Draft revision to the approved afforestation and reforestation baseline and monitoring methodology
AR-AM0006

"Afforestation/Reforestation with Trees Supported by Shrubs on Degraded Land"

(Version 03.1.0)

I. SOURCE, DEFINITIONS AND APPLICABILITY

1. Sources

This methodology is based on the draft CDM-AR-PDD "Afforestation for Combating Desertification in Aohan County, Northern China" whose 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, University of Tuscia, Italy, Department for Environmental Research and Development, Ministry for the Environment Land and Sea , Italy, Chifeng Institute of Forestry, Inner Mongolia Autonomous Region, China, Forestry Bureau of Aohan County, Inner Mongolia Autonomous Region, China, National Bureau to Combat Desertification, CCICCD, State Forestry Administration, China.

The methodology allows for accounting of biomass and changes in biomass of shrubs that are established in the A/R CDM project activity. Vegetation established shall meet threshold for the values for defining forest. For more information regarding the proposal and its consideration by the CDM Executive Board (the Board) please refer to the case ARNM0020-rev: "Afforestation for Combating Desertification in Aohan County, Northern China" on <http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html>.

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

(a) Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities;

(b) Guidance on application of the definition of the project boundary to A/R CDM project activities;

(c) Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities;

(d) Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities;

(e) Calculation of the number of sample plots for measurements within A/R CDM project activities;

(f) Tool for testing significance of GHG emissions in A/R CDM project activities;

(g) Estimation of GHG emissions due to clearing, burning and decay of existing vegetation attributable to a CDM A/R project activity;

(h) Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities;

(i) "Guidelines on conditions under which increase in GHG emissions attributable to displacement of pre-project crop cultivation activities in A/R CDM project activity is insignificant", and

(j) "Guidelines on conditions under which increase in GHG emissions related to displacement of pre-project grazing activities in A/R CDM project activity is insignificant".

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

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 project activities with the following conditions:

(a) Lands to be afforested or reforested are degraded or degrading and it is expected that the lands would remain degraded in the absence of the project activity;

(b) Lands to be afforested or reforested do not contain organic soils and do not fall into wetland[1] category;

(c) Carbon stocks in litter and deadwood can be expected to decrease more or increase less in the absence of the project activity, relative to the project scenario;

(d) The project activity does not lead to displacement of pre-project activities outside the project boundary, or the increase in GHG emissions due to displacement of pre-project activities is insignificant.

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

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. PPs may identify the areas of land to be included in the A/R CDM project activity

[1] "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).

using the latest version of the "Guidance on application of the definition of the project boundary to A/R CDM project activities".

PPs shall demonstrate that each discrete area of land to be included within the project boundary is eligible for an A/R CDM project activity using the current version of the "Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities".

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 affected by the project activity
Below-ground biomass	Yes	Major carbon pool affected by the project activity
Dead wood	No	Considering the applicability conditions of this methodology, the carbon stock in the pool is likely to increase less, or decrease more, in the baseline scenario compared to the project scenario. Therefore, excluding the pool from accounting will lead to a conservative estimation of net anthropogenic GHG removal by sinks
Litter	No	Considering the applicability conditions of this methodology, the carbon stock in the pool is likely to increase less, or decrease more, in the baseline scenario compared to the project scenario. Therefore, excluding the pool from accounting will lead to a conservative estimation of net anthropogenic GHG removal by sinks
Soil organic carbon (SOC)	Yes (alternatively No)	Carbon stock in this pool is likely to increase as a result of implementation of the project activity; however, PPs can choose not to account for this pool, as doing so will lead to a conservative estimation of net anthropogenic GHG removal by sinks

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

Source	Gas	Included/ excluded	Justification / Explanation
Burning of biomass	CO_2	Excluded	Carbon stock decreases due to burning are accounted as a change in carbon stock
	CH_4	Included	Burning of biomass for the purpose of site preparation or as part of forest management can lead to significant levels of emissions of methane
	N_2O	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

Stratification of the planned project area for baseline estimation is not required but may be carried out if it improves the accuracy and precision of biomass estimates. Different stratification may be required for the baseline and project scenarios in order to achieve optimal accuracy of the estimates.

Strata for biomass estimation may be defined on the basis of parameters that are key entry variables in the method (e.g. growth models or yield curves/tables) used to estimate changes in biomass stocks. Thus:

(a) **For baseline net GHG removals by sinks.** It will usually be sufficient to stratify according to area of major vegetation types and/or crown cover;

(b) **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.

4. Baseline net GHG removals by sinks

Under the applicability conditions of this methodology:

(a) Changes in carbon stock of above-ground and below-ground biomass of non-tree woody vegetation may be conservatively assumed to be zero for all strata in the baseline scenario;

(b) 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:

$$\Delta C_{BSL} = \Delta C_{BSL\_TREE} \quad \textbf{(1)}$$

where:

ΔC_{BSL}	Baseline net GHG removals by sinks; t CO_2-e
ΔC_{BSL_TREE}	Sum of the carbon stock changes in above-ground and below-ground biomass of trees in the baseline; t CO_2-e

4.1 Carbon stock changes in above-ground and below-ground tree biomass (ΔC_{BSL_TREE})

The estimation of change in carbon stock of above-ground and below-ground tree biomass in the baseline (ΔC_{BSL_TREE}) will be performed using the equations below. If there is more than one stratum in the baseline scenario, these equations are applied to each of the strata and the outcome is summed over all the strata to obtain the value for the whole project.

$$\Delta C_{BSL\_TREE,i} = \frac{44}{12} * \sum_{t=1}^{t^*} \Delta C_{BSL\_AGBG,i,t} * 1 year \quad \textbf{(2)}$$

where:

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

$\Delta C_{BSL\_AGBG,i,t}$ is estimated using the following equation:

$$\Delta C_{BSL\_AGBG,i,t} = \Delta C_{GAIN,i,t} - \Delta C_{LOSS,i,t} \quad \textbf{(3)}$$

where:

$\Delta C_{BSL\_AGBG,i,t}$	Baseline annual carbon stock net change in above-ground and below-ground tree biomass for stratum *i,* time *t*; t C yr^{-1}
$\Delta C_{GAIN,i,t}$	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}

$\Delta C_{LOSS,i,t}$	Annual decrease in above-ground and below-ground carbon stock of living trees due to biomass loss for stratum *i,* time *t*; t C yr^{-1} Note: Conservative assumption that $\Delta C_{LOSS,i,t} = 0$ is allowed for the baseline scenario
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

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

where:

$\Delta C_{GAIN,i,t}$	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}
$A_{BSL,j,i}$	Area under trees of species *j* in 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}
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

$$G_{TREE,j,i,t} = G_{W,j,i,t} * (1 + R_{1j}) \tag{5}$$

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

where:

$G_{TREE,j,i,t}$	Annual increment of total 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}
$G_{W,j,i,t}$	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 stem volume of trees 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) *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 increment in total above-ground tree biomass 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 5. Note that available data on average annual increment in the volume of species *j* in stratum *i* for year *t* ($I_{V,j,i,t}$) may be expressed as a net average annual increment (i.e. the term $\Delta C_{LOSS,i,t}$ is already implicitly allowed), in which case $\Delta C_{LOSS,i,t}$ shall be set to zero in equation 3 in order to avoid double counting.

If, on the other hand, 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 $\Delta C_{LOSS,i,t}$ may be either conservatively assumed as zero or could 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).

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:

$$C_{TREE\_BSL} = B_{TREE\_BSL} * CF_{TREE\_BSL} \quad \textbf{(7)}$$

where:

C_{TREE_BSL}	Carbon stock in living trees in the baseline at the start of the project activity; t C
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^{-1} d.m.

The biomass of living trees in the baseline at the start of the project activity (B_{TREE_BSL}) 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 content per unit area for the project area can be estimated, the data may be used provided that the estimated value of biomass content 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:

$$B_{TREE\_BSL} = BD_{TREE\_BSL} * A_{TREE\_BSL} \quad \textbf{(8)}$$

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 content per unit area of the project area (obtained from published literature); t d.m. ha^{-1}
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:

$$B_{TREE\_BSL} = \frac{P_{BSL}}{P_{FOREST}} * B_{FOREST} * A_{TREE\_BSL} * (1 + R_{TREE\_BSL}) \qquad \textbf{(9)}$$

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 (or country) where the project activity is located
B_{FOREST}	Default above-ground biomass content in forest in the region/country where the A/R CDM project activity is located; t d.m. ha^{-1}
A_{TREE_BSL}	Area of land within the project boundary where living trees are standing at start of the project activity and to which the parameter P_{BSL} relates; 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:

$$B_{TREE\_BSL} = \sum_{k=1}^{n} B_{TREE,k} \qquad \textbf{(10)}$$

where:

B_{TREE_BSL}	Biomass of living trees in the baseline at the start of the project activity; t d.m.
$B_{TREE,k}$	Biomass of the k^{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:

$$B_{TREE\_BSL} = \sum_{i} \left(\frac{A_{TREE,i}}{A_{PLOT,i}} \sum_{p} B_{TREE,i,p} \right) \quad \textbf{(11)}$$

where:

B_{TREE_BSL}	Biomass of living trees in the baseline at the start of the project activity; t d.m.
$A_{TREE,i}$	Area of baseline stratum i within the project boundary where living trees are standing at start of the project activity; ha
$A_{PLOT,i}$	Area of sample plots in baseline stratum i where dimensional measurements are carried out on the trees; ha
$B_{TREE,i,p}$	Biomass of living trees in plot p of baseline stratum i as estimated from dimensional measurements; t d.m.
i	*1, 2, 3*, … Baseline strata

4.3 Carbon stock in shrub biomass at the start of the project activity

The methodological tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in an A/R CDM project activity" can be applied to estimate carbon stock in shrub biomass at the start of the project activity (C_{SHRUB_BSL}).

$$C_{SHRUB\_BSL} = \frac{12}{44} * C_{SHRUB,t=1} \quad \textbf{(12)}$$

where:

$C_{SHRUB,BSL}$	Carbon stock in shrub biomass within the project boundary at the start of the project activity; t C
$C_{SHRUB,t=1}$	Carbon stock in shrub biomass within the project boundary at *t*=1, estimated following methodological tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO_2-e

4.4 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:

$$\Delta C_{BSL} = 0 \quad \textbf{(13)}$$

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

Actual net GHG removals by sinks and net anthropogenic GHG removals by sinks shall be calculated 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 commencement of monitoring activities.

Actual net GHG removals by sinks are calculated as:

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

where:

ΔC_{ACTUAL}	Actual net greenhouse gas removals by sinks; t CO_2-e
ΔC_P	Sum of changes in the C stocks in all selected carbon pools ; t CO_2-e
GHG_E	Increase in non-CO_2 GHG emissions within the project boundary, attributable to the A/R CDM project activity; t CO_2-e

5.1 Estimation of changes in the carbon stocks

The verifiable changes in the carbon stock in selected pools within the project boundary are calculated using the following equation:

$$\Delta C_P = \frac{44}{12} * \left(\sum_{t=1}^{t*} \Delta C_t - C_{TREE\_BSL} - C_{SHRUB\_BSL} \right) \quad \textbf{(15)}$$

where:

ΔC_P	Sum of the changes in carbon stock in all selected carbon pools during the monitoring period; t CO_2-e
ΔC_t	Change in carbon stock in all selected carbon pools, during the year *t*; t C
C_{TREE_BSL}	Carbon stock in living trees in the baseline at the start of the project activity; t CO_2-e
C_{SHRUB_BSL}	Carbon stock in shrub biomass in the baseline at the start of the project activity; t CO_2-e
t	*1, 2, 3, … t^** years elapsed since the start of the monitoring period; yr
44/12	Ratio of molecular weights of CO_2 and carbon

ΔC_t shall be calculated using the following equation:

$$\Delta C_t = \sum_{i=1}^{M_{PS}} (\Delta C_{TREE,i,t} + \Delta C_{SHRUB,i,t} + \Delta C_{SOC,i,t}) \quad \textbf{(16)}$$

where:

ΔC_t	Change in carbon stock in all selected carbon pools, during the 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
$\Delta C_{SHRUB,i,t}$	Change in carbon stock in above-ground and below-ground biomass of shrubs in stratum *i*, in year *t*; t CO_2
$\Delta C_{SOC,i,t}$	Change in carbon stock in the SOC pool in stratum *i*, during the 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 monitoring period

5.1.1 Changes in C Stock in Tree Biomass ($\Delta C_{TREE,i,t}$)

The mean carbon stock in above-ground and below-ground tree biomass per unit area is estimated on the basis of field measurements in permanent sample plots.

The annual change of carbon stock in trees is then calculated as:

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

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^{-1}
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

For the first verification C_{TREE,i,t_1} = 0.

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

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

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^{-1}

The value of $C_{TREE,i,t}$ is estimated by using one of the following methods:

(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 total above-ground tree biomass using biomass expansion factor (*BEF*) and basic wood density (*D*). Total tree biomass is then obtained by multiplying the total 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 Section III below 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 Section III below 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:

$$C_{TREE,j,p,i} = V_{TREE,j,p,i} * D_j * BEF_{2,j} * (1 + R_j) * CF_j \qquad \textbf{(19)}$$

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^3
D_j	Basic wood density of species or group 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 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 d.m.)$^{-1}$
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 Section III below 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:

$$C_{TREE,j,p,i} = f_j(DBH, H) * (1 + R_j) * CF_j \quad \textbf{(20)}$$

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.)$^{-1}$
$f_j(DBH, H)$	Allometric function returning total above-ground tree biomass on the basis of diameter at breast height (*DBH*) and/or height of the tree (*H*), for species or group of species *j*; 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:

$$C_{TREE,i} = \frac{A_i}{A_{PLOT,i}} \sum_{p=1}^{P_i} \sum_{j=1}^{J_i} C_{TREE,j,p,i} \quad \textbf{(21)}$$

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
$A_{PLOT,i}$	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, …* I_P strata in the project scenario

Equation 14 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 10.

5.1.2 Changes in C Stock in Shrub Biomass ($\Delta C_{SHRUB,i,t}$)

The rate of change of shrub biomass over any period of time is calculated assuming a linear growth. Therefore, the rate of change in carbon stock in shrub biomass over a period of time is calculated as:

$$dC_{SHRUB,i,(t_1,t_2)} = \frac{C_{SHRUB,i,t_2} - C_{SHRUB,i,t_1}}{T} \quad \textbf{(22)}$$

where:

$dC_{SHRUB,i,(t_1,t_2)}$	Rate of change in carbon stock in shrub biomass in stratum *i* within the project boundary during the period between a given point of time in year t_1 and the same point of time in year t_2; t CO_2-e yr^{-1}
C_{SHRUB,i,t_2}	Carbon stock in shrub biomass in stratum *i* within the project boundary at a given point of time in year t_2; t CO_2-e
C_{SHRUB,i,t_1}	Carbon stock in shrub biomass in stratum *i* within the project boundary at a given point of time in year t_1; t CO_2-e.
T	Time elapsed between two successive estimations ($T=t_2 - t_1$); yr

For the first verification $C_{SHRUB,i,t_1} = 0$.

Change in carbon stock in shrub biomass in stratum *i* within the project boundary in year *t* ($t_1 \leq t \leq t_2$) is given by:

$$\Delta C_{SHRUB,i,t} = dC_{SHRUB,i,(t_1,t_2)} * 1 year \text{ for } t_1 \leq t \leq t_2 \tag{23}$$

where:

$\Delta C_{SHRUB,i,t}$	Change in carbon stock in shrub biomass in stratum *i* within the project boundary in year *t*; t CO_2-e
$dC_{SHRUB,i,(t_1,t_2)}$	Rate of change in carbon stock in shrub biomass in stratum *i* within the project boundary during the period between a given point of time in year t_1 and the same point of time in year t_2; t CO_2-e yr^{-1}

For the *ex ante* estimation, method as contained in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities" can be followed to estimate carbon stock in shrub biomass in stratum *i*.

For the *ex post* estimation, the step-by-step procedure below is followed for estimating carbon stock in shrub biomass in stratum *i*.

Step 1: Measuring crown area (diameter), height, diameter at base of shrub and number of stems for all shrubs in the permanent sample plots.

Step 2: Choosing or establishing appropriate allometric equations for shrubs.

$$B_{SHRUB} = f(DB, H_s, CD, N) \tag{24}$$

where:

B_{SHRUB}	Above-ground biomass of planted shrub, tonnes d.m. ha^{-1}
$f(DB, H_s, CD, N)$	An allometric equation linking above-ground biomass (d.m. ha^{-1}) of shrubs (B_{SHRUB}) to diameter at base (*DB*), shrub height (*Hs*), crown diameter (*CD*) and number of stems (*N*)

Step 3: Carbon stock in shrub biomass in stratum *i* within the project boundary at a given point of time in year *t* is calculated as:

$$C_{SHRUB,i,t} = \frac{44}{12} * CF_S * (1 + R_S) * A_{SHRUB,i,t} * B_{SHRUB,i,t} \tag{25}$$

where:

$C_{SHRUB,i,t}$	Carbon stock in shrub biomass in stratum *i* within the project boundary at a given point of time in year *t*; t CO_2-e
$\frac{44}{12}$	Ratio of molecular weights of CO_2 and carbon; dimensionless
CF_S	Carbon fraction of shrub biomass; dimensionless
R_S	Root-shoot ratio for shrubs; dimensionless

$A_{SHRUB,i,t}$	Area of stratum *i* at a given point of time in year *t*; ha
$B_{SHRUB,i,t}$	Shrub biomass per unit area in stratum *i* at a given point of time in year *t*; t d.m. ha^{-1}
i	*1, 2, 3, …* strata
t	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

5.1.3 Soil organic carbon

Change in C stock in the SOC pool shall either be conservatively assumed to be zero or estimated as follows:

$$\Delta C_{SOC,i,t} = \Delta SOC_{AL,t}$$

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 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 only increase in GHG emissions within the project boundary which results from the implementation of the A/R CDM project activity and which is required to be accounted for is the non-CO_2 GHG emission from burning of biomass for site preparation and/or forest management. It is estimated as:

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

where:

GHG_E	Increase in non-CO_2 GHG emissions within the project boundary as a result of the implementation of the A/R CDM project activity; t CO_2-e
$E_{BIOMASS\_BURN,t}$	Increase in non-CO_2 GHG emissions due to burning of biomass of existing vegetation as part of site preparation and/or forest management in 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_2-e
t	*1, 2, 3, … t^** years elapsed since the start of the project

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 project activity does not lead to displacement of pre-project activities outside the project boundary, or the increase in GHG emissions due to displacement of pre-project activities is insignificant.

Therefore, leakage is calculated as :

$$LK = 0 \qquad \textbf{(27)}$$

where:

LK	Total GHG emissions due to leakage; t CO_2-e

If the project activity leads to displacement of pre-project activities, whether partially or fully, outside the project boundary, the PPs shall use:

(a) The "Guidelines on conditions under which increase in GHG emissions attributable to displacement of pre-project crop cultivation activities in A/R CDM project activity is insignificant"; and

(b) The "Guidelines on conditions under which increase in GHG emissions related to displacement of pre-project grazing activities in A/R CDM project activity is insignificant".

to demonstrate that increase in GHG emissions related to displacement of the pre-project activities is insignificant.

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 equation can be used to calculate the net anthropogenic GHG removals by sinks under the project:

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

where:

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

7.1 Calculation of tCERs and lCERs

To estimate the 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 equations approved by the Board,[2] which produce the same estimates as the following:

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

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

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

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 since start of the project crediting period, at time $t = t_2$; t CO_2-e
C_{AR-CDM,t_1}	Net anthropogenic GHG removals by sinks at beginning of the monitoring period, that is, at $t = t_1$; t CO_2-e

8. Data and parameters not monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters contained 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.

Data / Parameter:	$BEF_{2,j}$
Data unit:	dimensionless
Used in equations:	19
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: (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; (e) IPCC default values (e.g. Table 3A.1.10 of IPCC GPG-LULUCF 2003)[3]
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 30%

[3] Although the *BEFs* in Table 3A.1.10 apply to biomass, the dimensionless factors can be equally applied for wood volume expansions.

Data / Parameter:	$BEF_{1,j}$
Data unit:	dimensionless
Used in equations:	6
Description:	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to increment in total above-ground tree biomass for species *j*
Source of data:	The source of data shall be selected, in order of preference, from the following: (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; (e) IPCC default values (e.g. Table 3A.1.10 of IPCC GPG-LULUCF 2003)[4]
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 30%

Data / Parameter:	BD_{TREE_BSL}
Data unit:	t d.m. ha^{-1}
Used in equations:	8
Description:	Tree biomass content 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

Data / Parameter:	B_{FOREST}
Data unit:	t d.m. ha^{-1}
Used in equations:	9
Description:	Default above-ground biomass content in forest in the region/country where the A/R CDM project activity is located

[4] 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

Data / Parameter:	CF_j
Data unit:	t C t^{-1} d.m.
Used in equations:	4, 19, 20
Description:	Carbon fraction of tree biomass for species or group of species *j*
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^{-1} d.m.

Data / Parameter:	CF_{TREE_BSL}
Data unit:	t C t^{-1} d.m.
Used in equations:	7
Description:	Carbon fraction of dry matter for tree biomass in baseline
Source of data:	Default value 0.50 t C t^{-1} d.m. may be used

Data / Parameter:	D_j
Data unit:	t d.m. m^{-3}
Used in equations:	6, 19
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: (a) National and 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 species or group of species-specific data (e.g. Table 3A.1.9 IPCC GPG-LULUCF 2003)

Data / Parameter:	$f_j(DBH, H)$
Data unit:	t d.m.
Used in equations:	20
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: (a) Existing local and species or group of species-specific data; (b) National and 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 (e.g. Tables 4.A.1–4.A.3 of IPCC GPG-LULUCF 2003)

Data / Parameter:	$I_{V,j,i,t}$
Data unit:	$m^3\ ha^{-1}\ yr^{-1}$
Used in equations:	6
Description:	Current annual increment in stem volume of trees of species *j* in stratum *i*, for year *t*
Source of data:	The source of data, in order of preference, shall be the following: (a) Existing local and species or group of species-specific tree growth data or local volume tables; (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); (c) Species or group of species-specific tree growth data or volume tables from neighbouring countries with similar conditions; Globally available data applicable to species or group of species
Comments:	$I_{V,j,t}$ 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. 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)

Data / Parameter:	R_j
Data unit:	dimensionless
Used in equations:	19, 20
Description:	Root-shoot ratio for species or group of species *j*
Source of data:	The source of data, in order of preference, shall be any of the following: (a) Existing local and species or group of species-specific data; (b) National and 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 growing under similar conditions or similar forest type. If none of the above sources are available, then the value of R_j may be calculated as B/A where $B = exp[-1.085+0.9256*ln(A)]$, where A is above-ground biomass (t d.m. ha^{-1}) and B is below-ground biomass (t d.m. ha^{-1}) [Source: Table 4.A.4 of IPCC GPG-LULUCF 2003]

Data / Parameter:	R_{1j}
Data unit:	dimensionless
Used in equations:	5
Description:	Root-shoot ratio appropriate for biomass increment for species *j*
Source of data:	The source of data, in order of preference, 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. Sometimes (b) might be preferable to (a); (c) Species-specific or group of species-specific from global studies
Comments:	If none of the above sources are available, then the value of R_{1j} may be calculated as B/A where $B = exp[-1.085+0.9256*ln(A)]$, where A is above-ground biomass (t d.m. ha^{-1}) and B is below-ground biomass (t d.m. ha^{-1}) [Source: Table 4.A.4 of IPCC GPG-LULUCF 2003]

Data / Parameter:	$V_{TREE,j,p,i}$
Data unit:	m^3
Used in equations:	19
Description:	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
Source of data:	The source of data, in order of preference, shall be the following: (a) Existing local and species or group of species-specific tree growth data or local volume tables; (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); (c) Species or group of species-specific tree growth data or volume tables from neighbouring countries with similar conditions; (d) Globally available data applicable to species or group of species
Comments:	In case of *ex ante* 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

Data / Parameter:	R_S
Data unit:	dimensionless
Used in equations:	25
Description:	Root-shoot ratio for shrubs

Source of data:	The source of data, in order of preference, shall be any of the following: (a) Existing local and species or group of species-specific data; (b) National and 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. If none of the above sources are available, then a default value of 0.40 may be used [Source: Table 4.4 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories]

Data / Parameter:	CF_S
Data unit:	t C t^{-1} d.m.
Used in equations:	25
Description:	Carbon fraction of shrub biomass
Source of data:	IPCC default value of 0.50 t C t^{-1} d.m. may be used

Data / Parameter:	$f(DB, H_s, CC, N)$
Data unit:	t d.m.
Used in equations:	24
Description:	An allometric equation linking above-ground biomass (d.m. ha^{-1}) of shrubs (B_{SHRUB}) to diameter at base (*DB*), shrub height (*Hs*), crown diameter (*CC*) and number of stems (*N*)
Source of data:	The source of data, in order of preference, shall be any of the following: (a) Existing local and species or group of species-specific data; (b) National and species or group of species-specific data; (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

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 for the following reasons:

(a) Unexpected disturbances occurring during the crediting period (e.g. due to fire, pests or disease outbreaks) or other factors (e.g. soil type) have differing impacts on various parts of an originally homogeneous stratum;

(b) Forest management activities (cleaning, planting, thinning, harvesting, re-replanting) 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 required precision for biomass estimation is ± 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 estimations shall be based on measured or existing published data where possible, using 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:	21
Description:	Area of stratum *i*
Source of data:	Delineation 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 remotely sensed data)
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the first verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	$A_{BSL,j}$
Data unit:	ha
Used in equations:	4
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

Data / Parameter:	$A_{PLOT,i}$
Data unit:	ha
Used in equations:	21
Description:	Total area of 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 first verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	*DBH*
Data unit:	cm or any unit of length used in the model or data source used
Used in following equations:	Implicitly used in equations 19 and 20
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 measurement
Measurement procedures:	Typically measured 1.3 m above-ground. Measure all the trees above some minimum *DBH* in the permanent sample plots. The minimum *DBH* varies depending on tree species or group of species and climate; for instance, the minimum *DBH* may be as small as 2.5 cm for arid environments where trees grow slowly, whereas it could be up to 10 cm for humid environments where trees grow rapidly

Monitoring frequency:	At least every five years
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	*H*
Data unit:	m or any other unit of length
Used in equations:	Implicitly used in equations 19 and 20
Description:	Height of tree
Source of data:	Field measurement
Measurement procedures:	Models used may be based on total tree height (top height) or height of stem (clear bole height). The relevant dimension should be measured and used
Monitoring frequency:	At least every five years
QA/QC procedures:	See paragraph 1 (b) of Section III

Data / Parameter:	*DB*
Data unit:	cm
Used in equations:	Implicitly used in equation 24
Description:	Shrub diameter at base
Source of data:	Field measurement
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	H_s
Data unit:	meter
Used in equations:	Implicitly used in equation 24
Description:	Height of shrub
Source of data:	Field measurement
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	*CD*
Data unit:	meter
Used in equations:	Implicitly used in equation 24
Description:	Shrub crown diameter
Source of data:	Field measurement
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	*N*
Data unit:	dimensionless
Used in equations:	Implicitly used in equation 24
Description:	Number of shrub stem
Source of data:	Field measurement
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	*T*
Data unit:	year
Used in equations:	17, 22
Description:	Time period elapsed between two successive estimations of carbon stock in trees
Source of data:	Recorded time
Measurement procedures :	N/A
Comments:	If the two successive estimations of carbon stock in trees 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 the "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 anthropogenic 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(s)
03.1.0	EB 58, Annex # 26 November 2010	The revision mainly incorporates the following changes: (i) Inclusion of use of the tool on estimation of change in C stock in soil organic carbon; (ii) Removal of sections dealing with emission from enteric fermentation; (iii) Streamlining of the layout and style of the methodology on the lines of recently approved methodologies. Due to overall modification of the document, no highlights of the changes are provided.
03	EB 50, Annex 19 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.
02	EB 42, Para 35 26 September 2008	Revisions mainly in the following sections: *Section II. Baseline methodology* *7(b) GHG emissions by sources* *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.
01	EB 29, Annex 6 16 February 2007	Initial adoption.
Decision Class: Regulatory **Document Type**: Standard **Business Function**: Methodology		