Afforestation and reforestation baseline and monitoring methodology AR-AM0011

"Afforestation and reforestation of land subject to polyculture farming"

(Version 01)

I. SOURCE, DEFINITIONS AND APPLICABILITY

1. Source

This methodology is based on elements from the following:

- AR-NM0036 "Rubber outgrowing and carbon sequestration in Ghana (ROCS-Ghana)" and draft CDM-AR-PoA-DD "Rubber outgrowing and carbon sequestration in Ghana (ROCS-Ghana)", prepared by ONF-International for the Government of Ghana, Ministry of Food and Agriculture, Ghana Rubber Estate Ltd (GREL) and the Rubber Outgrowers and Agents Association of Ghana (ROAA), with support from Agence française du développement (AFD) and KFW.

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

- Procedures to demonstrate the eligibility of lands for A/R CDM project activities;
- Combined tool to identify the baseline scenario and demonstrate the additionality in A/R CDM project activities;
- Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities;
- Tool for estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of a A/R CDM project activity;
- Tool for estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity;
- Calculation of the number of sample plots for measurements within A/R CDM project activities;
- Guidance on the application of the definition of project boundary to A/R CDM project activities;
- Guidelines on conditions under which increase in GHG emissions related to displacement of pre-project crop cultivation activities in A/R CDM project activity is insignificant;
- Guidelines on conservative choice and application of default data in estimation of the net anthropogenic GHG removals by sinks.

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

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

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

3. Definitions

For the purpose of this methodology:

- **Polyculture** is an agriculture system that includes multiple crops, possibly including tree crops, alternatively cultivated over the same area of land. It includes crop rotation, multi-cropping, intercropping, companion planting among other similar practices. Fallow periods may occur between some crops. Crops and fallow period combine into a production cycle which is repeated over time;

- **A parcel** is the discrete and continuous area of land planted in a single year within a farm as part of the A/R CDM project activity. Parcels are mutually exclusive and collectively exhaustive within the boundary of the afforestation and reforestation CDM project activity.

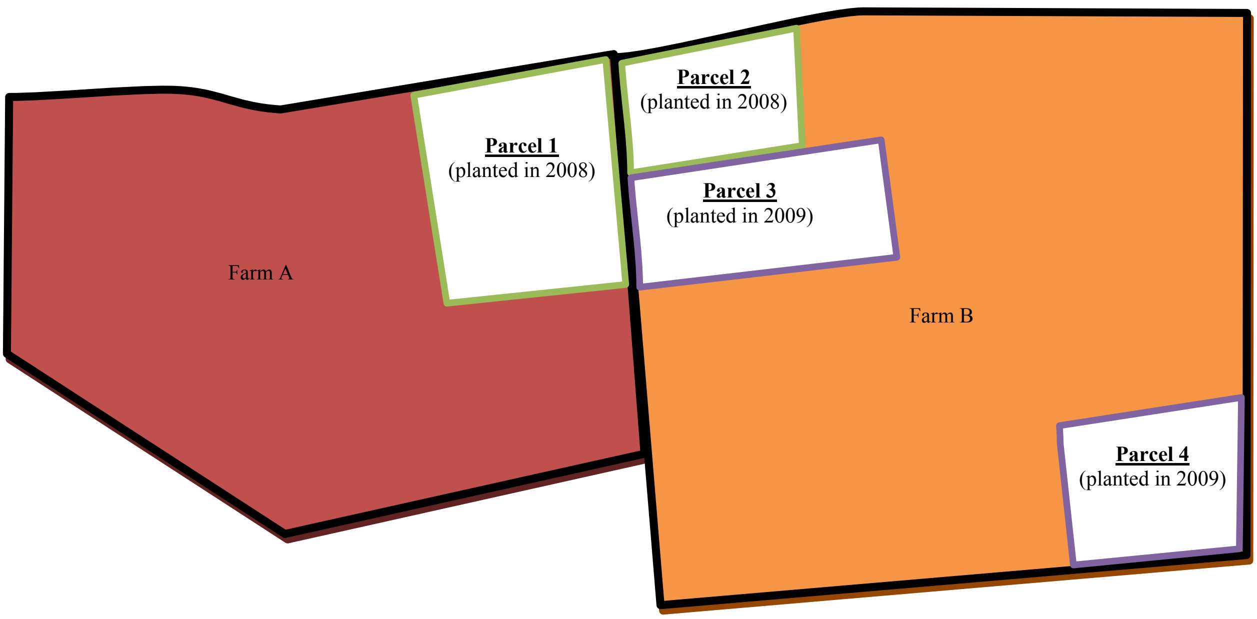

Figure 1: Illustration of the subdivision of the project area into parcels

4. Applicability

This methodology is applicable to afforestation and reforestation CDM project activities that are implemented on areas of land that contain polyculture, possibly including perennial tree crops and/or fallow periods with woody regrowth.

The conditions under which the methodology is applicable are:

(a) The project activity is not implemented on:

(i) Grasslands; and

(ii) Organic soils.

(b) The project activity is implemented on parcels subjected to polycultures in which the fallow part of the cycle is completed and all the existing vegetation present on the parcels is expected to be cleared as the first part of a next production cycle;

(c) A polyculture implemented in the pre-project conditions is expected to be continued in the absence of the project;

(d) Abandonment of farmland in a way that leads to the establishment of forests according to the national definition of forest for CDM purposes is not expected to occur;

(e) Flooding irrigation is not applied in the project activity.

II. BASELINE METHODOLOGY DESCRIPTION

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 many parcels. Each parcel 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. The PPs shall apply the latest version of "Procedures to demonstrate the eligibility of lands for A/R CDM project activities" as approved by the Board.

The latest version of "Guidance on the application of the definition of project boundary to A/R CDM project activities" may be applied in identification of areas of land planned for an A/R CDM project activity.

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

Table 1: Selected carbon pools

Carbon pools	Selected (Yes or No)	Justification / Explanation of choice
Above-ground biomass	Yes	Major carbon pool subjected to the project activity
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	No	The exclusion is conservative because dead wood production under the project scenario (tree crops) is higher than under the baseline scenario
Litter	No	The exclusion is conservative because litter production under the project scenario (tree crops) is higher than under the baseline scenario
Soil organic carbon (SOC)	No	The exclusion is conservative because soil organic carbon increases more or decreases less under the project scenario than under the baseline scenario. This is because the project scenario involves long term continuous vegetation cover on the soil, whereas the baseline scenario involves repeated soil disturbance (e.g. plowing)

The emissions sources included in or excluded from the project boundary are shown in Table 2 below.

Table 2: Emissions sources included in the project boundary

Sources	Gas	Included/ excluded	Justification/Explanation of choice
Burning of woody biomass	CO_2	Included	Burning of woody biomass may occur as a part of the forest management practices within the project activity
	CH_4	Included	
	N_2O	Excluded	

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".

It is assumed that application of the "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" confirms that the continuation of the polyculture allowed by the applicability conditions is the baseline scenario over the planned project area. It means that in the absence of the project activity each parcel within the project boundary would be subjected to the same agricultural practices as were applied in the pre-project conditions.

3. Stratification

If the planned 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 baseline net GHG removals by sinks.** It will be sufficient to stratify according to area of major polycultures;

- **For actual net GHG removals by sinks.** The *ex ante* estimations shall be based on the project planting/management plan. The *ex post* stratification shall be based on the actual implementation of the project management plan. The *ex post* stratification may be affected by natural or anthropogenic impacts if they are able to add variability to growth pattern in the project area, e.g. local fires (see Section III.2).

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

Ex post adjustments of the strata may be needed if unexpected disturbances occur during the crediting period (e.g. due to fire, pests or disease outbreaks), severely affecting different parts of an originally homogeneous stratum or stand, or when forest management operations (i.e. planting, thinning harvesting, replanting, etc.) occur at different intensities, dates and spatial locations than originally planned. In such a situation the project area affected by the disturbance and/or variation in forest management operations may be delineated as a separate stratum for the purpose of *ex post* monitoring.

Note: In the equations used in this methodology, the letter i is used to represent a stratum and the letter n_{strata} is used for the total number of strata, whether for the baseline or for the project scenario, whether for *ex ante* or for *ex post* estimations, depending on the context.

4. Baseline Net GHG Removals by Sinks

In this methodology the baseline is determined *ex ante* and remains fixed during the subsequent crediting period hence, the baseline is not monitored. The following conservative default approach is applied:

The baseline net GHG removals by sinks is estimated separately for each of the two types of polyculture described below.

(a) Polyculture located on degraded/degrading land;

If the application of the most recent version of the "Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities" leads to a conclusion that a polyculture is located on area of land that is degraded or degrading then the sum of carbon stocks in the carbon pools (at the project, individual stratum, or parcel level, as applicable) is expected to decrease and the baseline net GHG removals by sinks may be conservatively accounted as zero (at the level of area of the project, individual stratum, or parcel, as applicable).

(b) Other polycultures.

If the application of the most recent version of the "Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities" does not allow for a conclusion that a polyculture is located on area of land that is degraded or degrading then the polyculture is classified as "other polyculture". For all areas of land within the project boundary that contain "other polycultures" the baseline net GHG removals by sinks shall be accounted at the project, individual stratum, or parcel level, as applicable.

Under the applicability conditions of this methodology the pre-project activities are expected to be continued in the absence of the project hence, the change in the sum of carbon stocks in the carbon pools in the absence of the project (at the level of area of the project, individual stratum, or parcel, as applicable) is expected to result only from accumulation of biomass during the crop-fallow cycle which is cleared in the end of a cycle in order to initiate the next one. Therefore, the changes are limited in size and may be conservatively approximated (at the project, individual stratum, or parcel level, as applicable) by means of the following default approach (identical for *ex ante* and *ex post* calculations):

$$\Delta C_{baseline,t} = \frac{44}{12} * \sum_{k=1}^{K} \Delta Cd_{baseline,k,t} \quad \textbf{(1)}$$

and

$$\begin{aligned} \Delta Cd_{baseline,k,t} &= A_k \cdot \Delta Cd \text{ for } 0 < t \le t_{cycle} \\ \Delta Cd_{baseline,k,t} &= 0 \text{ for } t > t_{cycle} \end{aligned} \quad \textbf{(2)}$$

where:

$\Delta C_{baseline,t}$	Default baseline net GHG removals by sinks for all areas of land that contain "other polycultures" (as classified above) in year *t*; t CO_2-e yr^{-1}
$\Delta Cd_{baseline,k,t}$	Default average annual change in carbon stocks in the carbon pools for area of land (i.e. the individual stratum, or parcel level, as applicable) *k*, in year *t*; t C yr^{-1}
A_k	Area of land *k* that contains the "other polycultures" within boundary of the project; ha
ΔCd	Default annual increase in carbon stocks in the "other polycultures"; t C ha^{-1} yr^{-1}
t_{cycle}	Duration of the typical crop-fallow cycle, or, default duration of a crop-fallow cycle - 10 years (default or project specific data may be used as preferred by PPs); yr
K	*1, 2, 3, … K* index for area of land *k* that contains the "other polycultures" within the boundary of the project

The default values of ΔCd are calculated as follows:

$$\Delta Cd = \frac{1}{2} * \frac{\mathrm{V_{max}} * \mathrm{CF}}{\mathrm{t_{cycle}}} \quad \textbf{(3a)}$$

where:

ΔCd	Default annual increase in carbon stocks in the "other polycultures"; t C ha^{-1} yr^{-1}
$\frac{1}{2}$	Coefficient reflecting the fact that the long term average biomass is equal to $\frac{1}{2} * V_{max}$ (conservatively assuming a linear growth)
V_{max}	Default maximal above-ground biomass content during a crop-fallow cycle; t d.m. ha^{-1}

CF	IPCC default value for the carbon fraction of biomass; 0.5 t C (t d.m.)$^{-1}$
t_{cycle}	Duration of the typical crop-fallow cycle, or, default duration of a crop-fallow cycle - 10 years (default or project specific data may be applied as preferred by PPs); yr

The default maximal above-ground biomass content during a crop-fallow cycle is conservatively assumed to be equal to 10% of the above-ground biomass content in forest V_{forest} which shall be read from Table 3A.1.4 provided in the IPCC GPG-LULUCF 2003 that is:

$$V_{max} = 0.1 * V_{forest} \quad \textbf{(3b)}$$

where:

V_{max}	Default maximal above-ground biomass content during a crop-fallow cycle; t d.m. ha^{-1}
V_{forest}	Default above-ground biomass content in forest ; m^3 ha^{-1}

Baseline net GHG removals by sinks are not monitored *ex post*.

5. Actual net GHG removals by sinks

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 net anthropogenic GHG removals by sinks, PPs shall provide estimates of the values of those parameters that are not available before the start of the crediting period and commencement of monitoring activities. PPs should retain a conservative approach in making these estimates.

$$\Delta C_{ACTUAL} = \Delta C_P - GHG_E \quad \textbf{(4)}$$

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 and the loss of existing (pre-project) woody non-tree biomass due to site-preparation and/or competition from forest trees (or other vegetation) planted as part of the A/R CDM project activity in the project scenario; t CO_2-e
GHG_E	Increase in non-CO_2 GHG emissions as a result of the implementation of the proposed A/R CDM project activity within the project boundary; t CO_2-e

<u>Note</u>: In this methodology equation 4 is used to estimate actual net GHG removals by sinks for the period of time elapsed between project start ($t = 1$) and the year $t = t^*$, t^* being the year for which actual net GHG removals by sinks are estimated. The "stock change" method should be used to determine annual or periodical values.

5.1 Estimation of changes in the carbon stocks

The verifiable changes in the carbon stock in above-ground biomass and below-ground biomass within the project boundary are estimated using the following approach:[1]

$$\Delta C_P = \frac{44}{12} * \sum_{t=1}^{t*} \Delta C_t * 1 year \qquad \textbf{(5)}$$

where:

ΔC_P	Sum of the changes in C stock in all selected carbon pools and the loss of existing (pre-project) woody non-tree biomass due to site-preparation and/or competition from trees (or other vegetation) planted as part of the A/R CDM project activity in the project scenario; t CO_2-e
ΔC_t	Annual change in carbon stock in all selected carbon pools for year *t,* excluding loss of existing (pre-project) biomass due to site-preparation (including burning), and/or competition from trees (or other vegetation) planted as part of the A/R CDM project activity; t C yr^{-1}
T	*1, 2, 3, ...*t^* years elapsed since the start of the A/R project activity; yr
44/12	Ratio of molecular weights of CO_2 and carbon; t CO_2-e $(t\ C)^{-1}$

ΔC_t shall be estimated using the following equation:

$$\Delta C_t = \sum_{i=1}^{M_{PS}} (\Delta C_{AG,i,t} + \Delta C_{BG,i,t}) \qquad \textbf{(6)}$$

where:

ΔC_t	Annual change in carbon stock in all selected carbon pools for year *t,* excluding loss of existing (pre-project) biomass due to site-preparation (including burning), and/or competition from trees (or other vegetation) planted as part of the A/R CDM project activity); t C yr^{-1}
$\Delta C_{AG,i,t}$	Annual change in carbon stock in above-ground biomass of trees for stratum *i*, (possibly average over a monitoring period); t C yr^{-1}
$\Delta C_{BG,i,t}$	Annual change in carbon stock in below-ground biomass of trees for stratum *i*, (possibly average over a monitoring period); t C yr^{-1}
I	*1, 2, 3, ...* M_{PS} strata in the project scenario
t	*1, 2, 3, ...* t^* years elapsed since the start of the A/R CDM project activity

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

[1] IPCC GPG-LULUCF 2003, Equation 3.2.3

5.1.1 Changes in C Stock in Tree Biomass

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

BEF method

Step 1: For *ex ante* estimation, stem volume may be estimated from existing data such as volume tables and yield tables.

For *ex post* estimation, field measurement of diameter at breast height (*DBH*) or girth (*G*) at a defined height, and possibly height (*H*), of all trees (or all the trees above some minimum *G* or *DBH*) in the permanent sample plot should be taken. The stem volume of these trees should then be estimated by inserting the measurements into appropriate equations or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate).

In *ex post* situation, it is also possible to estimate volume by use of field instruments (e.g. a relascope) that measure the volume of each tree directly.

Step 2: Choose *BEF*, and root-shoot ratio (*R*) - see Section II.8 for guidance on source of data. If relevant information is available the *BEF* and *R* should be corrected for age.

Step 3: Convert the stem volume of trees into carbon stock in above-ground biomass via basic wood density, the *BEF* and the carbon fraction:

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

where:

$C_{AB\_tree,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*; t C tree^{-1}
$V_{l,j,i,sp,t}$	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*; m^3 tree^{-1}
D_j	Basic wood density of species *j*; t d.m. m^{-3}
$BEF_{2,j}$	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*; dimensionless
CF_j	Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m. (IPCC default value = 0.5 t C t^{-1} d.m.)
L	Sequence number of trees on plot *sp*
I	*1, 2, 3, ...* M_{PS} strata in the project scenario
J	*1, 2, 3, ...* S_{PS} tree species in the project scenario
t	*1, 2, 3, ...* t^* years elapsed since the start of the A/R CDM project activity

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

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

where:

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

Step 5: Calculate carbon stock in above-ground and below-ground biomass of all trees present in plot *sp* in stratum *i* at time *t* (i.e. summation over all trees *l* by species *j* followed by summation over all species *j* present in plot *sp*)

$$C_{tree,i,sp,t} = \sum_{j=1}^{S_{PS}} \sum_{l=1}^{N_{j,i,sp,t}} (C_{AB\_tree,l,j,i,sp,t} + C_{BB\_tree,l,j,i,sp,t}) \quad \textbf{(9)}$$

where:

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

Step 6: Calculate the mean carbon stock in tree biomass for each stratum:

$$C_{tree,i,t} = \frac{N_i}{N_{sp_i}} \sum_{sp=1}^{P_i} C_{tree,i,sp,t} \quad \textbf{(10)}$$

where:

$C_{tree,i,t}$	Carbon stock in trees in stratum *i*, at time *t*; t C
$C_{tree,i,sp,t}$	Carbon stock in trees on plot *sp* of stratum *i* at time *t*; t C
N_{sp_i}	Number of living trees in all sample plots in stratum *i*
N_i	Number of living trees in stratum *i*

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

If instead of monitoring the number of living trees in each stratum PPs prefer to monitor area of each stratum then the carbon stock in trees per stratum shall be estimated using the following equation:

$$C_{tree,i,t} = \frac{A_i}{A_{sp_i}} \sum_{sp=1}^{P_i} C_{tree,i,sp,t} \qquad \textbf{(11a)}$$

where:

$C_{tree,i,t}$	Carbon stock in trees in stratum *i*, at time *t*; t C
$C_{tree,i,sp,t}$	Carbon stock in trees on plot *sp* of stratum *i* at time *t*; t C
A_{sp_i}	Area of all sample plots in stratum *i*; ha
A_i	Area of the entire stratum *i*; ha
sp	*1, 2, 3, … P_i* sample plots in stratum *i* in the project scenario
i	*1, 2, 3, … M_{PS}* strata in the project scenario
t	*1, 2, 3, … t^** years elapsed since the start of the A/R CDM project activity

Area of all sample plots in stratum *i* is calculated using the following equation:

$$A_{sp_i} = n_i * A_{sp} \qquad \textbf{(11b)}$$

where:

A_{sp_i}	Area of all sample plots in stratum *i*; ha
n_i	Sample size for stratum *i* (calculated using the tool "Calculation of the number of sample plots for measurements within A/R CDM project activities"); dimensionless
A_{sp}	Area of individual sample plot; ha
sp	*1, 2, 3, … P_i* sample plots in stratum *i* in the project scenario
i	*1, 2, 3, … M_{PS}* strata in the project scenario

The area of individual sample plot is established following guidance contained in the tool "Calculation of the number of sample plots for measurements within A/R CDM project activities".

Allometric method

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

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

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

$$C_{AB\_tree,j,i,sp,t} = \sum_{l=1}^{N_{j,sp}} f_j(G,DBH,H) * CF_j \qquad \textbf{(12)}$$

where:

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

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

$$C_{BB\_tree,j,i,sp,t} = C_{AB\_tree,j,i,sp,t} * R_j \qquad \textbf{(13)}$$

where:

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

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

$$C_{tree,i,sp,t} = \sum_{j=1}^{S_{PS}} (C_{AB\_tree,j,i,sp,t} + C_{BB\_tree,j,i,sp,t}) \qquad \textbf{(14)}$$

where:

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

Step 6: Calculate the mean carbon stock in tree biomass for each stratum, as per Step 6 of the *BEF* method.

For both the *BEF* and the allometric methods calculate annual changes in *C* stocks:

$$\Delta C_{AG,i,t} + \Delta C_{BG,i,t} = \frac{C_{tree,i,t_2} - C_{tree,i,t_1}}{T} \quad \textbf{(15)}$$

where:

$\Delta C_{AG,i,t}$	Annual change in carbon stock in above-ground biomass of trees for stratum *i*; t C yr^{-1}
$\Delta C_{BG,i,t}$	Annual change in carbon stock in below-ground biomass of trees for stratum *i*; t C yr^{-1}
$C_{tree,i,t}$	Carbon stock in trees in stratum *i*, at time *t*; t C
T	Number of years between monitoring time t_2 and t_1 ($T = t_2 - t_1$); yr
i	*1, 2, 3, …* M_{PS} strata in the project scenario
t	*1, 2, 3, …* t^* years elapsed since the start of the A/R CDM project activity

5.2 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:

$$GHG_E = \sum_{t=1}^{t^*} E_{BiomassBurn,t} \quad \textbf{(16)}$$

where:

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

Note: In this methodology equation 16 is used to estimate the increase in GHG emissions for the period of time elapsed between project start (t =1) and the year $t = t^*$, t^* being the year for which actual net *GHG* removals by sinks are estimated.

The monitoring of emissions by sources is only required if significant; if insignificant, evidence should be provided (e.g. as 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.

5.2.1 Estimation of non-CO_2 emissions due to biomass burning of existing vegetation as part of the forest management

If prescribed burning of existing woody vegetation[2] is included in the forest management plan, then the non-CO_2 emissions due to burning of the vegetation ($E_{BiomassBurn,t}$) shall be estimated using the relevant instructions provided in the most recent version of the methodological tool "Tool for estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of a A/R CDM project activity".

6. Leakage

Under applicability conditions of this methodology leakage emissions due to displacement of pre-project agricultural activities in A/R CDM project activity occur because in absence of the A/R CDM project activity the entire area included in its boundary would be subjected to agricultural activities. In order to estimate the leakage PPs shall apply the most recent versions of:

- Guidelines on conditions under which increase in GHG emissions related to displacement of pre-project crop cultivation activities in A/R CDM project activity is insignificant; and
- A/R Methodological Tool: "Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity".

Leakage emissions shall be estimated as follows:

$$LK = \sum_{t=1}^{t^*} LK_{Agric,\,t} \qquad \textbf{(17)}$$

where:

LK	Total GHG emissions due to leakage; t CO_2-e
$LK_{Agric,\,t}$	Leakage due to the displacement of agricultural activities in year t (calculated using the A/R methodological tool: "Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity"); t CO_2-e
t	*1, 2, 3, …*t^* years elapsed since the start of the A/R project activity; yr

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

[2] GHG emissions from burning of herbaceous vegetation as per para 35, EB 42 guidance is neglected.

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 ($C_{AR\text{-}CDM}$), in t CO_2-e.

$$C_{AR-CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK \quad \textbf{(18)}$$

where:

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

7.1 Calculation of tCERs and lCERs

To estimate the 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,[3] which produces the same estimates as the following:

$$tCERs = C_{AR-CDM,t_2} \quad \textbf{(19)}$$

$$lCERs = C_{AR-CDM,t_2} - C_{AR-CDM,t_1} \quad \textbf{(20)}$$

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_2.e
C_{AR-CDM,t_1}	Net anthropogenic GHG removals by sinks, as estimated for $t^* = t_1$; t CO_2.e

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

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

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

Data / Parameter:	CF_j
Data unit:	t C (t-d.m.)$^{-1}$
Used in equations:	7, 12
Description:	Carbon fraction of dry matter for species of type *j*
Source of data:	The source of data shall be any of the following: (a) National forest inventory (species-specific inventory - if available or group of species-specific - e.g. from national GHG inventory); (b) Species-specific or group of species-specific inventory of neighbouring countries with similar conditions; (c) Globally applicable sources or default values, preferably species-specific (e.g. IPCC GPG-LULUCF 2003); (d) The default value of 0.5 t C (t-d.m.)$^{-1}$ may be used
Measurement procedures:	N/A
Any comment:	

Data / Parameter:	V_{forest}
Data unit:	m^3 ha^{-1}
Used in equations:	3b
Description:	Default above-ground biomass content in forest
Source of data:	Shall be read from Table 3A.1.4 provided in the IPCC GPG-LULUCF 2003
Measurement procedures (if any):	N/A
Any comment:	

Data / Parameter:	$BEF_{2,j}$
Data unit:	Dimensionless
Used in equations:	7
Description:	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for tree species *j*
Source of data:	The source of data shall be any of the following: (a) Existing local and species-specific or group of species-specific data; (b) National forest inventory, preferably species-specific or group of species-specific (e.g. from national GHG inventory); (c) Species-specific or group of species-specific data from neighbouring countries with similar conditions; (d) Globally species-specific or group of species-specific data (e.g. IPCC GPG-LULUCF 2003)
Measurement procedures:	N/A
Any comment:	*BEFs* in IPCC literature and national inventory are usually applicable to closed canopy forest. If applied to individual trees growing in open field it is recommended that the selected *BEF* be increased by a further 30% to be conservative

Data / Parameter:	D_j
Data unit:	t d.m. m^{-3}
Used in equations:	7
Description:	Basic wood density for species *j*
Source of data:	The source of data shall be any of the following: (a) National forest inventory (species-specific inventory - if available or group of species-specific - e.g. from national GHG inventory); (b) Species-specific or group of species-specific inventory of neighbouring countries with similar conditions; (c) Globally applicable sources or default values, preferably species-specific (e.g. IPCC GPG-LULUCF 2003)
Measurement procedures:	N/A
Any comment:	

Data / Parameter:	R_j
Data unit:	kg d.m. (kg d.m. $)^{-1}$
Used in equations:	8, 13
Description:	Root-shoot ratio appropriate for biomass stock, for species *j*
Source of data:	The source of data shall be any of the following: (a) National and species-specific or group of species-specific (e.g. from national GHG inventory); (b) Species-specific or group of species-specific from neighbouring countries with similar conditions; (c) Species-specific or group of species-specific from global studies
Measurement procedures:	N/A
Any comment:	Conservative choice of default values: 1. If in the sources of data mentioned above, default data are available for conditions that are similar to the project (same vegetation genus, same climate zone, similar forest type), then mean values of default data may be used and are considered conservative; 2. Global values may be selected from Table 3A.1.8 of the IPCC GPG-LULUCF 2003, or equivalently from Table 4.4 of the AFOLU Guidelines (IPCC 2006), by choosing a climatic zone and species that most closely matches the project circumstances; 3. Alternatively, given that many datasets of root-shoot ratios are relatively small because of the difficulty of determining this parameter, conservative selection of a value from the global study by Cairns *et al.* (1997) is likely to provide a reliable default value. For the purpose of estimating the project removals by sinks, use a value about one standard deviation below the mean; i.e. 0.22 kg d.m. (kg-d.m.$)^{-1}$

Data / Parameter:	$f_j(G, DBH, H)$
Data unit:	t d.m.
Used in equations:	12
Description:	Allometric equation for species *j* linking the girth (*G*) and/or diameter at breast height (*DBH*) and possibly height (*H*) to above-ground biomass of living trees
Source of data:	Whenever available, use allometric equations that are species-specific or group of species-specific, provided the equations have been derived using a wide range of diameters and heights, based on datasets that comprise at least 20 trees. Otherwise, default equations from IPCC literature, national inventory reports or published peer-reviewed studies may be used—such as those provided in Tables 4.A.1 to 4.A.3 of the IPCC GPG-LULUCF 2003
Measurement procedures:	N/A
Any comment:	If default allometric equations are available for conditions that are similar to the conditions prevailing in the project area (same vegetation genus; same climate zone; similar forest type), then the equation may be used and considered conservative. Otherwise, it is necessary either to use conservatively assessed values, or to verify the applicability of the equation if mean predicted values are to be used. Allometric equation can be verified by: • Selecting at least five trees covering the range of *DBH* existing in the project area, and felling and weighing the above-ground biomass to determine the total (wet) weight of the stem and branch components; • Extracting and immediately weighing[4] sub-samples from each of the wet stem and branch components,[5] followed by oven drying at 70ºC to determine dry biomass; • Determining the total dry weight of each tree from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components. If the biomass of the harvested trees is within about ±10% of the mean values predicted by the selected default allometric equation, and is not biased—or if biased, is wrong on the conservative side (i.e. use of the equation results in an underestimate rather than overestimate of project net anthropogenic GHG removals by sinks)—then mean values from the default equation may be used

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

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

Data / Parameter:	t_{cycle}
Data unit:	years
Used in equations:	2, 3
Description:	Duration of the typical crop-fallow cycle, or, default duration of a crop-fallow cycle - 10 years (default or project specific data may be applied as preferred by PPs)
Source of data:	Questionnaire, literature or default
Measurement procedures (if any):	N/A
Any comment:	

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 project boundary is delineated for each parcel subjected to the project activity, that is, the relevant geographic coordinates are established, recorded and archived. This can be achieved by field survey (e.g. by using GPS), or by using georeferenced spatial data (e.g. maps, GIS datasets, orthorectified aerial photographs or georeferenced remote sensing images);

(b) Commonly accepted principles of forest inventory and management are implemented, that is, standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for forest inventory, including field data collection and data management, shall be applied. Use or adaptation of SOPs already applied in national forest monitoring practice, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended.

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*).

If age cohorts made of parcels planted in the same planting season are easily distinguishable, they may be grouped in age classes and treated as separate strata (or sub-strata within each stratum). Extensive grouping may increase variability and may result in increased number of sampling plots.

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 operations (e.g. cleaning, planting, thinning, harvesting, coppicing, re-replanting) that are implemented in a way that affects the existing stratification.

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

2.2 Sampling framework

To determine the sample size and allocation among strata, this methodology uses the latest version of the tool for the "Calculation of the number of sample plots for measurements within A/R CDM project activities", approved by the Board. The targeted precision level for biomass estimation within each stratum shall be ±10% of the mean at a 90% confidence level.

3. Data and parameters monitored

The following parameters should be monitored during the project activity. When applying all relevant equations provided in this methodology for the *ex ante* calculation of net anthropogenic GHG removals by sinks, PPs shall provide transparent estimates for the parameters that are monitored during the crediting period. These estimates shall be based on measured or existing published data where possible.

Data / Parameter:	A_i
Data unit:	ha
Used in equations:	11a
Description:	Area of stratum *i*
Source of data:	Monitoring of strata and stand boundaries shall be done preferably using a Geographical Information System (GIS) platform, which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data)
Measurement procedures:	Calculated using the GIS data or measured using methods used in the forest Inventory applicable at the local level
Monitoring frequency:	Following the requirements set in paragraph 32 of the "Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol"[6]
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures for forest inventory including field data collection and data management applicable in management of forests in the region containing the project area
Any comment:	Estimated *ex ante*. Measured *ex post*

[6] Decision 5/CMP.1., FCCC/KP/CMP/2005/8/Add.1, Annex, paragraph 32, page 69, <http://cdm.unfccc.int/Reference/COPMOP/08a01.pdf#page=69>.

Data / Parameter:	A_k
Data unit:	ha
Used in equations:	2
Description:	Area of land *k* that contains the “other polycultures” within boundary of the project
Source of data:	Monitoring of areas of land that contain the “other polycultures” is done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data), or applying methods used in the forest inventory applicable in the region containing the project area
Measurement procedures:	Calculated using the GIS data or measured applying methods used in the forest inventory applicable in the region containing the project area
Monitoring frequency:	At the project start
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures for forest inventory, including field data collection and data management, applicable in management of forests in the region containing the project area
Any comment:	Estimated *ex ante*. Measured *ex post*

Data / Parameter:	A_{sp}
Data unit:	ha
Used in equations:	11b
Description:	Area of individual sample plot
Source of data:	Field measurement
Measurement procedures:	Depending on shape of sample plot (e.g. circle, square, rectangle) the length of the radius or the side(s) is measured and the area is calculated using the relevant formula
Monitoring frequency:	Following the requirements set in paragraph 32 of the “Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol”[7]
QA/QC procedures:	The length of the radius or the side(s), as appropriate, is remeasured for randomly selected 5% of sample plots established each day and any differences between the measured and remeasured data are explained and corrective actions (if any) are applied before any more measurements are taken. The remeasurements shall be taken after all measurements scheduled for a day are completed in order to reveal a possible decalibration of instruments during the day
Any comment:	Estimated *ex ante*. Measured *ex post*

Data / Parameter:	*DBH*
Data unit:	cm
Used in following equations	Implicitly used in equation 12
Description:	Diameter at breast height of tree
Source of data:	Field measurements in sample plots

[7] Ibidem

Measurement procedures:	Typically measured 1.3 m above-ground. Measurement techniques and methods shall be based on commonly accepted principles of forest inventory
Monitoring frequency:	Following the requirements set in paragraph 32 of the "Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol"[8]
QA/QC procedures:	The DBH is remeasured for all living trees located on randomly selected 5% of sample plots established each day and any differences between the measured and remeasured data are explained and corrective actions (if any) are applied before any further measurements are taken. The remeasurements shall be taken after all measurements scheduled for a day are completed in order to reveal a possible decalibration of instruments during the day
Any comment:	PP may opt to measure trees girths (circumference) instead of diameters, or take measurements at heights other than breast height (130cm)

Data / Parameter:	*H*
Data unit:	M
Used in equations:	Implicitly used in equation 12
Description:	Height of tree
Source of data:	Field measurements in sample plots
Measurement procedures:	Measurement techniques and methods shall be based on commonly accepted principles of forest inventory
Monitoring frequency:	Following requirements set in paragraph 32 of the "Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol"[9]
QA/QC procedures:	The height is remeasured for all living trees located on randomly selected 5% of sample plots established each day and any differences between the measured and remeasured data are explained and corrective actions (if any) are applied before any more measurements are taken. The remeasurements shall be taken after all measurements scheduled for a day are completed in order to reveal a possible decalibration of instruments during the day
Any comment:	For *ex ante* estimations, mean *DBH* and *H* values should be estimated for tree species *j* in stratum *i*, at time *t* using a growth model or yield table that gives the expected tree dimensions as a function of tree age. *H* need not to be measured if the applied allometric equation does not require it as an entry data

Data / Parameter:	N_i
Data unit:	Tree count
Used in equations:	10
Description:	Number of living trees in stratum *i*
Source of data:	Field measurements in sample plots
Measurement procedures:	Inventory

[8] Ibidem
[9] Ibidem

Monitoring frequency:	Following the requirements set in paragraph 32 of the "Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol"[10]
QA/QC procedures:	Trees are recounted on randomly selected 5% of sample plots and any differences between the counted and recounted data are explained and corrective actions (if any) are applied before any further counting is done. The recounting shall be done after all counting scheduled for a day is completed in order to reveal possible errors during the day
Any comment:	Shall be collected only if A_i and A_{sp_i} are not used in estimation of biomass

Data / Parameter:	N_{sp_i}
Data unit:	Tree count
Used in equations:	10
Description:	Number of living trees in all sample plots in stratum *i*
Source of data:	Field measurements in sample plots
Measurement procedures:	Inventory
Monitoring frequency:	Following the requirements set in paragraph 32 of the "Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol"[11]
QA/QC procedures:	Trees are recounted on randomly selected 5% of sample plots and any differences between the counted and recounted data are explained and corrective actions (if any) are applied before any further counting is done. The recounting shall be done after all counting scheduled for a day is completed in order to reveal possible errors during the day
Any comment:	Data collected together with *DBH*

4. Conservative Approach and Uncertainties

To help reduce uncertainties in the accounting of emissions and removals**,** this methodology uses, whenever possible, the proven methods from the GPG-LULUCF, GPG-2000, and the IPCC's Revised 2006 Guidelines, as well as tools and guidance from the CDM Executive Board on conservative estimation of emissions and removals. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from, for example, biomass expansion factors (*BEFs*) or wood density, would result in uncertainties in the estimation of both baseline net GHG removals by sinks and the actual net GHG removals by sinks, especially when global default values are used.

[10] Ibidem
[11] Ibidem

It is recommended that PPs identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances should then be obtained for these key parameters, whenever possible. These values should be based on:

(a) Data from well-referenced peer-reviewed literature or other well-established published sources;[12] or

(b) National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or

(c) In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value should be briefly noted in the CDM-AR-PDD. For any data provided by an expert, the CDM-AR-PDD shall also record the expert's name, affiliation, and principal qualification as an expert (e.g. that he is a member of a country's national forest inventory technical advisory group). A one-page summary CV for each expert consulted should be included in an annex.

In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, PPs shall follow the most recent version of the "Guidelines on conservative choice and application of default data in estimation of the net anthropogenic GHG removals by sinks".

IV. REFERENCES AND ANY OTHER INFORMATION

1. References

Cairns M.A., S. Brown, E.H. Helmer and G.A. Baumgardner (1997) , Root biomass allocation in the world's upland forests. Oecologia 111: 1-11.

Cochran, W.G., "Sampling Techniques", J.W. Wiley and Sons , New York, 3rd edition, 1977.

IPCC GPG-LULUCF 2003: IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry, 2003. URL: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.htm.

IPCC Guidelines for National Greenhouse Gas Inventories, 2006. URL: <http://www.ipcc-nggip.iges.or.jp/public/2006gl/ppd.htm>.

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

History of the document

Version	Date	Nature of revision(s)
01	EB 53, Annex 11 26 March 2010	Initial adoption.
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