	N_2O	Excluded	Potential emissions are negligibly small

2. Identification of the baseline scenario and additionality

Project participants shall use the most recent version of the "Combined tool to identify the baseline scenario and demonstrate the additionality in A/R CDM project activities".

3. Stratification

If the project activity area is not homogeneous, stratification should be carried out to improve the accuracy and precision of biomass estimates. Different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy of the estimates of net GHG removal by sinks.

For estimation of baseline net GHG removals by sinks, or estimation of actual net GHG removals by sinks, strata should be defined by:

(i) Using procedures to stratify lands for A/R project activities under the clean development mechanism when 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 changes in biomass stocks:

- *For baseline net* 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 stratify according to area of major vegetation types;
- *For actual net* GHG *removals by sinks:* the project area should be stratified *ex ante* according to the project planting plan—that is, by forest species, age class, and possibly management regime. These strata may change during the crediting period (see section III.2).

Further subdivision of the project strata to represent spatial variation in the distribution of baseline or project biomass / removals is not usually warranted, unless methods used explicitly include variables for which spatial data also exist (for example, stratification by rainfall or pruning regime is not warranted when estimating biomass stocks or removals unless the estimation methods are formulated with rainfall or pruning regime as explicit variables). However, other parameters (e.g. soil type, climate) may be useful for *ex post* stratification.

Note: In the equations used in this methodology, the letter i is used to represent a stratum and the letter M for the total number of strata: M_B is the number of *ex ante* defined baseline strata as determined with the procedures above; M_B remains fixed for the whole crediting period. M_{PS} is the number of strata in the project scenario as determined *ex ante*. *Ex post* adjustments of the strata may be needed if unexpected disturbances occur during the crediting period (e.g. due to fire, pests or disease outbreaks), severely affecting different parts of an originally homogeneous stratum or stand, or when forest management (planting, thinning harvesting, replanting) occurs at different intensities, dates and spatial locations than originally planned. In such a situation the project area affected by the disturbance and / or variation in forest management may be delineated as a separate stratum for the purpose of monitoring the carbon stock changes.

4. Baseline Net GHG Removals by Sinks

Under the applicability conditions of this methodology:

- Changes in carbon stock of above-ground and below-ground biomass of non tree vegetation may be conservatively assumed to be zero for all strata in the baseline scenario;
- It is expected that the baseline dead wood and litter carbon pools will not show a permanent net increase. It is therefore conservative to assume that the sum of the changes in the carbon stocks of dead wood and litter carbon pools is zero for all strata in the baseline scenario;
- Changes in carbon stock in soil organic carbon may be conservatively assumed to be zero for all strata in the baseline scenario.

Therefore the baseline net GHG removals by sinks will be determined as:

$$\Delta C_{BSL} = \Delta C_{BSL,tree} \qquad \textbf{(1)}$$

where:

ΔC_{BSL}	Baseline net greenhouse gas removals by sinks; t CO_2-e
$\Delta C_{BSL,tree}$	Sum of the carbon stock changes in above-ground and below-ground biomass of trees in the baseline; t CO_2-e

4.1 Carbon stock changes in above-ground and below-ground tree biomass

The estimation of carbon stock changes in above- and below-ground tree biomass in the baseline ($\Delta C_{BSL,tree}$) will be performed as per the equations below. These equations provide for the calculations to be performed for each stratum. If there is more than one stratum in the baseline scenario, the outcome will be summed over all the strata to obtain the value for the whole project.

$$\Delta C_{BSL,tree,i} = \sum_{t=1}^{t^*} \Delta C_{BSL,AG/BG,i,t} * \frac{44}{12} \qquad \textbf{(2)}$$

where:

$\Delta C_{BSL,tree,i}$	Sum of the baseline annual carbon stock change in above-ground and below-ground tree biomass for stratum *i*; t CO_2-e
$\Delta C_{BSL,AG/BG,i,t}$	Baseline annual net carbon stock change in above-ground and below-ground biomass for stratum *i*, time *t;* t C yr^{-1}
i	*1, 2, 3, …* M_B strata in the baseline scenario
t	*1, 2, 3, …*t^* years elapsed since the start of the A/R CDM project activity
44/12	Ratio of molecular weight of CO_2 to carbon; t CO_2-e t C^{-1}

$\Delta C_{BSL,AG/BG,,i,t}$ is estimated using one of the following methods that can be selected based on the availability of data.

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

$$\Delta C_{BSL,AG/BG,i,t} = \Delta C_{G,i,t} - \Delta C_{L,i,t} \qquad \textbf{(3)}$$

where:

$\Delta C_{BSL,AG/BG,i,t}$	Baseline annual carbon stock net change in above-ground and below-ground biomass for stratum *i*, time *t;* t C yr^{-1}
$\Delta C_{G,i,t}$	Annual increase in above- and below-ground carbon due to biomass growth of living trees in stratum *i*, for year *t*; t C yr^{-1} <u>Note</u>: this is the "potential growth" which is greater than the "observed growth"
$\Delta C_{L,i,t}$	Annual decrease in above- and below-ground carbon stock due to biomass loss for stratum *i*, time *t*; t C yr^{-1} <u>Note</u>: Conservative assumption that $\Delta C_{L,i,t}$ = 0 is allowed for the baseline scenario[2]
i	*1, 2, 3, …* M_B strata in the baseline scenario
t	*1, 2, 3, …t* years elapsed since the start of the A/R CDM project activity

[1] *IPCC GPG-LULUCF 2003*, Equation 3.2.2, Equation 3.2.4 and Equation 3.2.5.

[2] This assumption implies that all baseline woody biomass is assumed to remain living and growing during the entire crediting period. This is conservative because the proportion of living biomass that will die or will be harvested is not deduced from the estimation of baseline net GHG removals by sinks and because the growth of the baseline biomass will cease (i.e. the biomass will reach saturation) at some point in time.

$$\Delta C_{G,i,t} = A_{BSL,i} * \sum_{j=1}^{J} G_{tree,j,i,t} * CF_j \tag{4}$$

where:

$\Delta C_{G,i,t}$	Annual increase in carbon due to biomass growth of living trees in stratum *i*, for year *t*; t C yr^{-1}
$A_{BSL,i}$	Area of baseline stratum *i*; ha
$G_{tree,j,i,t}$	Annual increment of total above- and below-ground 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 *j*; t C t^{-1} d.m.
i	*1, 2, 3, …* M_B strata in the baseline scenario
j	*1, 2, 3, … J* tree species in the baseline scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

and

$$G_{tree,j,i,t} = G_{w,j,i,t} * (1 + R1_j) \tag{5}$$

$$G_{w,j,i,t} = I_{V,j,i,t} * D_j * BEF_{1,j} \tag{6}$$

where:

$G_{tree,j,i,t}$	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}
$G_{w,j,i,t}$	Average annual above-ground 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*; t d.m. t^{-1} d.m
$I_{V,j,i,t}$	Current annual increment in volume of species *j* in stratum *i*, for year *t*; m^3 ha^{-1} yr^{-1} Note: $I_{V,j,i,t}$ can be estimated as a constant annual average value over a period including the year *t* (Periodical Annual Increment). Note: *t* is likely to be different than age of individual trees in the year *t*.
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 above-ground tree biomass increment for species *j*; t d.m. t^{-1} d.m.
i	*1, 2, 3, …* M_B strata in the baseline scenario
j	*1, 2, 3, … J* tree species in the baseline scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

If biomass increment tables are available and applicable to the species used in the project activity, these can directly be used in equation 5. Note that available data on average annual increment in the volume of species *j* in stratum *i* for year *t* ($I_{V,j,i,t}$) may be expressed as a net average annual increment (i.e. the term $\Delta C_{L,i,t}$ is already implicitly allowed for and shall be set to zero in eqn. (3) in order to avoid double counting).

Alternatively, if the average annual increment in volume of species *j* in stratum *i*, for year *t* ($I_{V,j.i,t}$) is expressed as the gross average annual increment, then $\Delta C_{L,i,t}$ may be conservatively assumed as zero. Otherwise $\Delta C_{L,i,t}$ must be estimated based on transparent and verifiable information on the rate at which pre-project activities (or mortality) are reducing carbon stocks in existing live trees (e.g., due to harvesting for local timber consumption, or for fuelwood).

Method 2 (stock change method)[3]

$$\Delta C_{BSL,AG/BG,i,t} = \sum_{j=1}^{J} \frac{C_{j,i,t2} - C_{j,i,t1}}{T} \quad \textbf{(7)}$$

$$C_{j,i,t} = C_{AB\_tree,j,i,t} + C_{BB\_tree,j,i,t} \quad \textbf{(8)}$$

$$C_{AB\_tree,j,i,t} = A_{BSL,i} * V_{tree,j,i,t} * D_j * BEF_{2,j} * CF_j \quad \textbf{(9)}$$

$$C_{BB\_tree,j,i,t} = C_{AB\_tree,j,i,t} * R_j \quad \textbf{(10)}$$

where:

$\Delta C_{BSL,AG/BG,i,t}$	Annual carbon stock change in above-ground and below-ground tree biomass for stratum *i*, time *t*; t C yr^{-1}
$C_{j,i,t2}$	Total carbon stock in living biomass of trees of species *j* in stratum *i*, calculated at time *t*2; t C
$C_{j,i,t1}$	Total carbon stock in living biomass of trees of species *j* in stratum *i*, calculated at time *t*1; t C

[3] GPG-LULUCF Equation 3.2.3

T	Number of years between times 2 and 1; yr
$C_{AB\_tree,j,i,t}$	Carbon stock in above-ground tree biomass of species *j* in stratum *i*, at time *t*; t C
$C_{BB\_tree,j,i,t}$	Carbon stock in below-ground tree biomass of species *j* in stratum *i*, at time *t*; t C
$A_{BSL,i}$	Area of baseline stratum *i*; ha
$V_{tree,j,i,t}$	Pre-project tree stem volume for species *j*, stratum *i*, 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 stem biomass to above-ground tree biomass for tree species *j*; t d.m t^{-1} d.m
CF_j	Carbon fraction of dry matter for species *j*; t C t^{-1} d.m.
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; t C t^{-1} C
i	*1, 2, 3, …* M_B strata in the baseline scenario
j	*1, 2, 3, … J* tree species in the baseline scenario
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

An alternative way of estimating $C_{AB\_tree,j,i,t}$ is to use allometric equations:

$$C_{AB\_tree,j,i,t} = A_{BSL,i} * nTR_{j,i,t} * CF_j * f_j(DBH, H) \qquad \textbf{(11)}$$

where:

$C_{AB\_tree,j,i,t}$	Carbon stock in above-ground tree biomass of species *j* in stratum *i*, at time *t*; t C
$A_{BSL,i}$	Area of baseline stratum *i*; ha
$nTR_{j,i,t}$	Pre-project tree stand density of species *j* in stratum *i*, at time *t*; trees ha^{-1}
CF_j	Carbon fraction of dry matter for species *j*; t C t^{-1} d.m.
$f_j(DBH, H)$	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly tree height (*H*) to above-ground biomass of living trees; t d.m. $tree^{-1}$ (<u>Note</u>: if using an average *DBH* in an allometric equation, the average must be calculated as the square root of the sum of the squares of the individual tree diameters making up the sample divided by their number - i.e. so called “quadratic mean” or “root mean square”)
i	*1, 2, 3, …* M_B strata in the baseline scenario

j	*1, 2, 3,…* J tree species in the baseline scenario
t	*1, 2, 3,…* t years elapsed since the start of the A/R CDM project activity

Note that volume tables from which $V_{tree,j,i,t}$ are obtained may or may not include allowance for losses due to harvesting or mortality. Such losses may be conservatively neglected when estimating baseline removals in pre-project trees. Otherwise $\Delta C_{L,i,t}$ must be estimated based on credible and transparent information on the rate at which pre-project activities (and mortality, if applicable) are reducing carbon stocks in existing live trees (e.g., due to harvesting for local timber consumption, or for fuelwood).

4.2 Steady state under the baseline conditions

The baseline net GHG removals by sinks, if greater than zero, shall be assumed to be constant until steady state is reached under the baseline conditions. Under steady state:

$$\Delta C_{BSL} = 0$$

Project participants may, on a project specific basis, assess when a steady state is reached during the crediting period. This shall be estimated based on transparent and verifiable information originating as appropriate from available literature, data from comparable areas, from field measurements in the planned project area, or from other sources relevant to the baseline circumstances. If no data is available, a default period of 20 years since commencement of the CDM project activity will be applied.

5. Actual net GHG removals by sinks

The actual net greenhouse gas removals by shall be estimated using the equations in this section. When applying these equations for the *ex ante* calculation of net anthropogenic GHG removals by sinks, project participants shall provide estimates of the values of those parameters that are not available before the start of the crediting period and commencement of monitoring activities. Project participants should retain a conservative approach in making these estimates.

$$\Delta C_{ACTUAL} = \Delta C_P - GHG_E \qquad \textbf{(12)}$$

where:

ΔC_{ACTUAL}	Actual net greenhouse gas removals by sinks; t CO_2-e
ΔC_P	Sum of the changes in above-ground and below-ground biomass, dead wood, litter and soil organic carbon stocks in the project scenario; t CO_2-e
GHG_E	Increase in GHG emissions as a result of the implementation of the proposed A/R CDM project activity within the project boundary; t CO_2-e

Note: In this methodology Equation (12) is used to estimate actual net greenhouse gas removals by sinks for the period of time elapsed between project start (t = 1) and the year $t = t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated. The "stock change" method should be used to determine annual, or periodical values.

5.1 Estimation of changes in the carbon stocks

The verifiable changes in the carbon stock in tree above-ground biomass and below-ground biomass, litter and soil organic carbon within the project boundary are estimated using the following approach[4]:

$$\Delta C_P = \sum_{t=1}^{t*} \Delta C_t * \frac{44}{12} - E_{BiomassLoss} \quad \textbf{(13)}$$

where:

ΔC_P	Sum of the changes in above-ground and below-ground biomass, dead wood, litter and soil organic carbon stocks in the project scenario; t CO_2-e
ΔC_t	Annual change in carbon stock in all selected carbon pools for year *t*; t C yr^{-1}
$E_{BiomassLoss}$	Increase in CO_2 emissions from loss of existing biomass due to site-preparation (including burning), and/or to competition from forest (or other vegetation) planted as part of the A/R CDM project activity; t CO_2
t	*1, 2, 3, …*t^* years elapsed since the start of the AR project activity; yr
44/12	Ratio of molecular weights of CO_2 and carbon; t CO_2 t^{-1} C

$E_{BiomassLoss}$ shall be estimated using the most recent version of the approved methodological tool: "Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of a CDM A/R project activity".

ΔC_t shall be estimated using the following equation:

$$\Delta C_t = \sum_{i=1}^{M_{PS}} (\Delta C_{AG,i,t} + \Delta C_{BG,i,t} + \Delta C_{DW,i,t} + \Delta C_{LI,i,t} + \Delta C_{SOC,i,t}) \quad \textbf{(14)}$$

where:

? C_t	Annual change in carbon stock in all carbon pools for *year t*; t C yr^{-1}
$\Delta C_{AG,i,t}$	Annual carbon stock change in above-ground biomass of trees for stratum *i*, (possibly average over a monitoring period); t C yr^{-1}
$\Delta C_{BG,i,t}$	Annual carbon stock change in below-ground biomass of trees for stratum *i*, (possibly average over a monitoring period); t C yr^{-1}
$\Delta C_{DW,i,t}$	Annual change in the dead wood carbon pool in stratum *i*, (possibly averaged over a monitoring period); t C yr^{-1}

[4] IPCC GPG-LULUCF 2003, equation 3.2.3

$\Delta C_{LI,i,t}$	Annual change in the litter carbon pool in stratum *i*, (possibly averaged over a monitoring period); t C yr^{-1}
$\Delta C_{SOC,i,t}$	Annual carbon stock change in the soil organic carbon pool[5] for stratum *i*, time *t*; t C 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

Changes in the carbon pools that are conservatively excluded from accounting shall be set equal to zero.

5.1.1 Tree Biomass

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

BEF method

Step 1: Determine based on available data, e.g. volume tables (*ex ante*) and measurements (*ex post*), the diameter at breast height (*DBH*, at typically 1.3 m above-ground level), and also preferably height (*H*), of all the trees above some minimum *DBH* in the permanent sample plots.

Step 2: Estimate the volume of the commercial (merchantable) component of trees based on available equations or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate). It is possible to combine steps 1 and 2 if there are field instruments (e.g. a relascope) that measure the volume of each tree directly.

Step 3: Choose *BEF*, and root-shoot ratio (*R*) - see Section II.8 for guidance on source of data. If relevant information is available the *BEF* and *R* should be corrected for age.

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

$$C_{AB\_tree,l,j,i,sp,t} = V_{l,j,i,sp,t} * D_j * BEF_{2,j} * CF_j \quad \textbf{(15)}$$

where:

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

[5] *Ex post* the carbon stock change in the soil organic carbon pool may be estimated one time over the entire crediting period or several parts of it summing up to the entire crediting period.

	ground tree biomass for species j; dimensionless
CF_j	Carbon fraction of biomass for tree species j; t C t^{-1} d.m. (IPCC default value = 0.5 t C t^{-1} d.m.)
l	Sequence number of trees on plot sp
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
t	$1, 2, 3, \ldots t$ years elapsed since the start of the A/R CDM project activity

Step 5: Convert the carbon stock in above-ground biomass to the carbon stock in below-ground biomass via root-shoot ratio, given by:

$$C_{BB\_tree,l,j,i,sp,t} = C_{AB\_tree,l,j,i,sp,t} * R_j \qquad \textbf{(16)}$$

where:

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

Step 6: Calculate carbon stock in above-ground and below-ground biomass of all trees present in plot sp in stratum i at time t (i.e. summation over all trees l by species j followed by summation over all species j present in plot sp)

$$C_{tree,i,sp,t} = \sum_{j=1}^{S_{PS}} \sum_{l=1}^{N_{j,i,sp,t}} (C_{AB\_tree,l,j,i,sp,t} + C_{BB\_tree,l,j,i,sp,t}) \qquad \textbf{(17)}$$

where:

$C_{tree,i,sp,t}$	Carbon stock in trees on plot sp of stratum i at time t, t C
$C_{AB\_tree,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree l of species j in plot sp in stratum i at time t; t C $tree^{-1}$
$C_{BB\_tree,l,j,i,sp,t}$	Carbon stock in below-ground biomass of tree l of species j in plot sp in stratum i at time t, t C $tree^{-1}$
$N_{j,i,sp,t}$	Number of trees of species j on plot sp of stratum i at time t
l	Sequence number of trees on plot sp

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

Step 7: Calculate the mean carbon stock in treebiomass for eachstratum:

$$C_{tree,i,t} = \frac{A_i}{Asp_i} \sum_{sp=1}^{P_i} C_{tree,i,sp,t} \qquad \textbf{(18)}$$

where:

$C_{tree,i,t}$	Carbon stock in trees in stratum i, at time t; t C
$C_{tree,i,sp,t}$	Carbon stock in trees on plot *sp* of stratum i at time t, t C
Asp_i	Total area of all sample plots in stratum i; ha
A_i	Area of stratum i; ha
sp	*1, 2, 3, …* P_i sample plots in stratum i in the project scenario
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

Allometric method

Step 1: As with Step 1 of the *BEF* Method.

Step 2: Select or develop an appropriate allometric equation (if possible species-specific, or if not from a similar species) - see Section II.8 for additional guidance.

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

$$C_{AB\_tree,j,i,sp,t} = \sum_{l=1}^{N_{j,sp}} f_j(DBH,H) * CF_j \qquad \textbf{(19)}$$

where:

$C_{AB\_tree,j,i,sp,t}$	Carbon stock in above-ground biomass of trees of species j on sample plot *sp* of stratum i at time t; t C
CF_j	Carbon fraction of dry matter for species or type j; t C t^{-1} d.m.
$f_j(DBH,H)$	Allometric equation for species j linking diameter at breast height (*DBH*) and possibly height (*H*) to above-ground biomass of living trees; t d.m. tree^{-1}

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

Step 4: Convert the carbon stock in above-ground biomass to the carbon stock in below-ground biomass via root-shoot ratio, given by:

$$C_{BB\_tree,j,i,sp,t} = C_{AB\_tree,j,i,sp,t} * R_j \quad \textbf{(20)}$$

where:

$C_{BB\_tree,j,i,sp,t}$	Carbon stock in below-ground biomass of trees of species *j* in plot *sp* in stratum *i* at time *t*, t C
$C_{AB\_tree,j,i,sp,t}$	Carbon stock in above-ground biomass of trees of species *j* in plot *sp* in stratum *i* at time *t*, t C
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless

Step 5: Calculate total carbon stock in the biomass of all trees present in the sample plot *sp* in stratum *i* at time *t*

$$C_{tree,i,sp,t} = \sum_{j=1}^{S_{PS}} (C_{AB\_tree,j,i,sp,t} + C_{BB\_tree,j,i,sp,t}) \quad \textbf{(21)}$$

where:

$C_{tree,i,sp,t}$	Carbon stock in trees on plot *sp* of stratum *i* at time *t*, t C
$C_{AB\_tree,j,i,sp,t}$	Carbon stock in above-ground biomass of trees of species *j* in plot *sp* in stratum *i* at time *t*; t C tree^{-1}
$C_{BB\_tree,j,i,sp,t}$	Carbon stock in below-ground biomass of trees of species *j* in plot *sp* in stratum *i* at time *t*, t C 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
t	*1, 2, 3, …* t years elapsed since the start of the A/R CDM project activity

Step 6: Calculate the mean carbon stock in above biomass for each stratum, as per Equation (18)- i.e. Step 7 of the *BEF* method

For both *BEF* and allometric methods calculate:

$$\Delta C_{AG,i,t} + \Delta C_{BG,i,t} = \frac{C_{tree,i,t2} - C_{tree,i,t1}}{T} \quad \textbf{(22)}$$

where:

$\Delta C_{AG,i,t}$	Annual carbon stock change in above-ground biomass of trees for stratum *i*; t C yr^{-1}
$\Delta C_{BG,i,t}$	Annual carbon stock change in below-ground biomass of trees for stratum *i*; t C yr^{-1}
$C_{tree,i,t}$	Carbon stock in trees in stratum *i*, at time *t*; t C
T	Number of years between monitoring time $t2$ and $t1$ ($T = t2 - t1$); yr
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

5.1.2 Dead wood (if selected in Table 1)

For *ex ante* estimates, the changes in carbon stocks of dead wood shall be conservatively neglected.

Dead wood included in the methodology comprises two components only—*standing dead wood* and *lying dead wood* (that is, below-ground dead wood is conservatively neglected). Considering the differences in the two components, different sampling and estimation procedures shall be used to calculate the changes in dead wood biomass of the two components.

For the *ex post* situation, the change is estimated by: dead wood

$$\Delta C_{DW,i,t} = \frac{C_{DW,i,t2} - C_{DW,i,t1}}{T} \qquad \textbf{(23)}$$

where:

$\Delta C_{DW,i,t}$	Annual carbon stock change in the dead wood in stratum *i*, (averaged over a monitoring period); t C yr^{-1}
$C_{DW,i,t2}$	Carbon stock of dead wood in stratum *i*, at time *t* = 2; t C
$C_{DW,i,t1}$	Carbon stock of dead wood in stratum *i*, at time *t* = 1; t C
T	Number of years between monitoring time $t2$ and $t1$ ($T = t2 - t1$); yr
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

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

$$C_{DW,i,t} = (B_{SDW,i,t} + B_{LDW,i,t}) * CF_{DW} \qquad \textbf{(24)}$$

where:

$C_{DW,i,t}$	Carbon stock of dead wood biomass in stratum *i*, at time *t*; t C
$B_{SDW,i,t}$	Biomass of standing dead wood in stratum *i*, at time *t*; t d.m.
$B_{LDW,i,t}$	Biomass of lying dead wood in stratum *i*, at time *t*; t d.m.
CF_{DW}	Carbon fraction of dry matter in dead wood, t C t^{-1} d.m.
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

(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 above-ground and below-ground 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.

If the top of the standing dead tree is missing, then the top diameter:

1) May be assumed as zero;
2) May be measured if reachable or the broken top is identifiable on ground;
3) May be calculated proportionally to height assuming that the height of the intact dead tree would be equal to average height of all intact dead trees present in the same sample plot.

Step 4: The volume of dead wood is converted to biomass using the appropriate dead wood density class.

(2) Lying Dead Wood

The lying dead wood pool is highly variable, and stocks increase 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 presence of lying dead wood can be assessed from the plot surveys.

Step 1: Lying dead wood should be sampled using the line intersect method (Harmon and Sexton, 1996)[6]. 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) using the 'machete test', as recommended by *IPCC Good Practice Guidance for LULUCF* (2003), Section 4.3.3.5.3.

Step 3: The volume of lying dead wood per unit area is calculated using the equation (Warren and Olsen, 1964)[7] as modified by van Wagner (1968)[8] separately for each density state:

$$V_{LDW,i,t} = \frac{p^2 * (\sum_{n=1}^{N} D_{n,i,t}^{\ 2})}{8 * L} \quad \textbf{(25)}$$

where:

$V_{LDW,i,t}$	Volume of lying dead wood per unit area in stratum *i*, at time *t*; $m^3\ ha^{-1}$
$D_{n,i,t}$	Diameter of piece *n* of dead wood along the transect in stratum *i*, at time *t*; cm
N	Total number of wood pieces intersecting the transect; dimensionless
L	Length of the transect; m
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

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

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

$$B_{LDW,i,t} = A_i * \sum_{dc=1}^{3} V_{LDW,i,t} * D_{DW,dc} \quad \textbf{(26)}$$

[6] 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.

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

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

where:

$B_{LDW,i,t}$	Biomass of lying dead wood in stratum *i* at time *t*; t.d.m.
$V_{LDW,i,t}$	Volume of lying dead wood in stratum *i*, at time *t*; m^3 ha^{-1}
$D_{DW,dc}$	Basic wood density of dead wood in the density class-sound (1), intermediate (2), and rotten (3); t d.m. m^{-3} Note: to estimate density of each class, follow the procedure described in IPCC Good Practice Guidance for LULUCF (2003), Section 4.3.3.5.3
A_i	Area of stratum *i*; ha
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

5.1.3 Litter (if selected in Table 1)

For *ex ante* estimates, the changes in carbon stocks of litter shall be conservatively neglected.

For *ex post* estimates, four litter samples shall be collected per sample plot and well mixed into one composite sample. Samples shall be taken 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.

A sub-sample from the composite sample of litter is taken, oven dried and weighed to determine the dry weight. The dry to wet weight ratio of the sub-sample is calculated and used for estimations of the litter dry weight.

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

$$B_{LI,i,sp} = 2.5 * B_{LI\_wet,i,sp} * \frac{MP_{LI}}{a_{i,sp}} \qquad \textbf{(27)}$$

where:

$B_{LI,i,sp}$	Biomass of dry litter for plot *sp* in stratum *i* at monitor time; *t* d.m. ha^{-1}
$B_{LI\_wet,i,sp}$	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); dimensionless
$a_{i,sp}$	Area of sampling frame for plot *sp* in stratum *i*; m^2
i	*1, 2, 3, … M_{PS}* strata in the project scenario
sp	Index for sample plots

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

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^{-1} d.m. as a default value for the carbon fraction[9].

$$\Delta C_{LI,i,t} = \frac{B_{LI,i,t2} - B_{LI,i,t1}}{T} * CF_{LI} \qquad \textbf{(28)}$$

where:

$\Delta C_{LI,i,t}$	Annual change in the litter carbon pool in stratum i, (averaged over a monitoring period); t C yr^{-1}
$B_{LI,i,t2}$	Biomass of litter in stratum i at time t = 2; t d.m.
$B_{LI,i,t1}$	Biomass of litter in stratum i at time t = 1; t d.m.
T	Number of years between monitoring time $t2$ and $t1$ ($T = t2 - t1$); yr
CF_{LI}	Carbon fraction of litter (default value 0.370 t C t^{-1} d.m.); t C t^{-1} d.m.
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

5.1.4 Soil Carbon (if selected in Table 1)

For *ex ante* estimations, the changes in stocks of soil organic carbon shall be conservatively neglected.

The soil carbon pool inflows (through plant growth) and outflows (through mineralization) between two monitoring intervals shall be estimated as the difference between the carbon stock estimates of the two consecutive soil monitoring events. Due of low rate of changes in soil organic carbon, it is not required to monitor the soil organic carbon during each verification. As a minimum however, the soil carbon pool should be monitored in the beginning and the end of the first crediting period and in the end of any subsequent crediting period.

As a minimum, 5 samples will be collected in each sample plot used for biomass estimation. In each sample plot, all samples shall be collected to the same depth throughout the entire crediting period. However, the depth may vary among the sample plots. Soil samples from each sample plot shall be mixed and a composite sample taken for analysis. The mass of carbon per unit volume is calculated by multiplying the carbon concentration ($C_{SOC_{Sample,i,p,t}}$) and bulk density (g/cm^3). The bulk density equals the oven dry weight of the soil core divided by the core volume after discounting the volume of coarse fraction of >2 mm.

[9] Smith and Heath, 2002.

$$C_{SOC,i,p,t} = C_{SOC_{Sample,i,p,t}} * BD_{i,p,t} * Depth_{i,p,t} * FC_{i,p,t} * M \quad \textbf{(29)}$$

where:

$C_{SOC,i,p,t}$	Carbon stock of soil organic carbon pool of plot p in stratum i, time t; t C ha^{-1}
$C_{SOC_{Sample,i,p,t}}$	Soil organic carbon of the sample in plot p in stratum i, time t; determined in laboratory in g C/100 g soil
$BD_{i,p,t}$	Bulk density (soil mass/volume of sample) of plot p in stratum i, time t determined in laboratory; t m^{-3}
$Depth_{i,p,t}$	Soil depth to which soil sample is collected for plot p in stratum i, time t; m
$FC_{i,p,t}$	1 – (% volume of coarse fragments/100) to adjust the fraction of sample occupied by coarse fragments > 2mm at plot p in stratum i, time t; dimensionless.
M	Multiplier to convert units into t C ha^{-1}; 10000 m^2 ha^{-1}
i	*1, 2, 3, …* M_{PS} strata in the project scenario
p	*1, 2, 3, …* P_i sample plots in stratum i in the project scenario
t	*1, 2, 3, …* t years elapsed since the start of the A/R CDM project activity

$$\Delta C_{SOC,i,p,T} = \frac{C_{SOC,i,p,t_2} - C_{SOC,i,p,t_1}}{T} \quad \textbf{(30)}$$

where:

$\Delta C_{SOC,i,p,T}$	Average annual change in the carbon stock of soil organic carbon pool of plot p in stratum i, between monitoring periods $t1$ and $t2$; t C ha^{-1} yr^{-1}
C_{SOC,i,p,t_2}	Carbon stock of soil organic carbon pool of plot p in stratum i, time $t = t2$; t C ha^{-1}
C_{SOC,i,p,t_1}	Carbon stock of soil organic carbon pool of plot p in stratum i, time $t = t1$; t C ha^{-1}
T	Number of years between monitoring time $t2$ and $t1$ ($T = t2 - t1$); yr
i	*1, 2, 3, …* M_{PS} strata in the project scenario
p	*1, 2, 3, …* P_i sample plots in stratum i in the project scenario
t	*1, 2, 3, …* t years elapsed since the start of the A/R CDM project activity

If the soil carbon pool is monitored only in the beginning and the end of the first crediting period and in the end of any subsequent crediting period then: $C_{SOC,i,p,t_1} = C_{SOC,i,p,t_2} = C_{SOC,i,p,t}$ until t reaches duration of the crediting period minus one year. It means that the entire change in the soil carbon pool is credited to the project in the last year of the crediting period.

The mean soil organic carbon accumulation shall be calculated by pooling the soil carbon estimates of samples at the monitoring interval.

$$M\Delta C_{SOC,i,p,T} = \frac{\sum_{p=1}^{P_i} \Delta C_{SOC_{i,p,T}}}{P_i} \quad \textbf{(31)}$$

where:

$M\Delta C_{SOC,i,T}$	Mean average annual carbon stock change in the soil organic carbon pool in stratum *i*, between monitoring periods *t*1 and *t*2; t C ha^{-1} yr^{-1}
$\Delta C_{SOC_{i,p,T}}$	Average annual change in the carbon stock of soil organic carbon pool of plot *p* in stratum *i*, between monitoring periods *t*1 and *t*2; t C ha^{-1} yr^{-1}
p	*1, 2, 3, … P_i* sample plots in stratum *i* in the project scenario
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

The average annual change in the carbon stock of soil organic carbon pool in stratum *i*, between monitoring periods *t1* and *t2* will be estimated as:

$$\Delta C_{SOC_{i,t}} = M\Delta C_{SOC,i,T} * A_i \quad \textbf{(32)}$$

where:

$\Delta C_{SOC,i,t}$	Annual carbon stock change in the soil organic carbon pool for stratum *i*, time *t*; t C yr^{-1}
$M\Delta C_{SOC,i,T}$	Mean average annual carbon stock change in the soil organic carbon pool in stratum *i*, between monitoring periods *t*1 and *t*2; t C ha^{-1} yr^{-1}
A_i	Area of stratum *i*; ha
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

5.2 Estimation of GHG emissions within the project boundary

The increase in GHG emissions as a result of the implementation of the proposed AR CDM project activity within the project boundary can be estimated as:

$$GHG_E = \sum_{t=1}^{t^*} (ET_{FC,t} + E_{BiomassBurn,t} + N_2O_{direct-N,t}) \quad \textbf{(33)}$$

where:

GHG_E	Increase in GHG emissions as a result of the implementation of the proposed A/R CDM project activity within the project boundary; t CO_2-e
$ET_{FC,t}$	CO_2 emissions from fossil fuel combustion during the year t; t CO_2-e
$E_{BiomassBurn,t}$	Non-CO_2 emissions due to biomass burning of existing vegetation as part of site preparation during the year t; t CO_2-e
$N_2O_{direct-N,t}$	Direct N_2O emission as a result of nitrogen application within the project boundary in year t; t CO_2-e
t	*1, 2, 3, …* t^* years elapsed since the start of the A/R CDM project activity

Note: In this methodology Equation (33) is used to estimate the increase in GHG emissions for the period of time elapsed between project start (t =1) and the year $t = t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated.

The monitoring of emissions by sources is only required if significant; if insignificant, evidence should be provided (e.g. as relevant part of the monitoring of the project implementation) that the assumptions for the exclusion made in the *ex ante* assessment still hold in the *ex post* situation.

5.2.1 Estimation of GHG emissions from fossil fuel combustion

GHG emissions from burning of fossil fuels ($ET_{FC,t}$) shall be estimated using the latest version of the methodological tool: “Estimation of GHG emissions related to fossil fuel combustion in A/R project activities”.

5.2.2 Estimation of non-CO_2 emissions due to biomass burning of existing vegetation as part of site preparation

Considering the limited combustible material in degraded lands, fire is not likely to be a major source of GHG emissions in the site preparation. However, if significant, the non-CO_2 emissions due to biomass burning of existing vegetation as part of site preparation ($E_{BiomassBurn,t}$) shall be estimated using the relevant instructions provided by the most recent version of the methodological tool: “Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of a CDM A/R project activity”.

If prescribed burning is included in the forest management cycle, the same tool should be used to account for the non-CO_2 emissions arising from this practice.

5.2.3 Estimation of direct N_2O emission as a result of nitrogen application within the project boundary

Nitrous oxide emissions from nitrogen application ($N_2O_{direct\text{-}N,t}$) shall be estimated using the latest version of the methodological tool “Estimation of direct nitrous oxide emissions from nitrogen fertilization”.

6. Leakage

Under applicability conditions of this methodology the following types of leakage emissions are allowed: GHG emissions due to fossil fuel combustion in vehicles, GHG emissions due to activity displacement and GHG emissions due to increase in use of wood posts for fencing.

Leakage shall be estimated as follows:

$$LK = LK_{Vehicle} + LK_{ActivityDisplacement} + LK_{fencing} \tag{34}$$

where:

LK	Total GHG emissions due to leakage; t CO_2-e
$LK_{Vehicle}$	Total GHG emissions due to fossil fuel combustion in vehicles; t CO_2-e
$LK_{ActivityDisplacement}$	Leakage due to activity displacement; t CO_2-e
$LK_{fencing}$	Leakage due to increase in use of wood posts for fencing up to year t^*; t CO_2-e

Note: In this methodology the equation above is used to estimate leakage for the period of time elapsed between project start (t =1) and the year $t = t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated.

6.1 Estimation of leakage due to fossil fuel consumption

GHG emissions from fossil fuel consumption ($LK_{Vehicle}$) shall be estimated using the latest version of the methodological tool: "Estimation of GHG emissions related to fossil fuel combustion in A/R project activities".

$$LK_{Vehicle} = \sum_{t=1}^{t^*} ET_{FC,t} \tag{35}$$

where:

$LK_{Vehicle}$	Total GHG emissions due to fossil fuel combustion from vehicles; t CO_2-e
$ET_{FC,t}$	CO_2 emissions from fossil fuel combustion during the year t; t CO_2 Note: $ET_{FC,t}$ is calculated according to methodological tool: "Estimation of GHG emissions related to fossil fuel combustion in A/R project activities"
t	*1, 2, 3, … t^** years elapsed since the start of the A/R CDM project activity

6.2 Estimation of leakage due to activity displacement

Leakage due to activity displacement ($LK_{ActivityDisplacement}$) is estimated as follows:

$$LK_{ActiviyDisplacement} = LK_{Conversion} + LK_{Fuelwood} \tag{36}$$

where:

$LK_{ActiviyDisplacement}$	Leakage due to activity displacement; t CO_2-e
$LK_{Conversion}$	Leakage due to conversion of land to grazing land; t CO_2-e
$LK_{Fuelwooc}$	Leakage due to the displacement of fuelwood collection; t CO_2-e

6.2.1 Estimation of leakage due to conversion of land to grazing land

Leakage due to conversion of land to grazing land *($LK_{Conversion}$)* shall be calculated using the latest version of the A/R methodological tool: "Estimation of GHG emissions related to displacement of grazing activities in A/R CDM project activity" where $LK_{Conversion}$ is calculated as the sum of the parameter $LK_{Displacement,t}$ (Leakage due to the displacement of animals in year t) as provided by the tool. The summation is between project start (t =1) and the year $t = t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are determined.

6.2.2 Estimation of leakage due to displacement of fuelwood collection

The management practices implemented by PPs may require at least temporary displacement of fuelwood collection[10]. If part the fuelwood gathered outside the project boundary does not obey the most recent definition of renewable biomass as approved by the EB[11] then leakage due to displacement of fuelwood collection ($LK_{fuelwood}$) shall be estimated.

If application of the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities" leads to a conclusion that $LK_{fuelwood}$ (as calculated using the equation 38) is insignificant then can be neglected, i.e. accounted for as zero.

To calculate $LK_{fuelwood}$, first the volume of fuelwood gathered outside the project area will be estimated as follows:

$$FG_{outside,t} = FG_{BL} - FG_{AR,t} - FG_{Conv,t} \qquad \textbf{(37)}$$

[10] In this context, fuelwood refers both to fuelwood collection for direct use and for charcoal production

[11] See Glossary of CDM terms available at: http://cdm.unfccc.int/Reference/Guidclarif/

where:

$FG_{outside,t}$	Volume of fuelwood gathering displaced outside the project area at year t; m^3 yr^{-1}
FG_{BL}	Average annual pre-project volume of fuelwood gathering in the project area; m^3 yr^{-1}
$FG_{AR,t}$	Average annual volume of fuelwood collected in the project area under the proposed A/R CDM project activity; m^3 yr^{-1}
$FG_{Conv,t}$	Average annual volume of fuelwood collected during conversion of land to grazing land; m^3 yr^{-1}
t	*1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Leakage due to displacement of fuelwood collection can be set as zero ($LK_{fuelwood} = 0$) under the following condition:

- $FG_{BL} \leq FG_{AR,t} + FG_{Conv,t}$

In all other cases, leakage due to displacement of fuelwood collection shall be estimated as follows (*IPCCGPG-LULUCF 2003* - Eq. 3.2.8):

$$LK_{fuelwood} = \sum_{t=1}^{t^*} FG_{outside,t} * (1 - FRF) * D_{DS} * BEF_{2,DS} * CF_{DS} * \frac{44}{12} \qquad \textbf{(38)}$$

where:

$LK_{fuelwood}$	Leakage due to displacement of fuelwood collection up to year t^*; t CO_2-e
$FG_{outside,t}$	Volume of fuelwood gathering displaced outside the project area at year t; m^3 yr^{-1}
FRF	Fraction of fuelwood collected outside the project boundary that obeys the definition of renewable biomass; %
D_{DS}	Basic wood density of dominant species DS collected as fuelwood; t d.m. m^{-3} (see IPCC GPG-LULUCF 2003, Table 3A.1.9)
$BEF_{2,DS}$	Biomass expansion factor for conversion of volumes of extracted roundwood to total above-ground tree biomass for dominant species DS collected as fuelwood; dimensionless
CF_{DS}	Carbon fraction of dry matter for dominant species DS collected as fuelwood; t C t^{-1} d.m.
t	*1, 2, 3, …* t^* years elapsed since the start of the A/R CDM project activity

6.3 Estimation of leakage due to increased use of wood posts for fencing

The management practices implemented by PPs may require fencing using wood posts. If not all the posts are obtained from sources inside the project boundary, and not all the posts collected outside the project boundary obey the most recent definition of renewable biomass as approved by the EB[12] then leakage due to increased use of wood posts for fencing ($LK_{fencing}$) shall be estimated.

If application of the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities" leads to a conclusion that $LK_{fencing}$ (as calculated using the equation 39) is insignificant then can be neglected, i.e. accounted for as zero.

$LK_{fencing}$ is calculated as follows:

$$LK_{fencing} = \sum_{t=1}^{t^*} \frac{PAR_t}{DBP} * APV * (1 - FRP) * D_{DS} * BEF_{2,DS} * CF_{DS} * \frac{44}{12} \quad \textbf{(39)}$$

where:

$LK_{fencing}$	Leakage due to increased use of wood posts for fencing up to year t^*; t CO_2-e
PAR_t	Perimeter of the areas to be fenced at year *t*; m
DBP	Average distance between wood posts; m
FRP	Fraction of posts from renewable sources located outside the project boundary; %
APV	Average volume of wood posts (estimated from sampling); m^3
D_{DS}	Basic wood density of dominant species *DS* used for posts; t d.m. m^{-3} (see IPCC GPG-LULUCF 2003, Table 3A.1.9)
$BEF_{2,DS}$	Biomass expansion factor for conversion of volumes of extracted roundwood to total above-ground tree biomass for dominant species *DS* used for posts; dimensionless
CF_{DS}	Carbon fraction of dry matter for dominant species *DS* used for posts (default = 0.5); t C t^{-1} d.m.
t	*1, 2, 3, … t^** years elapsed since the start of the A/R CDM project activity

If the fence or any other kind of barrier constructed as part of the management practices implemented by PPs, does not specifically require the use of wooden posts but requires use of another wooden construction then in equation 39 the term $\frac{PAR_t}{DBP} * APV$ shall be replaced with an estimate of volume of wood collected outside the project boundary which is used annually for fencing.

12 See Glossary of CDM terms available at: http://cdm.unfccc.int/Reference/Guidclarif/

Possible double counting should be avoided if fences are made of wood collectedduring conversion of land to grazing land. Note that wood collected during conversion of land to grazing land and accounted for as leakage under *Estimation of leakage due to conversion of land to grazing land* may be utilized for fencing or as fuelwood.

7. Net Anthropogenic GHG Removals by Sinks

The net anthropogenic GHG removals by sinks is the actual net GHG removals by sinks minus the baseline net GHG removals by sinks minus leakage, therefore, the following general formula can be used to calculate the net anthropogenic GHG removals by sinks of an AR CDM project activity (C_{AR-CDM}), in t CO_2-e.

$$C_{AR-CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK \quad \textbf{(40)}$$

where:

C_{AR-CDM}	Net anthropogenic greenhouse gas removals by sinks; t CO_2-e
ΔC_{ACTUAL}	Actual net greenhouse gas removals by sinks; t CO_2-e
ΔC_{BSL}	Baseline net greenhouse gas removals by sinks; t CO_2-e
LK	Total GHG emissions due to leakage; t CO_2-e

7.1 Calculation of tCERs and lCERs

To estimate the amount of CERs that can be issued at time $t^* = t_2$ (the date of verification) for the monitoring period $T = t_2 - t_1$, this methodology uses the most recent version of the EB approved equations[13], which produces the same estimates as the following:

$$tCERs = C_{AR-CDM,t_2} \quad \textbf{(41)}$$

$$lCERs = C_{AR-CDM,t_2} - C_{AR-CDM,t_1} \quad \textbf{(42)}$$

where:

$tCERs$	Number of units of temporary Certified Emission Reductions
$lCERs$	Number of units of long-term Certified Emission Reductions
C_{AR-CDM,t_2}	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t2$; t CO_2-e
C_{AR-CDM,t_1}	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t1$; t CO_2-e

[13] See http://cdm.unfccc.int/Reference/Guidclarif/

8. Data and parameters not monitored (default or possibly measured one time)

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of existing published data, project participants should retain a conservative approach: that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks should be selected.

Data / parameter:	$A_{BSL,i}$
Data unit:	ha
Used in equations:	4, 9, 11
Description	Area of baseline stratum *i*
Source of data:	GPS coordinates and/or Remote Sensing data
Measurement procedures (if any):	N/A
Any comment:	

Data / parameter:	$BEF_{1,j}$
Data unit:	Dimensionless
Used in equations:	6
Description	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total above-ground tree biomass increment for species *j*
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) Existing local and species-specific or group of species-specific; (b) National and species-specific or group of species-specific (e.g. from national GHG inventory); (c) Species-specific or group of species-specific from neighbouring countries with similar conditions. Sometimes c) might be preferable to b); (d) Globally species-specific or group of species-specific (e.g. IPCC literature: Table 3A.1.10[14] of the *GPG-LULUCF* (IPCC 2003), and Table 4.5[15] of the *AFOLU Guidelines* (IPCC 2006).)
Measurement procedures (if any):	
Any comment:	• *BEFs* are age dependent, and use of average data may result in significant errors for both young and old stands—as *BEFs* are usually large for young stands and quite small for old stands. • *BEFs* in IPCC literature and national inventory are usually applicable to closed canopy forest. If applied to individual trees growing in open field it is recommended that the selected *BEF* be increased by a further 30%.

[14] Use the parameter BEF_2 in Table 3A.1.10 in the GPG-LULUCF.

[15] Values of the *BEF* must be derived from the parameter $BCEF_S$ in Table 4.5 according to the equation $BEF = BCEF_S / D_V$, using age-dependent wood density if available.

Data / parameter:	$BEF_{2,j}$, $BEF_{2,DS}$
Data unit:	Dimensionless
Used in equations:	9, 15, 38, 39
Description	Biomass expansion factor for conversion of merchantable biomass to above-ground tree biomass for tree species *j*
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) Existing local and species-specific or group of species-specific; (b) National and species-specific or group of species-specific (e.g. from national GHG inventory); (c) Species-specific or group of species-specific from neighbouring countries with similar conditions. Sometimes c) might be preferable to b); (d) Globally species-specific or group of species-specific (e.g. IPCC GPG-LULUCF 2003).
Measurement procedures (if any):	
Any comment:	• $BEF_{2,DS}$ is equal to $BEF_{2,j}$ if the extracted wood is the merchantable one. • *BEFs* are age dependent, and use of average data may result in significant errors for both young and old stands—as *BEFs* are usually large for young stands and quite small for old stands. • *BEFs* in IPCC literature and national inventory are usually applicable to closed canopy forest. If applied to individual trees growing in open field it is recommended that the selected *BEF* be increased by a further 30%.

Data / parameter:	CF_{DW}
Data unit:	t C t^{-1} d.m.
Used in equations:	24
Description	Carbon fraction of dry matter in dead wood
Source of data:	Default value 0.5 t C t^{-1} d.m. shall be used
Measurement procedures (if any):	
Any comment:	

Data / parameter:	CF_j , CF_{DS}
Data unit:	t C t^{-1} d.m.
Used in equations:	4, 9, 11, 15, 19, 38, 39
Description	Carbon fraction of dry matter for species of type *j*
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g. from national GHG inventory); (b) Species-specific or group of species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (e.g. IPCC GPG-LULUCF 2003); (d) The default value 0.5 t C t^{-1} d.m. may be used.
Measurement procedures (if any):	N/A
Any comment:	Carbon fraction of dry matter for dominant species *DS* when *j=DS*

Data / parameter:	CF_{LI}
Data unit:	t C t^{-1} d.m.
Used in equations:	28
Description	Carbon fraction of litter
Source of data:	Default value 0.37 t C t^{-1} d.m. shall be used
Measurement procedures (if any):	
Any comment:	

Data / parameter:	D_j , D_{DS}
Data unit:	t d.m. m^{-3}
Used in equations:	6, 9, 15, 38, 39
Description	Basic wood density for species *j*
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g. from national GHG inventory); (b) Species-specific or group of species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (e.g. IPCC GPG-LULUCF 2003).
Measurement procedures (if any):	N/A
Any comment:	Basic wood density for dominant species *DS* when *j=DS*

Data / Parameter:	$D_{DW,dc}$
Data unit:	t d.m. m^{-3}
Used in equations:	26
Description	Basic wood density of dead wood in the density class-sound (1), intermediate (2), and rotten (3)
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g. from national GHG inventory); (b) Species-specific or group of species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (e.g. IPCC GPG-LULUCF 2003).
Measurement procedures (if any):	Project specific determination of the density is allowed.
Any comment:	

Data / Parameter:	$f_j(DBH, H)$
Data unit:	t d.m. tree^{-1}
Used in equations:	11, 19
Description	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly tree height (*H*) to above-ground biomass of living trees
Source of data:	Whenever available, use allometric equations that are species-specific or group of species-specific, provided the equations have been derived using a wide range of diameters and heights, based on datasets that comprise at least 20 trees. Otherwise, default equations from IPCC literature, national inventory reports or published peer-reviewed studies may be used—such as those provided in Tables 4.A.1 to 4.A.3 of the *GPG-LULUCF* (IPCC 2003).
Measurement procedures (if any):	
Any comment:	If default allometric equations are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then the equation may be used and considered conservative. Otherwise, it is necessary either to use conservatively assessed values, or to verify the applicability of the equation if mean predicted values are to be used. Allometric equations can be verified by: • Selecting at least 5 trees covering the range of *DBH* existing in the project area, and felling and weighing the above-ground biomass to determine the total (wet) weight of the stem and branch components; • Extracting and immediately weighing[16] sub-samples from each of the wet stem and branch components[17], followed by oven drying at 70ºC to determine dry biomass; • Determining the total dry weight of each tree from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components. If the biomass of the harvested trees is within about ±10% of the mean values predicted by the selected default allometric equation, and is not biased—or if biased is wrong on the conservative side (i.e., use of the equation results in an under- rather than over-estimate of project net anthropogenic removals by sinks)—then mean values from the default equation may be used.

[16] Or, alternatively, seal the sub-samples immediately in plastic bags of known weight, and determine wet weights in the laboratory.

[17] Use at least 3 sub-samples for branch material, and at least 5 sub-samples for stem wood. If cutting slices of stem or branch wood using a chainsaw, ensure cutting does not cause excessive heating and evaporation of water from the wood before the sub-sample is weighed.

Data / parameter:	FG_{BL}
Data unit:	$m^3\ yr^{-1}$
Used in equations:	37
Description	Average pre-project annual volume of fuelwood gathering in the project area
Source of data:	Interviews and/or Participatory Rural Appraisal (PRA)
Measurement procedures (if any):	Where pre-project fuelwood collection or charcoal production activities exist, it should be estimated. This can be done by interviewing households or implementing a Participatory Rural Appraisal (PRA). Others sources of information, such as local studies on fuelwood consumption or charcoal production may also be used. Average data based on at least 3 and no more than 10 years time period preceding the starting date of the AR CDM project activity is appropriate for the purpose of this methodology. $$FG_{BL} = \frac{sFG_{BL}}{SFR_{PAfw}}$$ where: FG_{BL} Average pre-project annual volume of fuelwood gathering in the project area; $m^3\ yr^{-1}$ sFG_{BL} Sampled average pre-project annual volume of fuelwood gathering in the project area; $m^3\ yr^{-1}$ SFR_{PAfw} Fraction of total plots or households in the project area sampled; dimensionless
Any comment:	

Data / parameter:	FRF
Data unit:	%
Used in equations:	38
Description	Fraction of fuelwood collected outside the project boundary that obeys the definition of renewable biomass
Source of data:	If available, verifiable local or national estimates will be used. Otherwise a default value of 60% will be used.
Measurement procedures (if any):	
Any comment:	Project specific determination of the fraction is allowed.

Data / Parameter:	*FRP*
Data unit:	%
Used in equations:	39
Description	Fraction of posts from renewable sources located outside the project boundary
Source of data:	If available, published local or national estimates will be used. Otherwise a default value of 60% will be used.
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Project specific determination of the fraction is allowed.

Data / parameter:	$I_{V,j,i,t}$
Data unit:	m^3 ha^{-1} yr^{-1}
Used in equations:	6
Description	Average annual increment in merchantable volume of species *j* in stratum *i*, for year *t*
Source of data:	Shall be based on national / local growth curve / table that usually used in national / local forest inventory
Measurement procedures (if any):	N/A
Any comment:	To be determined if the carbon gain-loss method is used in the estimation of carbon stock changes in above-ground and below-ground biomass in the baseline Note: $I_{V,j,i,t}$ is estimated as "current annual increment – CAI". The "mean annual increment" – MAI in the forestry jargon – can only be used if its use leads to conservative estimates. Note: the values of tables data if expressed on the per unit of area basis will usually apply to forest. Thus, they should be corrected to be applicable in the baseline conditions, e.g. by multiplication by the fraction of tree crown cover or fraction of number of stems in the baseline stratum of interest (other ways of correction may be proposed by PPs).

Data / parameter:	$nTR_{j,i,t}$
Data unit:	trees ha^{-1}
Used in equations:	11
Description	Pre-project tree stand density of species *j* in stratum *i*, at time *t*
Source of data:	Field measurements (pre-project)
Measurement procedures (if any):	Tree counts on sample plots. These tree counts then are used to estimate number of trees per hectare.
Any comment:	

Data / parameter:	R_j
Data unit:	d.m. kg^{-1} d.m.
Used in equations:	10, 16, 20
Description	Root-shoot ratio appropriate for biomass stock, for species *j*
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g. from national GHG inventory); (b) Species-specific or group of species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Species-specific or group of species-specific from global studies.
Measurement procedures (if any):	N/A
Any comment:	Guidelines for Conservative Choice of Default Values: 1. If in the sources of data mentioned above, default data are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then mean values of default data may be used and are considered conservative; 2. Global values may be selected from Table 3A.1.8 of the *GPG-LULUCF* (IPCC 2003), or equivalently Table 4.4 of the AFOLU Guidelines (IPCC 2006), by choosing a climatic zone and species that most closely matches the project circumstances; 3. Alternatively, given that many datasets of root-shoot ratios are relatively small because of the difficulty of determining this parameter, conservative selection of a value from the global study by Cairns *et al*. (1997) is likely to provide a reliable default value. For the purpose of estimating baseline removals by sinks, conservative value is about one standard deviation (c. 0.04) above the mean (0.26); i.e. a value of 0.3 kg d.m. kg^{-1} d.m. For the purpose of estimating the project removals by sinks, use a value about one standard deviation below the mean; i.e. 0.22 kg d.m. kg^{-1} d.m.

Data / parameter:	$R1_j$
Data unit:	kg d.m.yr^{-1} (kg d.m.yr^{-1})$^{-1}$
Used in equations:	5
Description	Root-shoot ratio appropriate for biomass increment for species *j*
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g. from national GHG inventory); (b) Species-specific or group of species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Species-specific or group of species-specific from global studies.
Measurement procedures (if any):	N/A
Any comment:	Guidelines for Conservative Choice of Default Values: 1. If in the sources of data mentioned above, default data are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then mean values of default data may be used and are considered conservative; 2. Global values may be selected from Table 3A.1.8 of the *GPG-LULUCF* (IPCC 2003), or equivalently Table 4.4 of the AFOLU Guidelines (IPCC 2006), by choosing a climatic zone and species that most closely matches the project circumstances;

Data / parameter:	$V_{tree,j,i,t}$
Data unit:	m^3 ha^{-1}
Used in equations:	9
Description	Pre-project tree stem volume of stratum *i*, species *j*, at time *t*
Source of data:	Shall be estimated based on number of trees and national / local growth curve / table that is usually covered by national / local forest inventory
Measurement procedures (if any):	
Any comment:	To be determined if the stock change method is used in the estimation of carbon stock changes in above-ground and below-ground biomass in the baseline. <u>Note</u>: the values of tables data if expressed on the per unit of area basis will usually apply to forest. Thus, they should be corrected to be applicable in the baseline conditions, e.g. by multiplication by the fraction of tree crown cover or fraction of number of stems in the baseline stratum of interest (other ways of correction may be proposed by PPs).

III. MONITORING METHODOLOGY

All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted according to relevant standards. In addition, the monitoring provisions in the tools referred to in this methodology apply.

1. Monitoring of Project Implementation

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

(i) The geographic position of the project boundary is recorded for all areas of land;

- The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This 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).

(ii) Commonly accepted principles of forest inventory and management are implemented;

- Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management shall be applied. Use or adaptation of SOPs already applied in national forest monitoring, or available from published handbooks, or from the *IPCC GPG LULUCF 2003*, is recommended;
- Apply SOPs especially, for actions likely to minimize soil erosion in those circumstances in which site preparation or planting involves soil disturbance capable to increase soil erosion above the baseline one;
- The forest planting and management plan, together with a record of the plan as actually implemented during the project shall be available for validation or verification, as appropriate.

2. Sampling design and stratification

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

<u>*2.1 Updating of strata*</u>

The *ex post* stratification shall be updated due to the following reasons:

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

Established strata may be merged if reasons for their establishing have disappeared.

2.2 Sampling framework

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

3. Data and parameters monitored

The following parameters should be monitored during the project activity. When applying all relevant equations provided in this methodology for the *ex ante* calculation of net anthropogenic GHG removals by sinks, project participants shall provide transparent estimations for the parameters that are monitored during the crediting period. These estimates shall be based on measured or existing published data where possible and project participants should retain a conservative approach: that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks should be selected.

Data / Parameter:	A_i
Data unit:	ha
Used in equations:	18, 26, 32
Description:	Area of stratum *i*
Source of data:	Monitoring of strata and stand boundaries shall be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data).
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	$a_{i,sp}$
Data unit:	m^2
Used in equations:	27
Description:	Area of sampling frame
Source of data:	Simple measurement of manufacturers data
Measurement procedures (if any):	Once selected, the selected size of the sampling frame shall be fixed until the end of the last crediting period.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Sampling frame will be used to collect litter samples

Data / Parameter:	$A_{sp,i}$
Data unit:	ha
Used in equations:	18
Description:	Total area of all sample plots in stratum *i*
Source of data:	Field measurement
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	APV
Data unit:	m^3
Used in equations:	39
Description:	Average volume of wood posts
Source of data:	Estimated from sampling
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	$BD_{i,p,t}$
Data unit:	$t\ m^{-3}$
Used in equations:	29
Description:	Bulk density (soil mass / volume of sample) of plot *p* in stratum *i*, time *t*
Source of data:	Determined in laboratory
Measurement procedures (if any):	Refer to procedure for determining $C_{SOC_{Sample,i,p,t}}$. For bulk density analysis, a single core shall be taken next to one of the carbon analysis cores. The samples are oven dried and weighed for bulk density determination and the oven dry weight of the soil samples shall be used to estimate the soil organic carbon
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	$B_{LI\_wet,i,sp}$
Data unit:	kg m^{-2}
Used in equations:	27
Description:	Humid weight (field) of the litter in plot *sp* of stratum *i*
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	**Step 1**: Litter shall be sampled using a sampling 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.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	$C_{SOC_{Sample,i,p,t}}$
Data unit:	g C/100 g soil
Used in equations:	29
Description:	Soil organic carbon of the sample in plot *p* in stratum *i*, time *t*
Source of data:	Determined in laboratory
Measurement procedures (if any):	***Step 1:*** The sample plots for soil sampling are selected taking into account the soil type, depth, and bulk density in the estimates. ***Step 2:*** Soil organic carbon shall be measured to a fixed depth (e.g. 30 cm) by collecting soil samples with a soil corer. The samples shall be collected from five locations within the plot. ***Step 3:*** Soil samples collected are aggregated to reduce the variability and sieved through 2 mm sieve, mixed and analyzed in the laboratory.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	$D_{n,i,t}$
Data unit:	cm
Used in equations:	25
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*, at time *t*
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Lying dead wood should be sampled using the line intersect method (Harmon and Sexton, 1996)[18]. 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.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	*DBH*
Data unit:	cm
Used in following equations	Implicitly used in eq. 11, 15, 19
Description:	Diameter breast height of tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Typically measured 1.3 m above-ground. Measure all the trees above some minimum *DBH* in the permanent sample plots that result from the A/R project 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 cmfor humid environments where trees grow rapidly
Monitoring frequency:	
QA/QC procedures:	
Any comment:	<u>Note</u>: for *ex ante* estimations, mean *DBH* and *H* values should be estimated for tree species *j* in stratum *i*, at time *t* using a growth model or yield table that gives the expected tree dimensions as a function of tree age. The allometric relationship between above-ground biomass and *DBH* and possibly *H* is a function of the species considered.

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

Data / parameter:	*DBP*
Data unit:	m
Used in equations:	39
Description:	Average distance between wood posts
Source of data:	Forest management plan/measurements at 10% of the length of fences
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	$Depth_{i,p,t}$
Data unit:	m
Used in equations:	29
Description:	Soil depth to which soil sample is collected for plot *p* in stratum *i*, time *t*
Source of data:	Field measurement
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	$FC_{i,p,t}$
Data unit:	Dimensionless.
Used in equations:	29
Description:	1 – (% volume of coarse fragments/100) to adjust the fraction of sample occupied by coarse fragments > 2mm at plot *p* in stratum *i*, time *t*
Source of data:	Determined in laboratory
Measurement procedures (if any):	The fraction of coarse fragments is to be determined by standard particle size analysis performed in most soil laboratories.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	$FG_{AR,t}$
Data unit:	m^3 yr^{-1}
Used in equations:	37
Description:	Average annual volume of fuelwood collected in the project area under the proposed A/R CDM project activity
Source of data:	Project Management Plan or field sampling
Measurement procedures (if any):	For each verification period, estimate the fuelwood collected in the project area. Besides volume, also determine what the dominant species is that is collected as fuelwood.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	$FG_{Conv,t}$
Data unit:	m^3 yr^{-1}
Used in equations:	37
Description:	Average annual volume of fuelwood collected during conversion of land to grazing land
Source of data:	Field sampling
Measurement procedures (if any):	For each verification period, estimate the fuelwood collected during conversion of land to grazing land. Besides volume, also determine what the dominant species is that is collected as fuelwood.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	H
Data unit:	m
Used in equations:	Implicitly used in eq. 11, 15, 19
Description:	Height of tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	<u>Note</u>: for *ex ante* estimations, mean DBH and H values should be estimated for tree species j in stratum i, at time t using a growth model or yield table that gives the expected tree dimensions as a function of tree age. The allometric relationship between above-ground biomass and DBH and possibly H is a function of the species considered.

Data / Parameter:	L
Data unit:	m
Used in equations:	25
Description:	Length of the transect to determine volume of lying dead wood
Source of data:	Field measurements
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	MP_{LI}
Data unit:	Dimensionless
Used in equations:	27
Description:	Dry-to-wet weight ratio of the litter (dry weight/wet weight)
Source of data:	Laboratory measurement of field samples
Measurement procedures (if any):	Litter samples shall be collected and well mixed into one composite sample 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. A subsample from the composite sample of litter is taken, oven dried and weighed to determine the dry weight.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	N
Data unit:	Dimensionless
Used in equations:	25
Description:	Total number of wood pieces intersecting the transect
Source of data:	Field measurements
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	PAR_t
Data unit:	m
Used in equations:	39
Description:	Perimeter of the areas to be fenced at year *t*
Source of data:	Project management plan or field measurements
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / Parameter:	T
Data unit:	yr
Used in equations:	7, 22, 23, 28, 30
Description:	Number of years between monitoring time t_2 and t_1 ($T = t2 – t1$)
Source of data:	
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

4. Conservative Approach and 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[19]; or

[19] 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 CDM-AR-PDD if there is any likelihood such reports may not be permanently available.

- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or
- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value should be briefly noted in the CDM-AR-PDD. For any data provided by experts, the CDM-AR-PDD shall also record the experts name, affiliation, and principal qualification as an expert (e.g., that they are a member of a country's national forest inventory technical advisory group)—plus inclusion of a 1-page summary CV for each expert consulted, included in an annex.

In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, project participants should select values that will lead to an accurate estimation of net GHG removals by sinks, taking into account uncertainties. If uncertainty is significant, project participants should choose data such that it tends to under-estimate, rather than over-estimate, net GHG removals by sinks.

IV. REFERENCES AND ANY OTHER INFORMATION

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History of the document

Version	Date	Nature of revision(s)
01	EB 38, Annex 7 14 March 2008	Initial adoption