



**Draft revision** to the approved consolidated afforestation and reforestation baseline and monitoring methodology AR-ACM0001

**“Afforestation and reforestation of degraded land”**

(Version 05)

**I. SOURCE, DEFINITIONS AND APPLICABILITY**

**1. Source**

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”. The 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 “San Carlos Grassland Restoration through Afforestation”. The baseline study, monitoring and verification plan and project design document were prepared by Factor CO<sub>2</sub> Integral Services;
- AR-AM0006-rev “Afforestation/Reforestation with Trees Supported by Shrubs on Degraded Land.” The baseline study, monitoring and verification plan and project design document were prepared by the Institute of Forest Ecology and Environment, the Chinese Academy of Forestry, China; University of Tuscia, Italy; and others.

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

This methodology also refers to the latest approved versions of the following tools, procedures, guidelines and guidances:

- Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities;
- Guidance on application of the definition of the project boundary to A/R CDM project activities;
- Tool for the identification of degraded or degrading lands for consideration in implementing A/R CDM project activities;
- Combined tool to identify the baseline scenario and demonstrate the additionality 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;
- Estimation of GHG emissions due to clearing, burning and decay of existing vegetation attributable to a CDM A/R project activity;



- Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity;
- Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities.

All the above-mentioned tools, procedures, guidelines and guidances are available at:

<http://cdm.unfccc.int/Reference/tools>> and

<http://cdm.unfccc.int/Reference/Procedures/index.html>>.

## 2. Selected baseline approach from paragraph 22 of the A/R CDM 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:

- (a) 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, hence the land cannot be expected to revert to a non-degraded state without human intervention;
- (b) 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;
- (c) The land does not fall into wetland<sup>1</sup> category;
- (d) Litter shall remain on site and not be removed in the A/R CDM project activity; and
- (e) Ploughing/ripping/scarification attributable to the A/R CDM project activity, if any, is:
  - (i) Done in accordance with appropriate soil conservation practices, e.g. follows the land contour; and
  - (ii) Limited to the first five years from the year of initial site preparation; and
  - (iii) Not repeated, if at all, within a period of 20 years.

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.

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<sup>1</sup> “Wetlands”, “settlements”, “cropland” and “grassland” are land categories as defined in the *Good Practice Guidance for Land Use, Land-use Change and Forestry* (IPCC, 2003).



## 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 “Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities” as approved by the Board.

The latest version of “Guidance on application of the definition of the 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 accounting are shown in Table 1.

**Table 1: Carbon pools accounted for in the project boundary**

Carbon pools	Accounted for	Justification / Explanation
Above-ground biomass	Yes	Major carbon pool subjected to project activity
Below-ground biomass	Yes	Below-ground biomass stock is expected to increase due to the implementation of the A/R CDM project activity
Dead wood	Yes (alternatively No)	This stock may change (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 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 change (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



Carbon pools	Accounted for	Justification / Explanation
Soil organic carbon (SOC)	Yes (alternatively No if project implemented on organic soils )	Soil disturbance resulting from site preparation, if applied on more than 10% of the project area, may cause a temporary emission from soil carbon and therefore accounting of C stock changes in this pool is required, otherwise it is optional

The emission sources and associated GHGs included in or excluded from accounting 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: Emission sources and GHGs included in or excluded from accounting**

Sources	Gas	Included/ excluded	Justification/Explanation
Burning of woody biomass	CO <sub>2</sub>	Excluded	Carbon stock decreases due to burning are accounted as a change in carbon stock
	CH <sub>4</sub>	Included	Burning of woody biomass for the purpose of site preparation or as part of forest management can lead to significant levels of emissions of methane
	N <sub>2</sub> O	Excluded	Potential emissions are negligibly small

## 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”.

## 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 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. Thus:

- **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 stratification for *ex ante* estimations shall be based on the project planting/management plan. The stratification for *ex post* estimations shall be based on the actual implementation of the project planting/management plan. If natural or anthropogenic impacts (e.g. local fires) or other factors (e.g. soil type) add variability to the growth pattern of the biomass in the project area, then the *ex post* stratification shall be revised accordingly.



PPs may use remotely sensed data acquired close to the time of project commencement and/or the occurrence of natural or anthropogenic impacts for *ex ante* and *ex post* stratification.

PPs should treat the part of the project area which contains organic soils, if any, as a separate stratum and ensure that applicability condition 4(b) of this methodology is met in this stratum.

#### 4. Baseline Net GHG Removals by Sinks

The baseline net GHG removals by sinks is the sum of the changes in carbon stocks in the selected carbon pools within the project boundary that would have occurred in the absence of the A/R CDM project activity.

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;
- Since carbon stock in soil organic carbon (SOC) is unlikely to increase in the baseline, the change in carbon stock in SOC 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:

$$\Delta C_{BSL} = \Delta C_{TREE\_BSL} \quad (1)$$

where:

$\Delta C_{BSL}$  Baseline net GHG removals by sinks; t CO<sub>2</sub>-e

$\Delta C_{TREE\_BSL}$  Sum of the carbon stock changes in above-ground and below-ground biomass of trees in the baseline; t CO<sub>2</sub>-e

##### 4.1 Carbon stock changes in above-ground and below-ground tree biomass ( $\Delta C_{TREE\_BSL}$ )

The estimation of carbon stock changes in above-ground and below-ground tree biomass in the baseline ( $\Delta C_{TREE\_BSL}$ ) will be carried out using 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.

$$\Delta C_{TREE\_BSL} = \frac{44}{12} * \Delta B_{TREE\_BSL} * CF_{TREE\_BSL} \quad (2)$$



where:

$\Delta C_{TREE\_BSL}$  Change in carbon stock in living tree biomass in baseline; t CO<sub>2</sub>-e

$\frac{44}{12}$  Ratio of molecular weights of CO<sub>2</sub> and carbon; dimensionless

$\Delta B_{TREE\_BSL}$  Change in biomass of living trees in baseline; t d.m.

$CF_{TREE\_BSL}$  Carbon fraction of dry matter for tree biomass in baseline; t C t<sup>-1</sup> d.m.

Change in biomass of living trees ( $\Delta B_{TREE\_BSL}$ ) is estimated as follows:

$$\Delta B_{TREE\_BSL,t} = \sum_j A_{BSL,j} * I_{V,j,t} * D_j * BEF_{1,j} * (1 + R_{1j}) - \sum_j B_{LOSS\_BSL,j,t} \quad (3)$$

where:

$\Delta B_{TREE\_BSL,t}$  Change in biomass of living trees in baseline, in year  $t$ ; t d.m.

$A_{BSL,j}$  Area under trees of species or group of species  $j$ ; ha

$I_{V,j,t}$  Current annual increment in stem volume of trees of species or group of species  $j$ , in year  $t$ ; m<sup>3</sup> ha<sup>-1</sup> yr<sup>-1</sup>

$D_j$  Basic wood density for species or group of species  $j$ ; t d.m. m<sup>-3</sup>

$BEF_{1,j}$  Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to increment in total above-ground tree biomass for species or group of species  $j$ ; t d.m. (t d.m.)<sup>-1</sup>

$R_{1j}$  Root-shoot ratio appropriate for biomass increment for species or group of species  $j$ ; t d.m. t<sup>-1</sup> d.m

$B_{LOSS\_BSL,j,t}$  Loss of tree biomass of species or group of species  $j$  in year  $t$ ; t d.m.

$j$  1, 2, 3, ... tree species or group of species in the given stratum 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 3. Note that available data on average annual increment in the stem volume of trees ( $I_{V,j,t}$ ) may be expressed as a net average annual increment (i.e. biomass loss is already allowed for) and in such a case biomass loss ( $B_{LOSS\_BSL,j,t}$ ) shall be set to zero in equation 3 in order to avoid double counting.

On the other hand, the average annual increment in the stem volume of trees ( $I_{V,j,t}$ ) may be the gross average annual increment, in which case biomass loss ( $B_{LOSS\_BSL,j,t}$ ) may either be conservatively assumed as zero or must be estimated on the basis of transparent and verifiable information on the rate at which pre-project activities (such as collection fuelwood or fodder, selection harvesting, mortality of trees, etc) are reducing biomass stocks in existing live trees.



If species or group of species specific volume/biomass increment tables are not available then the product of the terms  $I_{V,j,t} * D_j * BEF_{1,j}$  in equation 3 may be estimated by multiplying the relevant data from Table 3A.1.5 of IPCC GPG-LULUCF 2003 by the fractional value of the crown cover of the trees in the baseline. For example, if the crown cover of trees in the baseline is estimated as 10%, the project is located in Africa, the age class of the trees is >20 years, and the climate/forest type is “Moist with Short Dry Season”, then the value of  $I_{V,j,t} * D_j * BEF_{1,j}$  may be estimated as  $0.10 \times 1.3 = 0.13 \text{ t d.m. ha}^{-1} \text{ yr}^{-1}$ .

#### 4.2 Carbon stock in living trees at the start of the project activity

Carbon stock in living trees at the start of the project activity is calculated as follows:

$$C_{TREE\_BSL} = \frac{44}{12} * B_{TREE\_BSL} * CF_{TREE\_BSL} \quad (3a)$$

where

$C_{TREE\_BSL}$	Carbon stock in living trees in the baseline at the start of the project activity; t CO <sub>2</sub> -e
$\frac{44}{12}$	Ratio of molecular weights of CO <sub>2</sub> and carbon; dimensionless
$B_{TREE\_BSL}$	Biomass of living trees in the baseline at the start of the project; t d.m.
$CF_{TREE\_BSL}$	Carbon fraction of dry matter for tree biomass in baseline; t C t <sup>-1</sup> d.m.

The biomass of living trees in the baseline at the start of the project activity is estimated using any one of the following methods:

##### 4.2.1 Estimation based on existing data

If published data is available from which biomass density per unit area for the project area can be estimated, the data may be used provided that the estimated value of biomass density per unit area does not underestimate biomass in the project area. In this case, the biomass of living trees in the baseline at the start of the project activity is calculated as:

$$B_{TREE\_BSL} = BD_{TREE\_BSL} * A_{TREE\_BSL} \quad (4)$$

where:

$B_{TREE\_BSL}$	Biomass of living trees in the baseline at the start of the project activity; t d.m.
$BD_{TREE\_BSL}$	Tree biomass density per unit area of the project area (obtained from published literature); t d.m. ha <sup>-1</sup>
$A_{TREE\_BSL}$	Area of land within the project boundary where living trees are standing at the start of the project activity; ha

##### 4.2.2 Default estimation using parameter ratio

Under this method one of the following parameters of the existing trees in baseline is estimated (denoted by  $P_{BSL}$  in the equation below): (a) Crown cover; (b) Basal area per hectare; and (c)



Stand density index. Project area may be stratified on the basis of the variability of the parameter selected.

The biomass of living trees in the baseline at the start of the project activity is then calculated as:

$$B_{TREE\_BSL} = \frac{P_{BSL}}{P_{FOREST}} * B_{FOREST} * A_{TREE\_BSL} * (1 + R_{TREE\_BSL}) \quad (5)$$

where:

$B_{TREE\_BSL}$	Biomass of living trees in the baseline at the start of the project activity; t d.m.
$P_{BSL}$	Parameter for living trees in the baseline at start of the project activity
$P_{FOREST}$	The same parameter for a fully stocked forest in the region/country where the project activity is located
$B_{FOREST}$	Biomass density of a fully stocked forest in the region/country where the project activity is located; t d.m. ha <sup>-1</sup>
$A_{TREE\_BSL}$	Area of land within the project boundary where living trees are standing at start of the project activity; ha
$R_{TREE\_BSL}$	Root-shoot ratio of trees in the baseline; dimensionless

Value of  $B_{FOREST}$  is obtained according to guidance provided in the relevant table following paragraph 8 of this section.

#### 4.2.3 Complete inventory of trees

If the trees in the baseline are few and scattered out, all the trees may be inventoried and dimensional measurements (diameter or height or both) may be carried out on them. One of the methods explained in paragraph 5.1.1 of this methodology is then used for estimating the biomass of each tree. Biomass of living trees in the baseline at the start of the project is then calculated as:

$$B_{TREE\_BSL} = \sum_{i=1}^n B_{TREE,i} \quad (6)$$

where:

$B_{TREE\_BSL}$	Biomass of living trees in the baseline at the start of the project activity; t d.m.
$B_{TREE,i}$	Biomass of the $i^{th}$ tree as estimated from dimensional measurements; t d.m.
$n$	Total number of living trees in the baseline at start of the project activity

#### 4.2.4 Inventory of trees in sample plots

If the number of trees in the baseline scenario is too large for a complete inventory to be carried out, sample plots are laid out and dimensional measurements are carried out on the trees in these sample plots. One of the methods explained in paragraph 5.1.1 of this methodology is then used for estimating the biomass of each tree. The biomass of living trees in the baseline at the start of the project activity is then calculated as:





$$B_{TREE\_BSL} = \frac{A_{TREE}}{A_{TREE,p}} \sum_p B_{TREE,p} \quad (7)$$

where

$B_{TREE\_BSL}$  Biomass of living trees in the baseline at the start of the project activity; t d.m.

$A_{TREE}$  Area of land within the project boundary where living trees are standing at start of the project activity; ha

$A_{TREE,p}$  Area of sample plots where dimensional measurements are carried out on the trees; ha

$B_{TREE,p}$  Biomass of living trees in plot  $p$  as estimated from dimensional measurements; t d.m.

### 4.3 Steady state under the baseline conditions

The baseline net GHG removals by sinks, if greater than zero, shall be estimated using the approach provided in Section 4.1 until steady state is reached under the baseline conditions. Under steady state:

$$\Delta C_{BSL} = 0 \quad (8)$$

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.

## 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 GHG removals by sinks shall be estimated using the equations in this section. When applying these equations for the *ex ante* calculation of actual net GHG removals by sinks, PPs shall provide estimates of the values of those parameters that are not available before the start of the project. PPs should retain a conservative approach in making these estimates.

The actual net GHG removals by sinks shall be calculated as:

$$\Delta C_{ACTUAL} = \Delta C_P - GHG_E \quad (9)$$

where:

$\Delta C_{ACTUAL}$  Actual net GHG removals by sinks; t CO<sub>2</sub>-e



$\Delta C_P$  Sum of the changes the carbon stock in the selected carbon pools within the project boundary; t CO<sub>2</sub>-e

$GHG_E$  Increase in non-CO<sub>2</sub> GHG emissions within the project boundary as a result of the implementation of the A/R CDM project activity; t CO<sub>2</sub>-e

### 5.1 Estimation of changes in the carbon stocks

The verifiable changes in the carbon stock in the selected carbon pools within the project boundary are estimated using the following equation:<sup>2</sup>

$$\Delta C_P = \frac{44}{12} * \sum_{t=1}^{t^*} \Delta C_t \quad (10)$$

where:

$\Delta C_P$  Sum of the changes in carbon stock in all selected carbon pools in stratum  $i$ , since start of the project; t CO<sub>2</sub>-e

$\Delta C_t$  Change in carbon stock in all selected carbon pools, in year  $t$ ; t C

$t$  1, 2, 3, ...  $t^*$  years elapsed since the start of the A/R project activity; yr

44/12 Ratio of molecular weights of CO<sub>2</sub> and carbon; dimensionless

Change in carbon stock in all selected carbon pools, in year  $t$ , is calculated as:

$$\Delta C_t = \sum_{i=1}^{M_{PS}} (\Delta C_{TREE,i,t} + \Delta C_{DW,i,t} + \Delta C_{LI,i,t} + \Delta C_{SOC,i,t}) \quad (11)$$

where:

$\Delta C_t$  Change in carbon stock in all selected carbon pools, in year  $t$ ; t C

$\Delta C_{TREE,i,t}$  Change in carbon stock in above-ground and below-ground biomass of trees in stratum  $i$ , in year  $t$ ; t C

$\Delta C_{DW,i,t}$  Change in carbon stock in the dead wood carbon pool in stratum  $i$ , in year  $t$ ; t C

$\Delta C_{LI,i,t}$  Change in carbon stock in the litter carbon pool in stratum  $i$ , in year  $t$ ; t C

$\Delta C_{SOC,i,t}$  Change in carbon stock in the soil organic carbon pool in stratum  $i$ , in year  $t$ ; t C

$i$  1, 2, 3, ...  $M_{PS}$  strata in the project scenario

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

#### 5.1.1 Estimating change in carbon stock in tree biomass ( $\Delta C_{TREE,i,t}$ )

The change in carbon stock in tree biomass is estimated on the basis of field measurements in permanent sample plots at a point of time in year  $t_1$  and again at a point of time in year  $t_2$ . The rate of change of carbon stock in trees is calculated as:

<sup>2</sup> IPCC GPG-LULUCF 2003, Equation 3.2.3.



$$dC_{TREE,i,(t_1,t_2)} = \frac{C_{TREE,i,t_2} - C_{TREE,i,t_1}}{T} \quad (12)$$

where:

$dC_{TREE,i,(t_1,t_2)}$  Rate of change in carbon stock in above-ground and below-ground biomass of trees in stratum  $i$ , for the period between year  $t_1$  and year  $t_2$ ; t C yr<sup>-1</sup>

$C_{TREE,i,t_2}$  Carbon stock in trees in stratum  $i$ , at a point of time in year  $t_2$ ; t C

$C_{TREE,i,t_1}$  Carbon stock in trees in stratum  $i$ , at a point of time in year  $t_1$ ; t C

$T$  Time elapsed between two successive estimations ( $T=t_2 - t_1$ ); yr

$i$  1, 2, 3, ...  $M_{PS}$  strata in the project scenario

Change in carbon stock in tree biomass in year  $t$  ( $t_1 \leq t \leq t_2$ ) is then calculated as:

$$\Delta C_{TREE,i,t} = dC_{TREE,i,(t_1,t_2)} * 1year \quad (13)$$

where:

$\Delta C_{TREE,i,t}$  Change in carbon stock in above-ground and below-ground biomass of trees in stratum  $i$ , in year  $t$ ; t C

$dC_{TREE,i,(t_1,t_2)}$  Rate of change in carbon stock in tree biomass within the project boundary during the period between a point of time in year  $t_1$  and a point of time in year  $t_2$ ; t C yr<sup>-1</sup>

Carbon stock in above-ground and below-ground tree biomass ( $C_{TREE,i,t}$ ) is estimated by one of the following two methods as applied in year  $t$ :

- (a) The biomass expansion factor (*BEF*) method; and
- (b) The allometric equation method.

### BEF method

In this method, first the stem volume (the commercial volume) of standing trees is estimated. *Ex ante* estimations of stem volume are based on tree growth models and *ex post* estimations are based on field measurements. The stem volume is expanded to the above-ground tree biomass using biomass expansion factor (*BEF*) and basic wood density (*D*). Total tree biomass is then obtained by multiplying the above-ground tree biomass by  $(1+R)$  where  $R$  is the root-shoot ratio.

The following step-by-step procedure shows practical application of this method:

**Step 1:** This step is applied differently for *ex ante* and *ex post* estimations.

**Step 1 (a):** *Ex ante* estimation

- (i) For each tree species or group of species under the project scenario, select a tree growth model from existing data or literature. Available growth models could be in form of yield tables, growth curves/equations, or growth simulation models.



See paragraph 8 of this section for exact guidance on selecting the growth model applicable;

- (ii) From the growth model selected, calculate the stem volume of trees per unit area according to the project planting/management plan.

**Step 1 (b):** *Ex post* estimation

*Ex post* estimation of tree biomass must be based on actual measurements carried out on all trees in the permanent sample plots. The permanent sample plots are laid out according to the approved methodological tool “Calculation of the number of sample plots for measurements within A/R CDM project activities”.

The following sub-steps apply for *ex post* estimation:

- (i) Select the volume tables (these could be in form of equations or curves) applicable to the tree species or group of species planted under the project. See paragraph 8 of this section for exact guidance on selecting the volume tables applicable;
- (ii) Depending on the volume tables selected in the sub-step above, measure the diameter at breast height (*DBH*) and/or tree height (*H*) of all trees in the permanent sample plots;
- (iii) Insert the above field measurements into the selected volume tables and calculate the stem volume of all trees in each sample plot.

Note: It is also possible to combine the sub-steps (i) and (ii) if a suitable field instrument (such as a Spiegel relascope) is used.

**Step 2:** Convert the stem volume to total carbon stock in tree biomass using the following equation:

$$C_{TREE,j,p,i} = V_{TREE,j,p,i} * D_j * BEF_{2,j} * (1 + R_j) * CF_j \quad (14)$$

where:

$C_{TREE,j,p,i}$  Total carbon stock in trees of species or group of species *j* in sample plot *p* in stratum *i*; t C

$V_{TREE,j,p,i}$  Stem volume of trees of species or group of species *j* in plot *p* in stratum *i* estimated by using the diameter at breast height (*DBH*) and/or tree height (*H*) as entry data into a volume table; m<sup>3</sup>

$D_j$  Basic wood density of species or group of species *j*; t d.m. m<sup>-3</sup>

$BEF_{2,j}$  Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species or group of species *j*; dimensionless

$R_j$  Root-shoot ratio for tree species or group of species *j*; dimensionless



$CF_j$	Carbon fraction of biomass for tree species or group of species $j$ ; t C t <sup>-1</sup> d.m.
$j$	1, 2, 3, ... tree species or group of species in the project scenario
$p$	1, 2, 3, ... sample plots in stratum $i$
$i$	1, 2, 3, ... strata in the project scenario

**Allometric method**

The allometric method directly calculates above-ground tree biomass without relating it to tree stem volume. The method depends upon availability of allometric equations which express above-ground tree biomass as a function of diameter at breast height (*DBH*) and/or tree height (*H*). Total tree biomass is then obtained by multiplying the above-ground tree biomass by (1+*R*) where *R* is the root-shoot ratio.

The following step-by-step procedure shows how this method is practically applied:

**Step 1:** This step is applied differently for *ex ante* and *ex post* estimations.

**Step 1 (a):** *Ex ante* estimation

- (i) For each tree species or group of species, select an allometric equation from existing data or literature. See paragraph 8 of this section for exact guidance on selecting the allometric equation applicable;
- (ii) For each tree species or group of species, select a tree growth model from existing data and literature, as explained in sub-step 1(a)(i) of the *BEF* method above;
- (iii) Obtain the diameter at breast height (*DBH*) and/or tree height (*H*) corresponding to the age of tree at a given time from the tree growth model selected above;
- (iv) Insert the diameter at breast height (*DBH*) and/or tree height (*H*) into the allometric equation and calculate the total above-ground tree biomass per unit area according to the project planting/management plan.

**Step 1 (b):** *Ex post* estimation

*Ex post* estimation of tree biomass must be based on actual measurements carried out on all trees in the permanent sample plots. The permanent sample plots are laid out according to the approved methodological tool “Calculation of the number of sample plots for measurements within A/R CDM project activities”.

The following sub-steps apply for *ex post* estimation.

- (i) Select an allometric equation for the tree species or group of species as described in sub-step 1(a)(i) above;
- (ii) Depending on the allometric equation, measure the diameter at breast height (*DBH*) and/or tree height (*H*) of all trees in the permanent sample plots;
- (iii) Insert the above measurements into the allometric equation and calculate the total above-ground tree biomass for each sample plot.



**Step 2:** Convert the above-ground tree biomass to total carbon stock in tree biomass using the following equation:

$$C_{TREE,j,p,i} = f_j(DBH, H) * (1 + R_j) * CF_j \quad (15)$$

where:

$C_{TREE,j,p,i}$  Total carbon stock in trees of species or group of species  $j$  in sample plot  $p$  in stratum  $i$ ; t C

$CF_j$  Carbon fraction of biomass for tree species or group of species  $j$ ; t C (t d.m.)<sup>-1</sup>

$f_j(DBH, H)$  Above-ground biomass of trees of species or group of species  $j$  in sample plot  $p$  calculated using allometric function returning total above-ground tree biomass on the basis of breast height ( $DBH$ ) and/or height of the tree ( $H$ ); t d.m.

$R_j$  Root-shoot ratio for tree species or group of species  $j$ ; dimensionless

$j$  1, 2, 3, ... tree species or group of species in the project scenario

$p$  1, 2, 3, ... sample plots in stratum  $i$

$i$  1, 2, 3, ... strata in the project scenario

**For both the BEF method and the allometric equation method**

The total carbon stock in tree biomass for each stratum is calculated as follows:

$$C_{TREE,i} = \frac{A_i}{A_{p,i}} \sum_{p=1}^{P_i} \sum_{j=1}^{J_i} C_{TREE,j,p,i} \quad (16)$$

where:

$C_{TREE,i}$  Carbon stock in trees in stratum  $i$ ; t C

$C_{TREE,j,p,i}$  Carbon stock in trees of species or group of species  $j$  in plot  $p$  of stratum  $i$ ; t C

$A_{p,i}$  Total area of sample plots in stratum  $i$ ; ha

$A_i$  Total area of stratum  $i$ ; ha

$j$  1, 2, 3, ...  $J_i$  species or group of species of trees in stratum  $i$

$p$  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

Equation 16 when applied at two consecutive years  $t_1$  and  $t_2$  (e.g. two consecutive verification years) provides two values  $C_{TREE,i,t_1}$  and  $C_{TREE,i,t_2}$  which are then inserted in equation 12.

Note: At start of the project activity (that is for  $t_1=1$ ) the baseline tree biomass is equal to initial biomass under the project, that is, the value of  $C_{TREE,i,t_1}$  in equation 12 is set equal to the baseline C stock as calculated in equation 3a.

### 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 rate of change in C stock in dead wood is estimated as follows:

$$dC_{DW,i,t} = \frac{C_{DW,i,t_2} - C_{DW,i,t_1}}{T} \quad (17)$$

where:

$dC_{DW,i,t}$	Rate of change in carbon stock in dead wood in stratum $i$ , for the period between year $t_1$ and year $t_2$ ; t C yr <sup>-1</sup>
$C_{DW,i,t}$	Carbon stock of dead wood in stratum $i$ , at time $t$ ; 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

Change in carbon stock in dead wood in year  $t$  ( $t_1 \leq t \leq t_2$ ) is then calculated as:

$$\Delta C_{DW,i,t} = dC_{DW,i,(t_1,t_2)} * 1year \quad (18)$$

where:

$\Delta C_{DW,i,t}$	Change in carbon stock in dead wood in stratum $i$ , in year $t$ ; t C
$dC_{DW,i,(t_1,t_2)}$	Rate of change in carbon stock in dead wood in stratum $i$ , for the period between year $t_1$ and year $t_2$ ; t C yr <sup>-1</sup>

Carbon stock of dead wood in stratum  $i$ , at time  $t$  is estimated as:

$$C_{DW,i,t} = (B_{SDW,i,t} + B_{LDW,i,t}) * CF_{DW} \quad (19)$$

where:

$C_{DW,i,t}$	Carbon stock of dead wood biomass in stratum $i$ , at a point of time in year $t$ ; t C
$B_{SDW,i,t}$	Biomass of standing dead wood in stratum $i$ , at a point of time in year $t$ ; t d.m.



$B_{LDW,i,t}$	Biomass of lying dead wood in stratum $i$ , at a point of time in year $t$ ; t d.m.
$CF_{DW}$	Carbon fraction of dead wood biomass; dimensionless
$i$	1, 2, 3, ... $M_{PS}$ strata in the project scenario
$t$	1, 2, 3, ... $t^*$ years elapsed since the start of the A/R CDM project activity

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

### (1) Standing dead wood

**Step 1:** Standing dead trees shall be measured on permanent sample plots (established for estimating tree biomass - see paragraph 5.1.1 above) using the same criteria and monitoring frequency used for measuring living 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 3a:** For tree in the decomposition class 1 biomass should be estimated using the allometric equation for living trees.

**Step 3b:** 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. Usually, there are no allometric equations applicable for such boles and their biomass is estimated based on volume assessment. The volume of dead wood is converted to biomass using the dead wood density appropriate for the decomposition class.

### (2) Lying dead wood

The lying dead wood pool is highly variable, and stocks increase as the stands grow; hence its monitoring may be taken up in the first, second or subsequent monitoring periods. The volume of lying dead wood can be assessed from the following survey.

**Step 1:** Lying dead wood should be sampled using the line intersect method (Harmon and Sexton, 1996).<sup>3</sup> Two 50-m lines bisecting each plot are established and the diameters of the lying dead wood ( $\geq 5$  cm diameter) intersecting the lines are measured.

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<sup>3</sup> 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.





**Step 2:** The dead wood is assigned to one of the three density states  $ds=1$  (sound),  $ds=2$  (intermediate), and  $ds=3$  (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)<sup>4</sup> as modified by van Wagner (1968)<sup>5</sup> separately for each density state:

$$V_{LDW,i,t} = \frac{\pi^2 * \left( \sum_{n=1}^N D_{n,i,t}^2 \right)}{8 * L} \quad (20)$$

where:

$V_{LDW,i,t}$	Volume of lying dead wood per unit area in stratum $i$ , at time $t$ ; $m^3 \text{ ha}^{-1}$
$D_{n,i,t}$	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

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

$$B_{LDW,i,t} = A_i * \sum_{ds=1}^3 V_{LDW,i,t} * D_{DW,ds} \quad (21)$$

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 $t$ ; $m^3 \text{ ha}^{-1}$
$D_{DW,ds}$	Basic wood density of dead wood in the density class $ds$ ; t d.m. $m^{-3}$ <b>Note:</b> 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
$ds$	Index for density state: 1 (sound), 2 (intermediate) or 3 (rotten)
$i$	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

<sup>4</sup> Warren, W.G. and Olsen, P.F. (1964) A line transect technique for assessing logging waste, *Forest Science* 10: 267-276.

<sup>5</sup> Van Wagner, C. E. (1968): The line intersect method in forest fuel sampling. *Forest Science* 14: 20-26.

### 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 hectare, the wet litter biomass for the 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 hectare ( $10,000 \text{ m}^2/4 * \text{area of sampling frame in m}^2$ ):

$$B_{LI,i,p} = 2.5 * B_{LI\_WET,i,p} * \frac{MP_{LI}}{a_{i,p}} \quad (22)$$

where:

$B_{LI,i,p}$	Biomass of dry litter for plot $p$ in stratum $i$ ; t d.m. ha <sup>-1</sup>
$B_{LI\_WET,i,p}$	Wet weight (field) of the litter in plot $p$ of stratum $i$ ; kg
$MP_{LI}$	Dry-to-wet weight ratio of the litter (dry weight/wet weight); dimensionless
$a_{i,p}$	Area of sampling frame for plot $p$ in stratum $i$ ; m <sup>2</sup>
$i$	1, 2, 3, ... $M_{PS}$ strata in the project scenario
$p$	Index for sample plots

The average annual rate of 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  $0.370 \text{ t C t}^{-1} \text{ d.m.}$  as a default value for the carbon fraction.<sup>6</sup> Thus:

$$dC_{LI,i,t} = \frac{B_{LI,i,t_2} - B_{LI,i,t_1}}{T} * CF_{LI} \quad (23)$$

where:

$dC_{LI,i,t}$	Rate of change in the litter carbon pool in stratum $i$ (averaged over a monitoring period); t C yr <sup>-1</sup>
$B_{LI,i,t}$	Biomass of litter in stratum $i$ at time $t$ ; t d.m.
$T$	Number of years between monitoring time $t_2$ and $t_1$ ( $T = t_2 - t_1$ ); yr
$CF_{LI}$	Carbon fraction of litter (default value $0.370 \text{ t C t}^{-1} \text{ d.m.}$ ); t C t <sup>-1</sup> d.m.

<sup>6</sup> Smith and Heath, 2002.



$i$  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

Change in carbon stock in litter in year  $t$  ( $t_1 \leq t \leq t_2$ ) is then calculated as:

$$\Delta C_{LI,i,t} = dC_{LI,i,(t_1,t_2)} * 1year \quad (24)$$

where:

$\Delta C_{LI,i,t}$  Change in carbon stock in litter in stratum  $i$ , in year  $t$ ; t C

$dC_{LI,i,(t_1,t_2)}$  Rate of change in carbon stock in litter in stratum  $i$ , for the period between year  $t_1$  and year  $t_2$ ; t C yr<sup>-1</sup>

#### 5.1.4 Soil Organic Carbon (if selected in Table 1)

For *ex ante* estimations, the changes in stocks of soil organic carbon may be assessed using the default method or the changes may be conservatively neglected.

For *ex post* estimations, the changes in stocks of soil organic carbon are estimated using the approved methodological tool “Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities”. That is:

$$\Delta C_{SOC,i,t} = \Delta SOC_{AL,t} \quad (25)$$

where:

$\Delta C_{SOC,i,t}$  Change in carbon stock in the SOC pool in stratum  $i$ , in year  $t$ ; t C

$\Delta SOC_{AL,t}$  Change in carbon stock in the SOC pool as estimated in the tool “Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities” applied to stratum  $i$ ; t C

#### 5.2 Estimation of GHG emissions within the project boundary

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

$$GHG_E = \sum_{t=1}^{t^*} E_{BIOMASS\_BURN,t} \quad (26)$$

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<sub>2</sub>-e

$E_{BIOMASS\_BURN,t}$  Non-CO<sub>2</sub> emissions due to burning of biomass of existing woody vegetation as part of site preparation during the year  $t$ , as estimated in the tool “Estimation of GHG emissions due to clearing, burning and decay of existing vegetation attributable to a CDM A/R project activity”; t CO<sub>2</sub>-e

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

## 6. Leakage

Under applicability conditions of this methodology the following types of leakage emissions can occur: GHG emissions due to activity displacement, the activity displaced being agricultural activities. Therefore, leakage is estimated as follows:

$$LK = \sum_{t=1}^{t^*} LK_{AGRIC,t} \quad (27)$$

where:

$LK$	Total GHG emissions due to leakage; t CO <sub>2</sub> -e
$LK_{AGRIC,t}$	Leakage due to the displacement of agricultural activities in year $t$ , as calculated in the tool “Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity”; t CO <sub>2</sub> -e

## 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<sub>2</sub>-e.

$$C_{AR-CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK \quad (28)$$

where:

$C_{AR-CDM}$	Net anthropogenic GHG removals by sinks; t CO <sub>2</sub> -e
$\Delta C_{ACTUAL}$	Actual net GHG removals by sinks; t CO <sub>2</sub> -e
$\Delta C_{BSL}$	Baseline net GHG removals by sinks; t CO <sub>2</sub> -e
$LK$	Total GHG emissions due to leakage; t CO <sub>2</sub> -e

### 7.1 Calculation of tCERs and ICERs

To estimate the CERs 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 equations approved by the Board,<sup>7</sup> which produces the same estimates as the following:

$$tCERs = C_{AR-CDM,t_2} \quad (29)$$

$$ICERs = C_{AR-CDM,t_2} - C_{AR-CDM,t_1} \quad (30)$$

<sup>7</sup> See <<http://cdm.unfccc.int/Reference/Guidclarif/>>.



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 GHG removals by sinks, as estimated for $t^* = t_2$ ; t CO <sub>2</sub> e
$C_{AR-CDM,t_1}$	Net anthropogenic GHG removals by sinks, as estimated for $t^* = t_1$ ; t CO <sub>2</sub> 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 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.

<b>Data / Parameter:</b>	$BEF_{2,j}$
Data unit:	Dimensionless
Used in equations:	14
Description:	Biomass expansion factor for conversion of stem biomass to above-ground biomass for tree species or group of species $j$
Source of data:	The source of data shall be selected, in order of preference, from the following: <ul style="list-style-type: none"> <li>(a) Local sources of species or group of species-specific data;</li> <li>(b) National sources of species or group of species-specific data (e.g. national forest inventory or national GHG inventory);</li> <li>(c) Species or group of species-specific data from neighbouring countries with similar conditions;</li> <li>(d) Globally available data applicable to species or group of species;</li> <li>(e) IPCC default values (e.g. Table 3A.1.10 of IPCC GPG-LULUCF 2003)<sup>8</sup></li> </ul>
Measurement procedures:	N/A
Comments:	$BEFs$ in IPCC literature and national forest inventories are usually applicable to closed canopy forests. If applied to individual trees growing in open field, it is recommended that the selected $BEF_2$ be increased by 30%

<b>Data / Parameter:</b>	$BEF_{1,j}$
Data unit:	Dimensionless
Used in equations:	3
Description:	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total above-ground tree biomass increment for species $j$

<sup>8</sup> Although the  $BEFs$  in Table 3A.1.10 apply to biomass, the dimensionless factors can be equally applied for wood volume expansions.



Source of data:	(a) Local sources of species or group of species-specific data; (b) National sources of species or group of species-specific data (e.g. national forest inventory or national GHG inventory); (c) Species or group of species-specific data from neighbouring countries with similar conditions; (d) Globally available data applicable to species or group of species; IPCC default values (e.g. Table 3A.1.10 of IPCC GPG-LULUCF 2003) <sup>9</sup>
Measurement procedures:	N/A
Comments:	<i>BEFs</i> 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 <i>BEF</i> be increased by a further 30%

<b>Data / Parameter:</b>	$B_{LOSS\_BSL,j,t}$
Data unit:	t d.m.
Used in equations:	3
Description:	Loss of tree biomass of species <i>j</i> in year <i>t</i>
Source of data:	Existing data from the records relating to the project area. The source data could be the basis for estimating the rate at which pre-project activities (such as collection fuelwood or fodder, selection harvesting, mortality of trees, etc) are reducing biomass stocks in existing live trees
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$BD_{TREE\_BSL}$
Data unit:	t d.m. ha <sup>-1</sup>
Used in equations:	4
Description:	Tree biomass density per unit area of the project area (obtained from published literature)
Source of data:	Published data may relate to the project area or to another area similar to the project area. If published data is in terms of volume and not in terms of biomass, or the biomass data does not include the below-ground biomass, then transparent and verifiable method using suitable parameters may be used for calculating the tree biomass per unit area from the available data
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$B_{FOREST}$
Data unit:	t d.m. ha <sup>-1</sup>
Used in equations:	5
Description:	Default above-ground biomass content in forest in the region/country where the A/R CDM project activity is located

<sup>9</sup> Although the *BEFs* in Table 3A.1.10 apply to biomass, the dimensionless factors can be equally applied for wood volume expansions.



Source of data:	The source of data shall be selected, in order of preference, from the following: (a) Regional/national inventories e.g. national forest inventory, national GHG inventory; (b) Inventory from neighbouring countries with similar conditions; (c) Globally available data applicable to the project site or to the region/country where the site is located (e.g. latest data from FAO); (d) IPCC default values from Table 3A.1.4 of IPCC GPG-LULUCF 2003
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$CF_j$
Data unit:	t C t <sup>-1</sup> d.m.
Used in equations:	14, 15
Description:	Carbon fraction of tree biomass for species or group of species <i>j</i>
Source of data:	The source of data, in order of preference, shall be the following: (a) National level species or group of species-specific data (e.g. from national GHG inventory); (b) Species or group of species-specific data from neighbouring countries with similar conditions; (c) Globally available data (e.g. IPCC GPG-LULUCF 2003); (d) The IPCC default value of 0.5 t C t <sup>-1</sup> d.m.
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$CF_{DW}$
Data unit:	t C t <sup>-1</sup> d.m.
Used in equations:	19
Description:	Carbon fraction of dry matter in dead wood biomass
Source of data:	Default value 0.5 t C t <sup>-1</sup> d.m. shall be used
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$CF_{LI}$
Data unit:	t C t <sup>-1</sup> d.m.
Used in equations:	23
Description:	Carbon fraction of dry matter in litter biomass
Source of data:	Default value 0.37 t C t <sup>-1</sup> d.m. shall be used
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$CF_{TREE\_BSL}$
Data unit:	t C t <sup>-1</sup> d.m.
Used in equations:	2



Description:	Carbon fraction of dry matter for tree biomass in baseline
Source of data:	Default value 0.50 t C t <sup>-1</sup> d.m. may be used
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$D_j$
Data unit:	t d.m. m <sup>-3</sup>
Used in equations:	14
Description:	Basic wood density for species or group of species $j$
Source of data:	The source of data, in order of preference, shall be any of the following: <ul style="list-style-type: none"> <li>(a) National and species or group of species-specific data (e.g. from national forest inventory or national GHG inventory);</li> <li>(b) Species or group of species-specific data from neighbouring countries with similar conditions;</li> <li>(c) Globally available species or group of species-specific data (e.g. Table 3A.1.9 IPCC GPG-LULUCF 2003)</li> </ul>
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$D_{DW,ds}$
Data unit:	t d.m. m <sup>-3</sup>
Used in equations:	21
Description:	Basic wood density of dead wood in the density state: 1 (sound), 2 (intermediate) or 3 (rotten)
Source of data:	The source of data, in order of preference, shall be any of the following: <ul style="list-style-type: none"> <li>(a) National and species-specific or group of species-specific data (e.g. from national GHG inventory);</li> <li>(b) Species-specific or group of species-specific data from neighbouring countries with similar conditions. Sometimes (b) might be preferable to (a);</li> <li>(c) Globally species-specific or group of species-specific (e.g. IPCC GPG-LULUCF 2003)</li> </ul>
Measurement procedures:	Project specific determination of the density is allowed
Comments:	

<b>Data / Parameter:</b>	$f_j(DBH, H)$
Data unit:	t d.m. tree <sup>-1</sup>
Used in equations:	15
Description:	Allometric function for species or group of species $j$ linking tree diameter (diameter at breast height or other diameter), and possibly tree height ( $H$ ), to above-ground biomass of living trees





Source of data:	The source of data, in order of preference, shall be any of the following: <ul style="list-style-type: none"> <li>(a) Existing local and species or group of species-specific data;</li> <li>(b) National and species or group of species-specific data (e.g. national forest inventory or national GHG inventory);</li> <li>(c) Species or group of species-specific data from neighbouring countries with similar conditions;</li> <li>(d) Globally available data applicable to species or group of species (e.g. Tables 4.A.1–4.A.3 of IPCC GPG-LULUCF 2003)</li> </ul>
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$I_{V,j,t}$
Data unit:	$\text{m}^3 \text{ha}^{-1} \text{yr}^{-1}$
Used in equations:	3
Description:	Average annual increment in stem volume of species $j$ , in year $t$
Source of data:	The source of data, in order of preference, shall be the following: <ul style="list-style-type: none"> <li>(a) Existing local and species or group of species-specific tree growth data or local volume tables;</li> <li>(b) National and species or group of species-specific tree growth data or standard volume tables (e.g. from national forest inventory or national GHG inventory);</li> <li>(c) Species or group of species-specific tree growth data or volume tables from neighbouring countries with similar conditions;</li> <li>(d) Globally available data applicable to species or group of species</li> </ul>
Measurement procedures:	N/A
Comments:	<p><math>I_{V,j,t}</math> is estimated as the “current annual increment – CAI”. The “mean annual increment” – often abbreviated as MAI in the forestry inventories – can only be used if its use leads to conservative estimates.</p> <p>The values read from tables if expressed on the per unit of area basis will usually apply to fully stocked 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)</p>

<b>Data / Parameter:</b>	$R_j$
Data unit:	dimensionless
Used in equations:	14, 15
Description:	Root-shoot ratio for species or group of species $j$



Source of data:	<p>The source of data, in order of preference, shall be any of the following:</p> <ul style="list-style-type: none"> <li>(a) Existing local and species or group of species-specific data;</li> <li>(b) National and species or group of species-specific data (e.g. national forest inventory or national GHG inventory);</li> <li>(c) Species or group of species-specific data from neighbouring countries with similar conditions;</li> <li>(d) Globally available data applicable to species or group of species growing under similar conditions or similar forest type.</li> </ul> <p>If none of the above sources are available, then the value of <math>R_j</math> may be calculated as <math>B/A</math> where <math>B = \exp[-1.085+0.9256*\ln(A)]</math>, where A is above-ground biomass (t d.m. ha<sup>-1</sup>) and B is below-ground biomass (t d.m. ha<sup>-1</sup>) [Source: Table 4.A.4 of IPCC GPG-LULUCF 2003]</p>
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$R_{ij}$
Data unit:	kg d.m.yr <sup>-1</sup> (kg d.m.yr <sup>-1</sup> ) <sup>-1</sup>
Used in equations:	3
Description:	Root-shoot ratio appropriate for biomass increment for species $j$
Source of data:	<p>The source of data, in order of preference, shall be any of the following:</p> <ul style="list-style-type: none"> <li>(a) National and species-specific or group of species-specific (e.g. from national GHG inventory);</li> <li>(b) Species-specific or group of species-specific from neighbouring countries with similar conditions. Sometimes (b) might be preferable to (a);</li> <li>(c) Species-specific or group of species-specific from global studies</li> </ul>
Measurement procedures:	N/A
Comments:	<p>If none of the above sources are available, then the value of <math>R_{ij}</math> may be calculated as <math>B/A</math> where <math>B = \exp[-1.085+0.9256*\ln(A)]</math>, where A is above-ground biomass (t d.m. ha<sup>-1</sup>) and B is below-ground biomass (t d.m. ha<sup>-1</sup>) [Source: Table 4.A.4 of IPCC GPG-LULUCF 2003]</p>

<b>Data / Parameter:</b>	$R_{TREE\_BSL}$
Data unit:	dimensionless
Used in equations:	5
Description:	Root-shoot ratio for the trees in the baseline



Source of data:	<p>The source of data, in order of preference, shall be any of the following:</p> <ul style="list-style-type: none"> <li>(a) Existing local and species or group of species-specific data;</li> <li>(b) National and species or group of species-specific data (e.g. national forest inventory or national GHG inventory);</li> <li>(c) Species or group of species-specific data from neighbouring countries with similar conditions;</li> <li>(d) Globally available data applicable to species or group of species growing under similar conditions or similar forest type.</li> </ul> <p>If none of the above sources are available, then the value of <math>R_{TREE\_BSL}</math> may be calculated as <math>B/A</math> where <math>B = \exp[-1.085 + 0.9256 \cdot \ln(A)]</math>, where A is above-ground biomass (t d.m. ha<sup>-1</sup>) and B is below-ground biomass (t d.m. ha<sup>-1</sup>) [Source: Table 4.A.4 of IPCC GPG-LULUCF 2003]</p>
Measurement procedures:	N/A

<b>Data / Parameter:</b>	$V_{TREE,j,p,i}$
Data unit:	m <sup>3</sup>
Used in equations:	14
Description:	Stem volume of trees of species or group of species $j$ in plot $p$ in stratum $i$
Source of data:	<p>The source of data, in order of preference, shall be the following:</p> <ul style="list-style-type: none"> <li>(a) Existing local and species or group of species-specific tree growth data or local volume tables;</li> <li>(b) National and species or group of species-specific tree growth data or standard volume tables (e.g. from national forest inventory or national GHG inventory);</li> <li>(c) Species or group of species-specific tree growth data or volume tables from neighbouring countries with similar conditions;</li> <li>(d) Globally available data applicable to species or group of species</li> </ul>
Measurement procedures:	N/A
Comments:	<p>In case of <i>ex ante</i> estimation, it would not be possible to measure diameter of trees to be used in volume tables. In such cases, species-specific or group of species-specific age-diameter curves from local/national sources may be used to estimate the diameter at a given point of time. Age of trees in baseline may be estimated from historical records, participatory appraisal, or tree dendrometry methods.</p> <p>If such age-diameter curves are not available then average growing stock values from Table 3A.1.4 of IPCC GPG-LULUCF 2003 may be multiplied by the fractional value of estimated crown cover of trees. For example, if crown cover of trees is estimated as 10% and the project is located in Cameroon (growing stock volume of 135 m<sup>3</sup>/ha), then the stem volume of trees may be estimated as <math>0.10 \times 135 = 13.50</math> m<sup>3</sup>/ha</p>



### III. MONITORING METHODOLOGY

All data collected as part of monitoring should be archived electronically and be kept at least for two 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 coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived;
- (b) Commonly accepted principles of forest inventory and management in the host country are implemented. In absence of these, standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for inventory operations, including field data collection and data management, shall be identified, recorded and applied. Use or adaptation of SOPs available from published handbooks, or from the *IPCC GPG LULUCF 2003*, is recommended;
- (c) The forest planting and management plan, together with a record of the plan as actually implemented during the project, shall be available for validation and/or verification.

#### 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-planting) 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 Precision requirements

The targeted precision level for biomass estimation shall be  $\pm 10\%$  of the mean at a 90% confidence level. PPs may use the latest version of the approved tool for “Calculation of the



number of sample plots for measurements within A/R CDM project activities” to determine the sample size and allocation of sample plots among strata.

### 3. Data and parameters monitored

The following data and 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.

<b>Data / Parameter:</b>	$A_i$
Data unit:	ha
Used in equations:	16
Description:	Area of tree biomass 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:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	$A_{BSL,j}$
Data unit:	ha
Used in equations:	3
Description:	Area under trees of species $j$ in baseline
Source of data:	GPS coordinates and/or remote sensing data
Measurement procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	$a_{i,p}$
Data unit:	$m^2$
Used in equations:	22
Description:	Area of sampling frame for plot $p$ in stratum $i$
Source of data:	Simple measurement or manufacturer's data
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III
Comments:	Once selected, the size of the sampling frame shall be fixed until the end of the last crediting period



<b>Data / Parameter:</b>	$A_{p,i}$
Data unit:	ha
Used in equations:	16
Description:	Total area of all sample plots in stratum $i$
Source of data:	Field measurement
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	$B_{LI\_WET,i,p}$
Data unit:	kg
Used in equations:	22
Description:	Wet weight (field) of the litter in plot $p$ of stratum $i$
Source of data:	Field measurements in sample plots
Measurement procedures:	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:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	$D_{n,i,t}$
Data unit:	cm
Used in equations:	20
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:	Lying dead wood should be sampled using the line intersect method (Harmon and Sexton, 1996). <sup>10</sup> Two 50-m lines bisecting each plot are established, and the diameters of the lying dead wood ( $\geq 5$ cm diameter) intersecting the lines are measured
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	$DBH$
Data unit:	inch/cm or any unit of length used in the model or data source used

<sup>10</sup> 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.



Used in equations:	Implicitly used in equation 14, 15
Description:	Usually the diameter at breast height of the tree; but it could be any other diameter or dimensional measurement used in the model or data source used, e.g. basal diameter, root-collar diameter, basal area, etc.
Source of data:	Field measurements in sample plots. For <i>ex ante</i> estimations, <i>DBH</i> values should be estimated using a growth curve, a growth model, or a yield table that gives the expected tree dimensions as a function of tree age
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	<i>H</i>
Data unit:	m or any other unit of length
Used in equations:	Implicitly used in equation 14, 15
Description:	Height of tree
Source of data:	Field measurements in sample plots. For <i>ex ante</i> estimations, <i>H</i> values should be estimated using a growth curve, a growth model, or a yield table that gives the expected tree dimensions as a function of tree age
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III
Comments:	Models used may be based on units of length other than metre (e.g. feet), in which case the appropriate unit of length only should be used

<b>Data / Parameter:</b>	<i>L</i>
Data unit:	m
Used in equations:	20
Description:	Length of the transect to determine volume of lying dead wood
Source of data:	Field measurements
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	$MP_{LI}$
Data unit:	Dimensionless
Used in equations:	22
Description:	Dry-to-wet weight ratio of the litter (dry weight/wet weight)
Source of data:	Laboratory measurement of field samples



Measurement procedures:	Litter samples shall be collected and well mixed into one composite sample at the same time of 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:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	<i>N</i>
Data unit:	Dimensionless
Used in equations:	20
Description:	Total number of wood pieces intersecting the transect
Source of data:	Field measurements
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

<b>Data / Parameter:</b>	<i>T</i>
Data unit:	year
Used in equations:	12, 17, 23
Description:	Time period elapsed between two successive estimations of carbon stock in a carbon pool
Source of data:	Recorded time
Measurement procedures:	N/A
Comments:	If the two successive estimations of carbon stock in a carbon pool are carried out at different points of time in year $t_2$ and $t_1$ , (e.g. in the month of April in year $t_1$ and in the month of September in year $t_2$ ), then a fractional value shall be assigned to $T$

#### 4. Conservative approach and uncertainties

While applying this methodology the PPs shall ensure that “Guidelines on conservative choice and application of default data in estimation of the net anthropogenic GHG removals by sinks” are followed for addressing uncertainty.

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.

#### IV. REFERENCES AND ANY OTHER INFORMATION

All references are quoted in footnotes.





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## History of the document

Version	Date	Nature of revision(s)
05	EB 56, Annex # 17 September 2010	The revision: (i) Broadens the applicability of the methodology by allowing more than 10% of project area to be ploughed in the project scenario; (ii) Allows use of the “Tool for estimation of change in soil organic carbon stocks due to the implementation of CDM A/R project activities”; (iii) Introduces simplified methods for estimation of initial biomass in living trees in the baseline; (iv) Inserts a note at the end of the section 5.1.1 explicitly stating how the biomass in baseline is to be accounted; and (v) Streamlines the general presentation of the methodology with the recently approved methodologies. Due to the overall modification of the document, no highlights of the changes are provided.
04	EB 53, Annex 12 26 March 2010	To correct editorial misprints in text and equations and improve the language. To delete a variable (Soil organic carbon of the sample in plot $p$ in stratum $i$ , time $t$ ) that is no longer used in the methodology.
03	EB 46, Annex 14 25 March 2009	To apply the guidance provided in para 37, EB 44 meeting report regarding accounting of GHG emissions in A/R CDM project activities, from the following sources: (i) fossil fuel combustion in A/R CDM project activities, (ii) collection of wood from non-renewable sources to be used for fencing of the project area, and (iii) nitrous oxide (N <sub>2</sub> O) emissions from decomposition of litter and fine roots from N-fixing trees. The Board agreed that emissions from these sources may be considered as insignificant. Approach allowing for estimation of default changes in soil organic carbon was added.
02	EB 42, para 35 26 September 2008	Revisions mainly in the following sections: <i>5.2 Estimation of GHG emissions within the project boundary,</i> <i>6.1 Leakage</i> 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.
01	EB 38, Annex 7 14 March 2008	Initial adoption.
<b>Decision Class:</b> Regulatory <b>Document Type:</b> Standard <b>Business Function:</b> Methodology		