Revision to the approved afforestation and reforestation baseline methodology AR-AM0005

"Afforestation and reforestation project activities implemented for industrial and/or commercial uses"

(Version 04)

I. SOURCE, DEFINITIONS AND APPLICABILITY

1. Sources

This methodology is based on the draft CDM-AR-PDD "Reforestation as Renewable Source of Wood Supplies for Industrial Use in Brazil" whose baseline study, monitoring and verification plan and project design document were prepared by Plantar S/A - Belo Horizonte, Brazil; World Bank - Carbon Finance Business, Washington DC, US. For more information regarding the proposal and its consideration by the Executive Board please refer to case ARNM0015-rev: "Reforestation as Renewable Source of Wood Supplies for Industrial Use in Brazil" at: <http://cdm.unfccc.int/goto/ARpropmeth>.

This methodology also refers to the latest approved versions of the following procedures and 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;
- Tool for the identification of degraded or degrading lands for consideration in implementing 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;
- Tool for the estimation of GHG emissions related to displacement of grazing activities in A/R CDM project activity.

All the above-mentioned procedures and tools are available at: <https://cdm.unfccc.int/Reference/Procedures> and <http://cdm.unfccc.int/Reference/tools>, respectively.

2. Selected Baseline Approach from Paragraph 22 of the CDM A/R Modalities and Procedures

"Changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts"

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 grasslands, possibly subject to afforestation and/or reforestation activity undertaken intermittently in small amounts prior to the A/R CDM project activity.

The conditions under which this methodology is applicable to A/R CDM project activities are:

- Land cover within the project boundary is degraded grasslands, which are expected to remain degraded without human intervention or to be partly afforested and/or reforested at a rate observed in the periods prior to the A/R CDM project activity;
- 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;
- Soil organic carbon pool may be conservatively neglected in the proposed A/R CDM project activity;
- Flooding irrigation is not applied in the project activity;
- Roots of the harvested trees shall not be removed from the soil;
- If at least a part of the project activity is implemented on organic soils, drainage of these soils is not allowed and not more than 10% of their area may be disturbed as result of soil preparation for planting.

The latest version of the "Tool for the identification of degraded or degrading lands for consideration in implementing A/R CDM project activities" shall be applied for demonstrating that lands are degraded or degrading.

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" shall be applied to demonstrate that the soil organic carbon pool may be conservatively neglected in A/R CDM project activities.

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 (PPs). The A/R CDM project activity may contain more than one discrete area of land. Each discrete area of land shall have a unique geographical identification.

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. PPs shall apply the latest version of the tool "Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities" as approved by the Executive Board.

The latest version of "Guidance on the application of the definition of project boundary to A/R CDM project activities" (available at: <http://cdm.unfccc.int/Reference/Guidclarif>) may be applied in identification of areas of land planned for an A/R CDM project activity.

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

Table 1: Selection and justification of carbon pools

Carbon Pools	Selected	Justification / Explanation
Above-ground	Yes	Major carbon pool subjected to the project activity
Below-ground	Yes	Major carbon pool subjected to the project activity
Dead wood	No	Conservative approach under applicability condition
Litter	No	Conservative approach under applicability condition
Soil organic carbon (SOC)	No	Conservative approach under applicability condition

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

Source	Gas	Included/ excluded	Justification / Explanation
Biomass burning	CO_2	Included	
	CH_4	Included	
	N_2O	Excluded	Potential emission is negligible
Removal of pre-existing non-tree woody vegetation	CO_2	Included	
	CH_4	Included	
	N_2O	Excluded	Potential emission is negligible

2. Identification of the baseline scenario and demonstration of additionality

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

In case the pre-project A/R activities occurred in a region subject to the same biophysical and socio-economic conditions as the planned project area, PPs must provide an estimate of: (i) the average regional, and (ii) the project entity-specific, annual rates of such activities.

(i) The average regional pre-project A/R annual rate shall be calculated for a region subject to the same biophysical and socio-economic conditions as the project area, including the planned project area. If regional data is not available or not reflecting sectoral conditions, average annual rate of pre-project A/R undertaken at the national level should be used instead;

(ii) The average project entity-specific annual pre-project A/R rate shall be calculated for the entire land under control of the project entity, including the planned project area.

The determination of such average rates must be established by means of historical data covering the period of at least five and not more than ten years preceding the year of: (i) signing the contractual agreement for validation, or (ii) the start of the project activity, whichever comes earlier.

The average annual pre-project A/R rate shall be calculated using the following formula:

$$R_{AR} = \frac{\sum_{t_1}^{t_2} a_{AR\ t}}{A_{AR} * (t_2 - t_1)} \quad (1)$$

where:

R_{AR}	Average annual pre-project A/R rate over: (i) land under control of the project entity; (ii) a region subject to the same biophysical, socio-economic conditions and legal circumstances as the project area, as appropriate; yr^{-1}
$a_{AR\ t}$	Area of the pre-project A/R in year *t* over: (i) land under control of the project entity; (ii) a region subject to the same biophysical and socio-economic conditions as the project area, as appropriate; ha
A_{AR}	Area of: (i) land under control of the project entity; (ii) a region subject to the same biophysical, socio-economic conditions and legal circumstances as the project area, as appropriate. The area shall be suitable for A/R in the year t_1 hence, it shall not contain forest in that year; ha
t_2 , t_1	Last and first year a period for which historical data are available; yr

To provide conservative estimates, the average regional and project-entity specific annual pre-project A/R rates shall be compared and the higher one shall be selected as the plausible baseline A/R rate.

The pre-project A/R activities at the above determined baseline rate shall be also included among the plausible land-use alternatives in Step 1of the “Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities”.

In addition, based on the paragraph 3 of Annex 19 in the EB 24 report, the assessment of additionality shall include the justification that the increased rate of A/R would not occur in the absence of the project activity and results from direct intervention by project participants.[1]

3. Stratification

If the project activity area is not homogeneous, stratification should be carried out to improve the accuracy and the 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 on the basis of parameters that are key entry 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.** It will usually be sufficient to stratify according to area of major vegetation types because baseline removals for degraded (or degrading) land are expected to be small in comparison to project removals;
- **For actual net GHG removals by sinks.** The *ex ante* estimations shall be based on the project planting/**management** plan. The *ex post* stratification shall be based on the actual implementation of the project planting/management plan. The *ex post* stratification may

[1] <http://cdm.unfccc.int/EB/024/eb24_repan19.pdf>.

be affected by natural or anthropogenic impacts if they are able to add variability to growth pattern in the project area, e.g., local fires (see Section III.2).

Further subdivision of the project strata to represent spatial variation in the distribution of the baseline or the project biomass stocks/removals is not usually warranted. However, factors impacting growth (e.g., soil type) might be useful for *ex post* stratification if their variability in the project area is large.

For *ex ante* and *ex post* stratification, PPs may optionally make use of remote sensing data acquired close to the time the project commences and/or close to the time of occurrence of natural or anthropogenic impacts if such impacts add variability to growth pattern in the project area.

4. Baseline Net GHG Removals by Sinks

Under the applicability conditions of this methodology the baseline net GHG removals by sinks consist of two components and will be determined as:

$$\Delta C_{BSL} = \Delta C_{BSL,tree} + \Delta C_{BSL,A/R} \quad \textbf{(2)}$$

where:

ΔC_{BSL}	Baseline net greenhouse gas removals by sinks; t CO_2-e
$\Delta C_{BSL,tree}$	Sum of the carbon stock changes caused by trees actually present in the planned project area in the baseline; t CO_2-e
$\Delta C_{BSL,A/R}$	Sum of the carbon stock changes caused by virtual continuation of the pre-project A/R in the baseline; t CO_2-e

4.1 Carbon stock changes caused by trees actually present in the planned project area

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 (SOC) may be conservatively assumed to be zero for all strata in the baseline scenario.

If the pre-project crown cover of trees within the project boundary is less than 20% of the threshold for crown cover reported to the EB by the host Party then the baseline net GHG removals by sinks may be accounted for as zero. Otherwise, the baseline net GHG removals by sinks are identical with carbon stock changes in above-ground and below-ground tree biomass ($\Delta C_{BSL,tree}$) and shall be estimated as per the equations below. 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.

$$\Delta C_{BSL,tree,i} = \frac{44}{12} * \sum_{t=1}^{t^*} \Delta C_{BSL,AG/BG,i,t} * 1\,year \quad \textbf{(3)}$$

where:

$\Delta C_{BSL,tree,i}$	Sum of the baseline annual carbon stock changes 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,* year *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 on the basis of the availability of data.

Method 1 (Carbon gain-loss method)[2]

$$\Delta C_{BSL,AG/BG,i,t} = \Delta C_{G,i,t} - \Delta C_{L,i,t} \qquad \textbf{(4)}$$

where:

$\Delta C_{BSL,AG/BG,i,t}$	Baseline annual carbon stock net change in above-ground and below-ground biomass for stratum *i,* year *t*; t C yr^{-1}
$\Delta C_{G,i,t}$	Annual increase in above-ground and below-ground carbon due to biomass growth of living trees in stratum *i*, for year *t*; t C yr^{-1} Note: This is the "potential growth" which is greater than the "observed growth".
$\Delta C_{L,i,t}$	Annual decrease in above-ground and below-ground carbon stock of living trees due to biomass loss for stratum *i*, year *t*; t C yr^{-1} Note: Conservative assumption that $\Delta C_{L,i,t} = 0$ is allowed for the baseline scenario.[3]
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

$$\Delta C_{G,i,t} = A_{BSL,i} * \sum_{j=1}^{J} G_{tree,j,i,t} * CF_j \qquad \textbf{(5)}$$

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-ground and below-ground dry biomass of living trees of species *j*, in stratum *i*, for year *t*; t d.m. ha^{-1} yr^{-1}

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

[3] 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.

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

$$G_{tree,j,i,t} = G_{w,j,i,t} * (1 + R_{1j}) \quad \textbf{(6)}$$

$$G_{w,j,i,t} = I_{V,j,i,t} * D_j * BEF_{1,j} \quad \textbf{(7)}$$

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}
R_{1j}	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. $(t\ d.m.)^{-1}$
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 (6). 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 equation (4) 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 on the basis of 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)[4]

$$\Delta C_{BSL,AG/BG,i,t} = \sum_{j=1}^{J} \frac{C_{j,i,t_2} - C_{j,i,t_1}}{T} \quad \textbf{(8)}$$

$$C_{j,i,t} = C_{AB\_tree,j,i,t} + C_{BB\_tree,j,i,t} \quad \textbf{(9)}$$

$$C_{AB\_tree,j,i,t} = A_{BSL,i} * V_{tree,j,i,t} * D_j * BEF_{2,j} * CF_j \quad \textbf{(10)}$$

$$C_{BB\_tree,j,i,t} = C_{AB\_tree,j,i,t} * R_j \quad \textbf{(11)}$$

where:

$\Delta C_{BSL,AG/BG,i,t}$	Annual carbon stock change in above-ground and below-ground tree biomass for stratum *i*, year *t*; t C yr^{-1}
$C_{j,i,t}$	Total carbon stock in living biomass of trees of species *j*, in stratum *i*, calculated at year *t*; t C
T	Number of years between times t_2 and t_1; yr
$C_{AB\_tree,j,i,t}$	Carbon stock in above-ground tree biomass of species *j*, in stratum *i*, at year *t*; t C
$C_{BB\_tree,j,i,t}$	Carbon stock in below-ground tree biomass of species *j*, in stratum *i*, at year *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 year *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:

$$C_{AB\_tree,j,i,t} = A_{BSL,i} * nTR_{j,i,t} * CF_j * f_j(DBH, H) \quad \textbf{(12)}$$

[4] GPG-LULUCF Equation 3.2.3.

where:

$C_{AB\_tree,j,i,t}$	Carbon stock in above-ground tree biomass of species *j*, in stratum *i*, at year *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 year *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. $tree^{-1}$ (Note: 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 on the basis of 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 estimated as per approach provided in Section 4.1 until steady state is reached under the baseline conditions. Under steady state:

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

PPs may, on a project specific basis, assess when a steady state is reached during the crediting period. This shall be estimated on the basis of 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.

4.3 Carbon stock changes caused by virtual continuation of the pre-project A/R in the baseline

If the A/R CDM project activities are implemented on degraded grasslands, subject to afforestation and/or reforestation activity undertaken intermittently in small amounts prior to the A/R CDM project activity then the following approach shall be applied to estimate their impact on the net anthropogenic GHG removals by sinks.

It is assumed that the pre-project A/R is virtually continued at the average annual rate selected according to the approach described in the Chapter 2. “Identification of the baseline scenario and demonstration of additionality” for a period of 20 years and discontinued afterwards.

It is expected that the stands resulting from baseline A/R are not managed towards maximization of net anthropogenic GHG removals by sinks hence, their GHG performance will always be worse than the project stands hence, the stands resulting from the virtual continuation of the pre-project A/R may be conservatively approximated by the project stands. The carbon stock changes caused by virtual continuation of the pre-project A/R in the baseline shall be estimated as follows:

$$\Delta C_{BSL,A/R} = R_{AR} * t^* * C_{AR-CDM} \text{ for } 0 < t^* \leq 20$$

$$\Delta C_{BSL,A/R} = 0 \text{ for } t^* > 20 \qquad \textbf{(13)}$$

where:

$\Delta C_{BSL,A/R}$	Sum of the carbon stock changes caused by virtual continuation of the pre-project A/R in the baseline between project start (t =1) and the year t^*, t^* being the year for which baseline net greenhouse gas removals by sinks are determined; t CO_2-e
R_{AR}	Average annual pre-project A/R rate over: (i) land under control of the project entity; (ii) a region subject to the same biophysical and socio-economic conditions as the project area, as appropriate; yr^{-1}
C_{AR-CDM}	Net anthropogenic greenhouse gas removals by sinks between project start (t =1) and the year t^*, t^* being the year for which baseline net greenhouse gas removals by sinks are determined; t CO_2-e

Equation 13 provides estimate for sum of the carbon stock changes caused by virtual continuation of the pre-project A/R in the baseline between project start (t =1) and the year t^* for all strata (hence, it does not require separate summation over strata).

5. Actual 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 project scenario.

The actual net greenhouse gas removals by sinks 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, PPs 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. PPs should retain a conservative approach in making these estimates.

$$\Delta C_{ACTUAL} = \Delta C_P - GHG_E \qquad \textbf{(14)}$$

where:

ΔC_{ACTUAL}	Actual net greenhouse gas removals by sinks; t CO_2-e
ΔC_P	Sum of the changes in carbon stocks of the above-ground and below-ground tree biomass, 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: Equation (14) 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

Under the applicability conditions of this methodology:

- Increase in CO_2 emissions from loss of existing woody biomass due to competition from forest (or other vegetation) planted as part of the A/R CDM project activity is negligible and may be assumed to be zero for all strata in the project scenario.

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:[5]

$$\Delta C_P = \sum_{t=1}^{t^*} \Delta C_t * \frac{44}{12} * 1\ year - E_{BiomassLoss} \qquad \textbf{(15)}$$

where:

ΔC_P	Sum of the changes in carbon pools in above-ground and below-ground tree biomass 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 removal (including burning) of the pre-project woody biomass as a part of the A/R CDM project activity; t CO_2-e
t	*1, 2, 3, ...* t^* years elapsed since the start of the A/R project activity; yr
44/12	Ratio of molecular weights of CO_2 and carbon; t CO_2-e $(t\ C)^{-1}$

ΔC_t shall be estimated using the following equation:

$$\Delta C_t = \sum_{i=1}^{M_{PS}} (\Delta C_{AG,i,t} + \Delta C_{BG,i,t}) \qquad \textbf{(16)}$$

where:

ΔC_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, year t (possibly average over a monitoring period); t C yr^{-1}

[5] IPCC GPG-LULUCF 2003, Equation 3.2.3.

$\Delta C_{BG,i,t}$	Annual carbon stock change in below-ground biomass of trees for stratum *i*, year *t* (possibly average over a monitoring period); 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-ground and below-ground biomass per unit area is estimated on the basis of field measurements in permanent sample plots. Two methods are available: the Biomass Expansion Factors (*BEF*) method and the Allometric Equations method.

BEF method

Step 1: Determine on the basis of available data, 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 stem volume of trees ($V_{l,j,i,sp,t}$) on the basis of 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 field instruments (e.g., a relascope) that measure the volume of each tree directly are applied.

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

$$C_{AB\_tree,l,j,i,sp,t} = V_{l,j,i,sp,t} * D_j * BEF_{2,j} * CF_j \quad \textbf{(17)}$$

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 year *t*; t C
$V_{l,j,i,sp,t}$	Stem volume of tree *l,* of species *j,* in plot *sp,* in stratum *i,* at year *t*; m^3
D_j	Basic wood density of species *j*; t d.m. m^{-3}
$BEF_{2,j}$	Biomass expansion factor for conversion of stem biomass to above-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, …* 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 5: Convert the carbon stock in above-ground biomass to the carbon stock in below-ground biomass via root-shoot ratio, given by:

$$C_{BB\_tree,l,j,i,sp,t} = C_{AB\_tree,l,j,i,sp,t} * R_j \quad \textbf{(18)}$$

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 year *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 year *t*; t C
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless

According to the applicability conditions of this methodology the below-ground carbon stock estimated in the year before each harvest shall be assumed to be constant until a year before the next harvest, when it shall be estimated again.

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

$$C_{tree,i,sp,t} = \sum_{j=1}^{S_{PS}} \sum_{l=1}^{N_{j,i,sp,t}} (C_{AB\_tree,l,j,i,sp,t} + C_{BB\_tree,l,j,i,sp,t}) \quad \textbf{(19)}$$

where:

$C_{tree,i,sp,t}$	Carbon stock in trees on plot *sp,* of stratum *i,* at year *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 year *t*; t C
$C_{BB\_tree,l,j,i,sp,t}$	Carbon stock in below-ground biomass of tree *l,* of species *j,* in plot *sp,* in stratum *i,* at year *t*; t C
$N_{j,i,sp,t}$	Number of trees of species *j,* on plot *sp,* of stratum *i,* at year *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 tree biomass for each stratum:

$$C_{tree,i,t} = \frac{A_i}{A_{sp_i}} \sum_{sp=1}^{P_i} C_{tree,i,sp,t} \quad \textbf{(20)}$$

where:

$C_{tree,i,t}$	Carbon stock in trees in stratum *i*, at year *t*; t C

$C_{tree,i,sp,t}$	Carbon stock in trees on plot *sp,* of stratum *i,* at year *t*; t C
A_{sp_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: Proceed as in 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 determined in Step 1, and sum the carbon stocks in the sample plot:

$$C_{AB\_tree,j,i,sp,t} = \sum_{l=1}^{N_{j,sp}} f_j(DBH,H) * CF_j \tag{21}$$

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 year *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 a living tree; t d.m.
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:

$$C_{BB\_tree,j,i,sp,t} = C_{AB\_tree,j,i,sp,t} * R_j \tag{22}$$

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 year *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 year *t*; t C
R_j	Root-shoot ratio appropriate for biomass stock, for species *j*; dimensionless

According to the applicability conditions of this methodology the below-ground carbon stock estimated in the year before each harvest shall be assumed to be constant until a year before the next harvest, when it shall be estimated again.

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

$$C_{tree,i,sp,t} = \sum_{j=1}^{S_{PS}} (C_{AB\_tree,j,i,sp,t} + C_{BB\_tree,j,i,sp,t}) \quad \textbf{(23)}$$

where:

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

Step 6: Calculate the mean carbon stock in tree biomass for each stratum, as per equation (20) - i.e., Step 7 of the *BEF* method.

For both the *BEF* and the allometric methods calculate:

$$\Delta C_{AG,i,t} + \Delta C_{BG,i,t} = \frac{C_{tree,i,t_2} - C_{tree,i,t_1}}{T} \quad \textbf{(24)}$$

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 year *t*; t C
T	Number of years between monitoring time t_2 and t_1 ($T = t_2 - t_1$); 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 Increase in CO_2 emissions from removal (including burning) of the pre-project woody biomass

Increase in CO_2 emissions from removal of the pre-project trees as a part of the A/R CDM project activity is negligible and shall be accounted for as zero when the pre-project crown cover of trees within the project boundary is less than 20% of the threshold for crown cover reported to the EB by the host Party. Otherwise, the increase is assumed to be equal to sum of the baseline annual carbon stock changes in above-ground and below-ground tree biomass removed during the site preparation for initiation of the project. One of the following two cases will occur.

5.1.2.1 Case 1: Method 1 (Carbon gain-loss method) is used to estimate the baseline net GHG removals by sinks

Carbon gain-loss method may be used only if PPs have data allowing calculation of baseline net GHG removals by sinks by strata during the initial twenty years of the project duration because it is assumed that amount of pre-project biomass present at the start of the project activity and subject to removal is equal to the baseline net GHG removals by sinks accumulated over that period. In such a case, the equations 4-7 shall be used to calculate the baseline net GHG removals by sinks for area subject to removal of pre-project woody biomass, that means for the purpose of this calculation:

$A_{BSL,i}$	Area of baseline stratum *i*; ha

shall be changed into:

$A_{BSL,i}$	Area subject to removal of pre-project woody biomass in baseline stratum *i*; ha

and used to estimate $\Delta C_{BSL,AG/BG,i,t}$ (understood here as the baseline net GHG removals by sinks over areas subject to removal of pre-project woody biomass in baseline stratum *i*).

The increase in CO_2 emissions from removal (including burning) of the pre-project woody biomass is approximated as:

$$E_{BiomassLoss} = \frac{44}{12} * \sum_{i=1}^{M_{PS}} \sum_{t=1}^{20} \Delta C_{BSL,AG/BG,i,t} * 1\, year \qquad \textbf{(25)}$$

where:

$E_{BiomassLoss}$	Increase in CO_2 emissions from removal (including burning) of the pre-project woody biomass as a part of the A/R CDM project activity; t CO_2-e
$\Delta C_{BSL,AG/BG,i,t}$	Baseline net GHG removals by sinks over areas subject to removal of pre-project woody biomass in baseline stratum *i*; t CO_2-e
i	*1, 2, 3, … M_{PS}* strata in the project scenario
t	*1, 2, 3, … 20* years elapsed since the start of the A/R CDM project activity

5.1.2.2 Case 2: Method 2 (stock change method) is used to estimate the baseline net GHG removals by sinks

Stock change method may be used only if PPs have data on carbon stock in above-ground biomass and below-ground tree biomass by species and strata at the project start (year 0). In such a case the Equations 9-11 shall be used to calculate the baseline net GHG removals by sinks for area subject to removal of pre-project woody biomass, that means for the purpose of this calculation:

$A_{BSL,i}$	Area of baseline stratum *i*; ha

shall be changed into:

$A_{BSL,i}$	Area subject to removal of pre-project woody biomass in baseline stratum *i*; ha

The increase in CO_2 emissions from removal (including burning) of the pre-project woody biomass is approximated as:

$$E_{BiomassLoss} = \sum_{i=1}^{M_{PS}} \sum_{j=1}^{S_{PS}} C_{j,i,0} = \sum_{i=1}^{M_{PS}} \sum_{j=1}^{S_{PS}} (C_{AB\_tree,j,i,0} + C_{BB\_tree,j,i,0}) \qquad \textbf{(26)}$$

where:

$E_{BiomassLoss}$	Increase in CO_2 emissions from removal (including burning) of the pre-project woody biomass as a part of the A/R CDM project activity; t CO_2-e
$C_{j,i,0}$	Total carbon stock in living biomass of pre-project trees of species *j*, in stratum *i*, calculated at year *0*; t C
$C_{AB\_tree,j,i,0}$	Carbon stock in above-ground tree biomass of species *j*, in stratum *i*, at year *0*; t C
$C_{BB\_tree,j,i,0}$	Carbon stock in below-ground tree biomass of species *j*, in stratum *i*, at year *0*; t C
i	*1, 2, 3, … M_{PS}* strata in the project scenario
j	*1, 2, 3, … S_{PS}* tree species in the project scenario

5.2 Estimation of increase in non-CO_2 GHG emissions within the project boundary

5.2.1 Burning of pre-project trees in preparation for the initial planting

If the pre-project crown cover of trees within the project boundary is less than 20% of the threshold for crown cover reported to the EB by the host Party and fire is used to remove them in the site preparation for the initial planting then the increase in non-CO_2 GHG emissions from burning of the trees is negligible and shall be accounted for as zero. Otherwise, the increase shall be assessed using the approach presented below.

5.2.2 Use of fire as a part of the forest management

The increase in GHG emissions as a result of the implementation of the proposed A/R CDM project activity within the project boundary is non-CO_2 GHG emission from biomass burning (e.g., prescribed burning, clearing site before replanting) as a part of the forest management. It is estimated as:

$$GHG_E = \sum_{t=1}^{t^*} E_{BiomassBurn,t} \qquad \textbf{(27)}$$

where:

GHG_E	Increase in non-CO_2 GHG emissions as a result of the implementation of the proposed A/R CDM project activity within the project boundary; t CO_2-e
$E_{BiomassBurn,t}$	Non-CO_2 GHG emissions due to biomass burning as part of the forest management in the year *t*; t CO_2-e
t	*1, 2, 3, … t^** years elapsed since the start of the A/R CDM project activity

Equation (27) 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 non-CO_2 emissions due to biomass burning are calculated using the following approach based on the IPCC GPG LULUCF.

5.2.2.1 Estimation of the non-CO_2 emissions due to biomass burning

The approach applied in Equation 3.2.20 of the IPCC GPG LULUCF requires data on the above-ground volume/biomass of a vegetation subject to burning as part of the forest management and leads to the following equation:

$$E_{BiomassBurn,t} = EF_{CH_4} * GWP_{CH_4} * C_f * 10^{-3} * \sum_{i=1}^{M_{PS}} A_{burn,i} * B_{burn,i,t} \qquad \textbf{(28)}$$

where:

$E_{BiomassBurn,t}$	Increase in non-CO_2 greenhouse gas emissions due to biomass burning as part of the forest management in year t; t CO_2-e
$A_{burn,i}$	Area subject to burning located in the stratum i; ha
$B_{burn,i,t}$	Average above-ground biomass stock of a vegetation subject to burning as part of the forest management in year t; t d.m. ha^{-1}
C_f	Combustion factor; dimensionless. (IPCC default values are available in Table 2.6, page 2.48, 2006 IPCC Guidelines for National Greenhouse Gas Inventories).
EF_{CH_4}	Emission factor for CH_4; g CH_4 (kg d.m. burned)$^{-1}$ (IPCC default values are available in Table 2.5, page 2.47, 2006 IPCC Guidelines for National Greenhouse Gas Inventories)
GWP_{CH_4}	Global warming potential for CH_4 (IPCC default: 21 for the first commitment period of the Kyoto Protocol); t CO_2-e (t CH_4)$^{-1}$
i	*1, 2, 3, …* M_{PS} strata in the project scenario

Estimation of the average above-ground biomass stock of a vegetation subject to burning as part of the forest management

The average stock of above-ground biomass of a vegetation subject to burning as part of the forest management in year t per unit area is estimated on the basis of field measurements in those permanent or temporary (for explanation see below) sample plots which are located in areas subject to burning.

Step 1: Determine on the basis of available data (*ex ante*) or measurements (*ex post*), the characteristic numerical data on a vegetation subject to burning as part of the forest management, e.g., diameter at grid, breast or other height as appropriate (*Dh*), height (*H*), crown cover (*CC*), number of stems (*NS*) or any other numerical data known to be related to volume or biomass of a vegetation subject to burning as part of the forest management in those permanent sample plots which are located in areas subject to burning (if burning is planned over an area where there is no permanent sample plots the temporal plots shall be used). The set of characteristic numerical data used by PPs is dependent on the species and the method and need not to follow the above list. The PPs shall however, provide in the PDD a description of the relationship (equation, yield tables, etc.) between measurements taken in the sample plots and the above-ground volume/biomass of a vegetation subject to burning as part of the forest management, including relevant references (this may include reference to own measurements).

Step 2: Estimate the above-ground volume/biomass of a vegetation subject to burning as part of the forest management on the basis of the above-mentioned equations or yield tables. It is possible to combine Steps 1 and 2 if a method that directly estimates the volume/biomass of a vegetation subject to burning as part of the forest management is applied. One of the two following cases will apply:

Case 1: The above-ground volume of a vegetation subject to burning as part of the forest management was estimated in Step 2 above.

Convert the volume into above-ground biomass via basic wood density:

$$B_{AB\_burn,l,j,i,sp,t} = f_{Vj}(Dh, H, ...)_{burn,l,i,sp,t} * D_j \quad \textbf{(29)}$$

Case 2: The above-ground biomass of a vegetation subject to burning as part of the forest management was estimated in Step 2 above:

$$B_{AB\_burn,l,j,i,sp,t} = f_j(Dh, H, ...)_{burn,l,i,sp,t} \quad \textbf{(30)}$$

where (for equations (29) and (30)):

$B_{AB\_burn,l,j,i,sp,t}$	Above-ground biomass of a vegetation subject to burning as part of the forest management individual *l,* of species *j,* in plot *sp,* in stratum *i,* at year *t*; t d.m.
$f_{Vj}(Dh, H, ...)_{burn,l,i,sp,t}$	Volume of a vegetation subject to burning as part of the forest management individual *l,* of species *j,* in plot *sp,* in stratum *i,* at year *t*; m^3
$f_j(Dh, H, ...)_{burn,l,i,sp,t}$	Biomass of a vegetation subject to burning as part of the forest management individual *l,* of species *j,* in plot *sp,* in stratum *i,* at year *t*; t d.m.
D_j	Basic wood density of a vegetation subject to burning as part of the forest management of species *j*; t d.m. m^{-3}
l	*1, 2, 3, …* $N_{j,i,sp,t}$ individuals of a vegetation subject to burning as part of the forest management of species *j,* on plot *sp,* of stratum *i,* at year *t*
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 3: Calculate above-ground biomass of a vegetation subject to burning as part of the forest management present in plot *sp* in stratum *i* at year *t* (i.e., summation over all individuals *l* by species *j* followed by summation over all species *j* present in plot *sp*):

$$B_{burn,i,sp,t} = \sum_{j=1}^{S_{PS}} \sum_{l=1}^{N_{j,i,sp,t}} B_{AB\_burn,l,j,i,sp,t} \quad \textbf{(31)}$$

where:

$B_{burn,i,sp,t}$	Biomass in a vegetation subject to burning as part of the forest management on plot *sp,* of stratum *i,* at year *t*; t d.m.

$B_{AB\_burn,l,j,i,sp,t}$	Above-ground biomass of a vegetation subject to burning as part of the forest management *l,* of species *j,* in plot *sp,* in stratum *i,* at year *t*; t d.m.
l	*1, 2, 3, …* $N_{j,i,sp,t}$ individuals of a vegetation subject to burning as part of the forest management of species *j,* on plot *sp,* of stratum *i,* at year *t*
i	*1, 2, 3, …* M_{PS} strata in the project scenario
j	*1, 2, 3, …* S_{PS} vegetation subject to burning as part of the forest management species in the project scenario
t	*1, 2, 3, …* t^* years elapsed since the start of the A/R CDM project activity

Step 4: Calculate the mean biomass per hectare of a vegetation subject to burning as part of the forest management for each stratum:

$$B_{burn,i,t} = \frac{1}{A_{burn,sp_i}} \sum_{sp=1}^{P_i} B_{burn,i,sp,t} \quad \textbf{(32)}$$

where:

$B_{burn,i,t}$	Biomass in a vegetation subject to burning as part of the forest management in stratum *i*, at year *t*; t d.m. ha^{-1}
$B_{burn,i,sp,t}$	Biomass in a vegetation subject to burning as part of the forest management on plot *sp,* of stratum *i,* at year *t*; t d.m.
A_{burn,sp_i}	Total area of all sample plots in stratum *i* which are located in areas subject to burning; ha
sp	*1, 2, 3, …* P_i sample plots in stratum *i* in the project scenario which are located in areas subject to burning
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 monitoring of emissions by sources is only required if significant; if insignificant, evidence should be provided (e.g., as a 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.

6. Leakage

Under applicability conditions for this methodology, the displacement of grazing activities (i.e. displacement of animals) to areas outside the project may occur under the project scenario. Therefore the leakage shall be estimated as follows:

$$LK = \sum_{t=1}^{t^*} LK_{Displacement,t} \quad \textbf{(33)}$$

where:

LK	Total GHG emissions due to leakage; t CO_2-e
$LK_{Displacement,t}$	Leakage due to displacement of animals in year *t*; t CO_2-e

Note: 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 the net anthropogenic greenhouse gas removals by sinks are estimated.

6.1 Estimation of leakage due to activity displacement

If application of the latest approved guidance on the conditions under which increase in GHG emissions related to displacement of pre-project grazing activities in A/R CDM project activity is insignificant leads to a conclusion that the conditions are not applicable to the project activity then the leakage due to displacement of animals 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".

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 A/R CDM project activity (C_{AR-CDM}), in t CO_2-e.

$$C_{AR-CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK \quad \textbf{(34)}$$

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

Under applicability conditions of this methodology the following equations shall apply for estimation of net anthropogenic greenhouse gas removals by sinks:

If $0 < t^* \leq 20$

$$C_{AR-CDM} = \frac{\Delta C_{ACTUAL} - \Delta C_{BSL,tree} - LK}{1 + R_{AR} * t^*} \quad \textbf{(35)}$$

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
$\Delta C_{BSL,tree}$	Sum of the carbon stock changes caused by trees actually present in the planned project area in the baseline; t CO_2-e
LK	Total GHG emissions due to leakage; t CO_2-e
R_{AR}	Average annual pre-project A/R rate over: (i) land under control of the project entity; (ii) a region subject to the same biophysical and socio-economic conditions as the project area, as appropriate; yr^{-1}

t^*	Year for which the net anthropogenic greenhouse gas removals by sinks are estimated; yr

For $20 < t^*$

$$C_{AR-CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL,tree} - LK \quad \textbf{(36)}$$

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
$\Delta C_{BSL,tree}$	Sum of the carbon stock changes caused by trees actually present in the planned project area in the baseline; 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 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,[6] which produces the same estimates as the following:

$$tCERs = C_{AR-CDM,t_2} \quad \textbf{(37)}$$

$$lCERs = C_{AR-CDM,t_2} - C_{AR-CDM,t_1} \quad \textbf{(38)}$$

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 $t^* = t_2$; t CO_2-e
C_{AR-CDM,t_1}	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; t CO_2-e

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, PPs 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.

[6] See <http://cdm.unfccc.int/Reference/Guidclarif/>.

Data / parameter:	$A_{BSL,i}$
Data unit:	ha
Used in equations:	(5),(10),(12)
Description:	Area of baseline stratum *i,* or, area subject to removal of pre-project woody biomass in baseline stratum *i*; ha
Source of data:	GPS coordinates and/or remote sensing data
Measurement procedures:	
Any comment:	In chapters 5.1.2.1 and 5.1.2.2: area subject to removal of pre-project woody biomass in baseline stratum *i*

Data / parameter:	$a_{AR\ t}$
Data unit:	ha
Used in equations:	(1)
Description:	Area of the pre-project A/R in year *t* over: (i) land under control of the project entity; (ii) a region subject to the same biophysical and socio-economic conditions as the project area, as appropriate
Source of data:	
Measurement procedures:	
Any comment:	

Data / parameter:	A_{AR}
Data unit:	ha
Used in equations:	(1)
Description:	Area of: (i) land under control of the project entity; (ii) a region subject to the same biophysical and socio-economic conditions as the project area, as appropriate. The area shall be suitable for A/R in the year t_I hence, it shall not contain forest in that year
Source of data:	
Measurement procedures:	
Any comment:	

Data / parameter:	$BEF_{1,j}$
Data unit:	Dimensionless
Used in equations:	(7)
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 any of the following: (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; (d) Globally species-specific or group of species-specific (e.g., IPCC literature: Table 3A.1.10[7] of the *GPG-LULUCF* (IPCC 2003), and Table 4.5[8] of the *AFOLU Guidelines* (IPCC 2006).)
Measurement procedures (if any):	
Any comment:	*BEFs* in IPCC literature and national inventory data 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:	$BEF_{2,j}$
Data unit:	Dimensionless
Used in equations:	(10),(17)
Description:	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for tree species *j*
Source of data:	The source of data shall be any of the following: (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; (d) Globally species-specific or group of species-specific (e.g., IPCC GPG-LULUCF 2003)
Measurement procedures:	
Any comment:	*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%

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

[8] Values of the *BEF* must be derived from the parameter $BCEF_S$ in Table 4.5 (AFOLU guidelines, IPCC 2006) according to the equation $BEF = BCEF_S/D_V$, using age-dependent wood density if available.

Data / parameter:	CF_j
Data unit:	t C t^{-1} d.m.
Used in equations:	(5), (10), (12), (17), (21)
Description:	Carbon fraction of dry matter for species of type *j*
Source of data:	The source of data shall be any of the following: (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; (c) Globally species-specific or group of species-specific (e.g., IPCC GPG-LULUCF 2003); (d) The default IPCC value 0.5 t C t^{-1} d.m.
Measurement procedures:	N/A
Any comment:	Carbon fraction of dry matter for dominant species *DS* when *j=DS*

Data / parameter:	D_j
Data unit:	t d.m. m^{-3}
Used in equations:	(7), (10), (29), (17)
Description:	Basic wood density for species *j*
Source of data:	The source of data shall be any of the following: (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; (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:	$f_j(DBH, H)$
Data unit:	t d.m.
Used in equations:	(12), (21)
Description:	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly tree height (*H*) to above-ground biomass of a living tree
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[9] sub-samples from each of the wet stem and branch components,[10] 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 underestimate rather than overestimate of project net anthropogenic removals by sinks)—then mean values from the default equation may be used

Data / parameter:	$f_{Vj}(Dh,H,...)_{burn,l,i,sp,t}$, $f_j(Dh,H,...)_{burn,l,i,sp,t}$
Data unit:	m^3
Used in equations:	(29), (30)
Description:	Volume (biomass) of a vegetation subject to burning as part of the forest management individual *l,* of species *j,* in plot *sp,* in stratum *i,* at year *t*
Source of data:	
Measurement procedures:	
Any comment:	

Data / parameter:	$I_{V,j,i,t}$
Data unit:	m^3 ha^{-1} yr^{-1}
Used in equations:	(7)
Description:	Average annual increment in stem 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

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

[10] 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.

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 the "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 read from tables 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 project proponents)

Data / parameter:	$nTR_{j,i,t}$
Data unit:	trees ha^{-1}
Used in equations:	(12)
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
Any comment:	Tree counts are used to estimate number of trees per hectare

Data / parameter:	R_j
Data unit:	kg d.m.yr^{-1} (kg d.m.yr^{-1} $)^{-1}$
Used in equations:	(11), (18), (22)
Description:	Root-shoot ratio appropriate for biomass stock, for species *j*
Source of data:	The source of data shall be any of the following: (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; (c) Species-specific or group of species-specific from global studies
Measurement procedures (if any):	N/A

Any comment:	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 from 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, a conservative value is about one standard deviation (circa 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:	R_{1j}
Data unit:	kg d.m.yr^{-1} (kg d.m.yr^{-1})$^{-1}$
Used in equations:	(6)
Description:	Root-shoot ratio appropriate for biomass increment for species *j*
Source of data:	The source of data shall be any of the following: (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; (c) Species-specific or group of species-specific from global studies
Measurement procedures (if any):	N/A
Any comment:	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 from 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:	(10)
Description:	Pre-project tree stem volume of stratum *i,* species *j*, at time *t*
Source of data:	Shall be estimated on the basis of 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. Note: The values read from tables 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. One hundred percent of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted according to relevant standards. In addition, the monitoring provisions in the tools referred to in this methodology apply.

1. Monitoring of Project Implementation

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

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

(i) 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).

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

(i) 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;

(ii) 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 value;

(iii) 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. PPs 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*).

2.1 Updating of strata

The *ex post* stratification shall be updated because of 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) that are 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 90% 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, PPs 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 PPs 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:	(20)
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_{sp_i}
Data unit:	ha
Used in equations:	(20)
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:	$A_{burn,i}$
Data unit:	ha
Used in equations:	(28)
Description:	Area subject to burning located in the stratum *i*
Source of data:	
Measurement procedures:	
Any comment:	

Data / parameter:	A_{burn,sp_i}
Data unit:	ha
Used in equations:	(32)
Description:	Total area of all sample plots in stratum *i* which are located in areas subject to burning
Source of data:	
Measurement procedures:	
Any comment:	

Data / parameter:	*DBH*
Data unit:	cm
Used in following equations	Implicitly used in equations (12), (21)
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 CDM 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 cm for humid environments where trees grow rapidly
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Note: 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 ag

Data / parameter:	*H*
Data unit:	m
Used in equations:	Implicitly used in equations (12), (21), (29), (30)
Description:	Height of tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	

Monitoring frequency:	
QA/QC procedures:	
Any comment:	Note: 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

Data / parameter:	t_2 and t_1
Data unit:	yr
Used in equations:	Equations (1), (8), (24), (37), (38)
Description:	Years of the monitoring activity
Source of data:	
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Used for calculation $T = t_2 – t_1$

4. Conservative Approach and Uncertainties

To help reduce uncertainties in the accounting of emissions and removals**,** this methodology uses whenever possible the proven methods from the GPG-LULUCF, GPG-2000, and the IPCC'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 PPs 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;[11] or
- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or

[11] 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.

- 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) as well as a 1-page summary CV for each expert consulted, included in an annex.

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

5. References

All references are quoted in footnotes.

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History of the document

Version	Date	Nature of revision
04	EB 50, Annex 18 16 October 2009	Application of the guidance covered by paragraph 37 of the report of the EB 44 meeting with respect to insignificant GHG emissions from selected sources related to A/R CDM project activities.
03	EB 42, Para 35 26 September 2008	Revisions mainly in the following sections: • Section II. Baseline methodology *7(b)* Increase in emissions of greenhouse gases 8 Leakage • Section III. Monitoring Methodology 5(b) GHG emissions by sources 7 Leakage • To apply the guidance provided in para 35, EB 42 meeting report regarding accounting of GHG emissions in A/R CDM project activities, from the following sources (i) fertilizer application, (ii) removal of herbaceous vegetation, and (iii) transportation. The Board agreed that emissions from these sources may be considered as insignificant.
02	EB 42, Annex 10 26 September 2008	Changes to the leakage section, including reference to the leakage tool; and editorial changes to correct minor errors and provide further clarity.
01	EB 28, Annex 17 15 December 2006	Initial adoption.
Decision Class: Regulatory **Document Type**: Standard **Business Function**: Methodology		