Methodology for Afforestation and Reforestation of Degraded Land

Version 1.1

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INTRODUCTION

The American Carbon Registry (ACR) in 2010 approved the use of the Clean Development Mechanism (CDM)-approved consolidated afforestation and reforestation baseline and monitoring methodology AR-ACM0001 Version 5.0.0, "Afforestation and reforestation of degraded land," for developing an afforestion/reforestation (AR) project for registration on ACR. See http://americancarbonregistry.org/carbon-accounting/carbon-accounting/other-accepted-methodologies. (AR-ACM0001 has since been retired by CDM and replaced by AR-ACM0003.)

In March 2011, ACR published its *Methodology for Afforestation and Reforestation of Degraded Land, v1.0*, which represented a modification to the CDM methodology with clarifications for project registration on ACR as well as the addition of harvested wood products accounting. This methodology modification was drafted by TREES Forest Carbon Consulting, using wood products accounting methods drawn from a "Methodology for Improved Forest Management through Extension of Rotation Age" developed by Winrock International for Ecotrust and approved under the Verified Carbon Standard (VCS) as VM0003. ACR wishes to thank TREES Forest Carbon Consulting for its assistance in making the first modification.

In a second modification, the U.S. Forest Service proposed adding its Forest Vegetation Simulator (FVS) as an approved tool to estimate carbon stock changes. This modification was reviewed by the ACR AFOLU Technical Committee and is published by ACR as the *Methodology for Afforestation and Reforestation of Degraded Land, v 1.1*. ACR wishes to thank the U.S. Forest Service for its assistance in making the second modification.

While new methodologies are approved through a process of public consultation and scientific peer review, methodology modifications such as these are reviewed by an independent ACR Agriculture, Forestry and Other Land Use (AFOLU) Technical Committee (see http://www.americancarbonregistry.org/carbon-accounting/acr-afolu-technical-committee). Both of the above modifications were considered by this Committee and recommended for approval. Version 1.1 was posted for public comment in June 2013.

Title page photo credits: *Lammers WESTCARB reforestation pilot*, Nicholas Martin, Winrock International; *seedling planted in burned area*, National Forest Foundation; *afforestation project in Tanzania*, Winrock International – Ecosystem Services

I. SOURCE, DEFINITIONS AND APPLICABILITY

1. Source

This methodology is a revision of CDM Methodology AR-ACM0001 to include accounting for harvested wood products, as well as the incorporation of Forest Vegetation Simulator (FVS) as an approved tool to estimate carbon stock changes. The methodology structure and text is directly adapted from these methodologies:

- AR-ACM0001, Version 5.0.0, "Afforestation and reforestation of degraded land", consolidated and published by the UNFCCC CDM Executive Board;

- VM0003 "Methodology for Improved Forest Management through Extension of Rotation Age", developed by Winrock International for Ecotrust, and approved under the Verified Carbon Standard (VCS).

- Additional text on the use of FVS, drafted by the U.S. Forest Service.

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 (note that AR-ACM0001 has since been retired by CDM and replaced by AR-ACM0003). For VM0003, please refer to http://www.v-c-s.org/vcsmethodologies.html. For Forest Vegetation Simulator, see http://www.fs.fed.us/fmsc/fvs/.

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

- Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities;

- Guidance on application of the definition of the project boundary to A/R CDM project activities;

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

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

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

- Tool for testing significance of GHG emissions in A/R CDM project activities;

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

- Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity;

- Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities.

All the above-mentioned tools, procedures, guidelines and guidance are available at: http://cdm.unfccc.int/Reference/tools and http://cdm.unfccc.int/Reference/Procedures/index.html.

Some sections of this methodology refer to the Forest Vegetation Simulator (FVS) as a tool to estimate carbon stock changes. FVS is the U.S. Forest Service's national forest growth model. The FVS software package is free and available on the internet. Please note that:

- The additional guidelines on using FVS in conjunction with this methodology, included in section IV, must be followed.

- When following this methodology, the latest version of the FVS software should always be used.

- FVS may only be used for projects located within the United States.

2. Selected baseline approach

"Existing or historical, as applicable, changes in carbon stocks in the carbon pools within the project boundary"

3. Definitions

All definitions, eligibility requirements, and other criteria of the ACR *Forest Carbon Project Standard* shall apply. This includes the definitions of "forest" and "Afforestation / Reforestation".

4. Applicability

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

The conditions under which the methodology is applicable are:

(a) The AR ACR project activity is implemented on degraded lands, which are expected to remain degraded or to continue to degrade in the absence of the project, hence the land cannot be expected to revert to a non-degraded state without human intervention.

(b) If at least a part of the project activity is implemented on organic soils, drainage of these soils is not allowed and not more than 10% of their area may be disturbed as result of soil preparation for planting.

(c) The land does not fall into wetland[1] category.

(d) Litter shall remain on site and not be removed in the AR ACR project activity.

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[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).

(e) Ploughing/ripping/scarification attributable to the AR ACR project activity, if any, is:

   (i) Done in accordance with appropriate soil conservation practices, e.g. follows the land contour; and

   (ii) Limited to the first five years from the year of initial site preparation; and

   (iii) Not repeated, if at all, within a period of 20 years.

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

Applicability condition 4(a) and the requirement to use the CDM tool for identification of degraded or degrading lands do not imply that there may be *no* remnant trees as of the project start date, or *no* natural regeneration in the baseline scenario. However, note the following:

- Remnant trees must be either excluded from the project boundary, if in patches large enough to exclude; or if individual remnant trees are present within the project boundary, these must be either included in both the baseline and project scenarios (using the guidance in II.4 and II.5) or tagged and excluded in both the baseline and project scenarios.

- Natural regeneration in the baseline scenario is expected to be minimal, such that the project lands continue to be classified as degraded or degrading. To ensure that this assumption remains valid over the Crediting Period, this methodology requires the establishment of Regeneration Monitoring Areas, outside the project boundary in areas similar to the project area but unplanted, in which baseline natural regeneration must be assessed at intervals not to exceed 10 years. See details in section III.3.

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 Proponent (PP). The AR ACR project activity may contain more than one discrete area of land. Each discrete area of land shall have a unique geographical identification.

It shall be demonstrated that each discrete area of land to be included in the boundary is eligible for an AR ACR project activity. PPs shall apply the "Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities" as approved by the Board.

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

Tables 1 and 2 shall be followed in determining the GHG assessment boundary, along with the guidance in the ACR *Forest Carbon Project Standard*, Chapter 2.[2] Exclusion of carbon pools and emission sources is allowed, subject to considerations of conservativeness and significance testing. Pools or sources may always be excluded if conservative, i.e. exclusion will tend to underestimate net GHG emission reductions/removal enhancements. Pools or sources may also be excluded if application of the most recent version of the CDM "Tool for testing significance of GHG emissions in A/R CDM project activities" leads to the conclusion that a particular pool or source is insignificant. Pools and sources deemed significant and/or selected for accounting in the baseline scenario shall also be accounted in the project scenario.

The carbon pools included in or excluded from accounting are shown in Table 1.

Table 1:   Carbon pools accounted for in the project boundary

Carbon pools	Accounted for	Justification / Explanation
Above-ground biomass	Yes	Major carbon pool subjected to project activity.
Below-ground biomass	Yes	Below-ground biomass stock is expected to increase due to the implementation of the AR

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[2] The Forest Carbon Project Standard, chapter 2, treats some GHG sources and pools as *a priori* insignificant; allows the Project Proponent to demonstrate using an approved significance-testing tool (such as the CDM tool cited above) that a particular source, sink or pool is *de minimis* per ACR definition; allows sources, sinks and pools to be excluded from accounting if exclusion is conservative, i.e. will tend to underestimate net GHG reductions; and imposes the additional rule that sources, sinks and pools that are not conservative to exclude may only be excluded if all combined sources, sinks and pools thus excluded represent less than 3% of the ex ante calculation of emission reductions/removal enhancements.

Carbon pools	Accounted for	Justification / Explanation
		ACR project activity.
Dead wood	Yes (alternatively No)	This stock may change (when compared to baseline) due to implementation of the project activity. The methodology provides an approach for accounting for this pool, but it also allows for exclusion of the dead wood carbon pool if transparent and verifiable information can be provided that carbon stocks in dead wood in the baseline scenario can be expected to decrease more or increase less, relative to the project scenario.
Litter	Yes (alternatively No)[3]	This stock may change (when compared to baseline) due to implementation of the project activity. The methodology provides an approach for accounting for this pool, but it also allows for exclusion of the litter carbon pool if transparent and verifiable information can be provided that carbon stocks in litter in the baseline scenario can be expected to decrease more or increase less, relative to the project scenario.
Soil organic carbon (SOC)	Yes (alternatively No if project implemented on organic soils)	Soil disturbance resulting from site preparation, if applied on more than 10% of the project area, may cause a temporary emission from soil carbon and therefore accounting of C stock changes in this pool is required, otherwise it is optional.
Wood products	Optional	This stock may increase (when compared to baseline) due to implementation of the project activity. The methodology provides an approach for accounting for this pool, but it allows also for exclusion of the wood products pool.

The emission sources and associated GHGs included in or excluded from accounting are shown in Table 2.

Table 2: Emission sources and GHGs included in or excluded from accounting

Sources	Gas	Included/ excluded	Justification/Explanation

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[3] Note that per the Forest Carbon Project Standard, chapter 2, litter is considered *a priori* insignificant and thus may be excluded (or optionally included).

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

2. Identification of the baseline scenario and demonstration of additionality

Project Proponents shall demonstrate additionality through the ACR three-prong test. The CDM "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities," required by ACM0001, is required; this amplifies but does not conflict with ACR's three-prong test.

3. Stratification

If the project activity area is not homogeneous, stratification should be carried out to improve the accuracy and precision of biomass estimates. Different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy of the estimates of net GHG removal by sinks. For estimation of baseline net GHG removals by sinks, or estimation of actual net GHG removals by sinks, strata should be defined on the basis of parameters that are key entry variables in any method (e.g. growth models or yield curves/tables) used to estimate changes in biomass stocks. Thus:

- **For baseline net GHG removals by sinks.** It will usually be sufficient to stratify according to area of major vegetation types because baseline removals for degraded (or degrading) land are expected to be small in comparison to project removals;

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

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

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

4. Baseline Net GHG Removals by Sinks

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

Under the applicability conditions of this methodology:

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

- If values for carbon stocks of dead wood and litter carbon pools are readily available (for example, from the Forest Vegetation Simulator) those values may be used to estimate changes in carbon stocks in the baseline scenario. If values are not readily available, it may conservatively be assumed that the sum of the changes in the carbon stocks of dead wood and litter carbon pools is zero for all strata in the baseline scenario;

- Since carbon stock in soil organic carbon (SOC) is unlikely to increase in the baseline, the change in carbon stock in SOC may be conservatively assumed to be zero for all strata in the baseline scenario.

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

$$\Delta C_{BSL} = \Delta C_{TREE\_BSL} + \Delta C_{WP\_BSL} \tag{1}$$

where:

ΔC_{BSL} Baseline net GHG removals by sinks; t CO_2-e

ΔC_{TREE_BSL} Sum of the carbon stock changes in above-ground and below-ground biomass of trees in the baseline; t CO_2-e

ΔC_{WP_BSL} Carbon stock changes in wood products in the baseline; t CO_2-e

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

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

The carbon stock changes in above-ground and below-ground tree biomass in the baseline is estimated by one of the following methods:

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

(b) $\quad \Delta C_{TREE\_BSL} = \Delta C_{TREE\_BSL\_FVS} * \dfrac{44}{12} * A_{BSL}$ **(2b)**

where:

ΔC_{TREE_BSL}	Change in carbon stock in living tree biomass in baseline; t CO_2-e
$\dfrac{44}{12}$	Ratio of molecular weights of CO_2 and carbon; dimensionless
ΔB_{TREE_BSL}	Change in biomass of living trees in baseline; t d.m.
CF_{TREE_BSL}	Carbon fraction of dry matter for tree biomass in baseline; t C t^{-1} d.m.
$\Delta C_{TREE\_BSL\_FVS}$	Change in carbon stock in living tree biomass in the baseline scenario from FVS. This is estimated by summing the Aboveground Live Total Carbon and the Belowground Live Carbon in the FVS stand carbon report and subtracting this value for the year at the start of the AR ACR project activity from the value for a future year. Units must be changed to metric tons per hectare; t C/ha
A_{BSL}	Area; ha

Change in biomass of living trees (ΔB_{TREE_BSL}) is estimated as follows:

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

where:

$\Delta B_{TREE\_BSL,t}$	Change in biomass of living trees in baseline, in year t; t d.m.
$A_{BSL,j}$	Area under trees of species or group of species j; ha
$I_{V,j,t}$	Current annual increment in stem volume of trees of species or group of species j, in year t; m^3 ha^{-1} yr^{-1}
D_j	Basic wood density for species or group of 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 or group of species j; t d.m. (t d.m.)$^{-1}$
R_{1j}	Root-shoot ratio appropriate for biomass increment for species or group of species j; t d.m. t^{-1} d.m
$B_{LOSS\_BSL,j,t}$	Loss of tree biomass of species or group of species j in year t; t d.m.
j	1, 2, 3, … tree species or group of species in the given stratum in the

baseline scenario

t 1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

If biomass increment tables are available and applicable to the species used in the project activity, these can directly be used in equation 3. Note that available data on average annual increment in the stem volume of trees ($I_{V,j,t}$) may be expressed as a <u>net</u> average annual increment (i.e. biomass loss is already allowed for) and in such a case biomass loss ($B_{LOSS\_BSL,j,t}$) shall be set to zero in equation 3 in order to avoid double counting.

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

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

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

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

$$C_{TREE\_BSL} = \frac{44}{12} * B_{TREE\_BSL} * CF_{TREE\_BSL} \qquad \qquad \textbf{(4)}$$

where

C_{TREE_BSL}	Carbon stock in living trees in the baseline at the start of the project activity; t CO$_2$-e
$\frac{44}{12}$	Ratio of molecular weights of CO$_2$ and carbon; dimensionless
B_{TREE_BSL}	Biomass of living trees in the baseline at the start of the project; t d.m.
CF_{TREE_BSL}	Carbon fraction of dry matter for tree biomass in baseline; t C t^{-1} d.m.

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

4.2.1 Estimation based on existing data

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

$$B_{TREE\_BSL} = BD_{TREE\_BSL} * A_{TREE\_BSL} \tag{5}$$

where:

B_{TREE_BSL} Biomass of living trees in the baseline at the start of the project activity; t d.m.

BD_{TREE_BSL} Tree biomass density per unit area of the project area (obtained from published literature); t d.m. ha^{-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:

$$B_{TREE\_BSL} = \frac{P_{BSL}}{P_{FOREST}} * B_{FOREST} * A_{TREE\_BSL} * (1 + R_{TREE\_BSL}) \tag{6}$$

where:

B_{TREE_BSL} Biomass of living trees in the baseline at the start of the project activity; t d.m.

P_{BSL} Parameter for living trees in the baseline at start of the project activity

P_{FOREST} The same parameter for a fully stocked forest in the region/country where the project activity is located

B_{FOREST} Biomass density of a fully stocked forest in the region/country where the project activity is located; t d.m. ha^{-1}

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

R_{TREE_BSL} Root-shoot ratio of trees in the baseline; dimensionless

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

4.2.3 Complete inventory of trees

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

$$B_{TREE\_BSL} = \sum_{i=1}^{n} B_{TREE,i}$$ (7)

where:

B_{TREE_BSL} Biomass of living trees in the baseline at the start of the project activity; t d.m.

$B_{TREE,i}$ Biomass of the ith tree as estimated from dimensional measurements; t d.m.

n Total number of living trees in the baseline at start of the project activity

4.2.4 Inventory of trees in sample plots

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

$$B_{TREE\_BSL} = \frac{A_{TREE}}{A_{TREE,p}} \sum_{p} B_{TREE,p}$$ (8)

where

B_{TREE_BSL} Biomass of living trees in the baseline at the start of the project activity; t d.m.

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

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

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

4.2.5 Estimation using the Forest Vegetation Simulator (FVS)

Under this method, the Forest Vegetation Simulator is used to estimate the carbon stock in living trees at the start of the project activity. Because carbon (rather than biomass) is estimated, the equation below is used in place of equation 4.

$$C_{TREE\_BSL} = \frac{44}{12} * C_{TREE\_BSL\_FVS} * A_{BSL}$$ (9)

where:

C_{TREE_BSL}	Carbon stock in living trees in the baseline at the start of the project activity; t CO_2-e
$C_{TREE\_BSL\_FVS}$	The carbon stock in living tree biomass in the baseline scenario from FVS. This is estimated by summing the Aboveground Live Total Carbon and the Belowground Live Carbon in the FVS stand carbon report for the year at the start of the AR ACR project. Units must be changed to metric tons per hectare; t C/ha
A_{BSL}	Area; ha
$\dfrac{44}{12}$	Ratio of molecular weights of CO_2 and carbon; dimensionless

4.3 Carbon stock in long-term wood products (ΔC_{WP_BSL})

Under the applicability conditions of this methodology, it can be assumed that there is no commercial timber produced on the degraded lands in the absence of the project activities. Carbon stock in long-term wood products can be assumed to be zero for the baseline scenario. Alternatively, the Forest Vegetation Simulator (FVS) may be used to produce a baseline stock.

Carbon stock change in wood products for commercial timber produced on degraded lands is estimated by one of the following methods:

(a) $\quad \Delta C_{WP\_BSL} = 0$ **(10a)**

(b) $\quad \Delta C_{WP\_BSL} = \dfrac{44}{12} * \Delta C_{WP\_BSL\_FVS} * A_{BSL}$ **(10b)**

where

ΔC_{WP_BSL}	Carbon stock changes in wood products in the baseline; t CO2-e
$\Delta C_{WP\_BSL\_FVS}$	The change in carbon in wood products in the baseline scenario as estimated by FVS. This is obtained from the Merchantable Carbon Stored column of the FVS harvested products carbon report and includes both the carbon still in use and sequestered in a landfill. Units must be changed to metric tons per hectare; t C/ha
A_{BSL}	Area; ha
$\dfrac{44}{12}$	Ratio of molecular weights of CO_2 and carbon; dimensionless

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:

$$\Delta C_{BSL} = 0 \qquad \textbf{(11)}$$

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 ACR project activity will be applied.

5. Actual net GHG removals by sinks

Under the applicability conditions of this methodology:

- Changes in carbon stock of above-ground and below-ground biomass of non-tree vegetation may be conservatively assumed to be zero for all strata in the project scenario. This includes changes in carbon stock of above-ground and below-ground biomass of herbaceous vegetation throughout the Crediting Period, and changes in carbon stock of above-ground and below-ground woody shrub biomass following planting.

- However, some afforestation/reforestation projects involve removal of a significant volume of shrub biomass during site preparation in order to create conditions favorable to the seedling establishment and survival. In such cases, changes in carbon stock of above-ground and below-ground biomass of woody shrub biomass must be accounted at the first verification following site preparation. PPs shall use the guidance on estimation of carbon stock and change in carbon stock in shrubs from the CDM tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities."[4]

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

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

$$\Delta C_{ACTUAL} = \Delta C_P - GHG_E \tag{12}$$

where:

ΔC_{ACTUAL} Actual net GHG removals by sinks; t CO_2-e

ΔC_P Sum of the changes the carbon stock in the selected carbon pools within the project boundary; t CO_2-e

GHG_E Increase in non-CO_2 GHG emissions within the project boundary as a result of the implementation of the AR ACR project activity; t CO_2-e

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[4] http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v3.0.0.pdf.

5.1   Estimation of changes in the carbon stocks

The verifiable changes in the carbon stock in the selected carbon pools within the project boundary are estimated using the following equation:[5]

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

where:

ΔC_P Sum of the changes in carbon stock in all selected carbon pools in stratum i, since start of the project; t CO_2-e

ΔC_t Change in carbon stock in all selected carbon pools, in year t; t C

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

44/12   Ratio of molecular weights of CO_2 and carbon; dimensionless

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

$$\Delta C_t = \sum_{i=1}^{M_{PS}} (\Delta C_{TREE,i,t} + \Delta C_{SHRUB,i,t} + \Delta C_{DW,i,t} + \Delta C_{LI,i,t} + \Delta C_{SOC,i,t} + \Delta C_{WP,i,t}) \qquad \textbf{(14)}$$

where:

ΔC_t Change in carbon stock in all selected carbon pools, in year t; t C

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

$\Delta C_{SHRUB,i,t}$ Change in carbon stock in shrub biomass within the project boundary in stratum i, in year t, calculated using the CDM tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t C

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

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

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

$\Delta C_{WP,i,t}$ Change in the wood products carbon pool for stratum i, in year t (possibly average over a monitoring period); 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 AR ACR project activity

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

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

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

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

(15)

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

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

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

(16)

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}

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

(a)   The biomass expansion factor (*BEF*) method;

(b)   The allometric equation method; and

(c)   The FVS method.

(a) BEF method

In this method, first the stem volume (the commercial volume) of standing trees is estimated. *Ex ante* estimations of stem volume are based on tree growth models and *ex post* estimations are based on field measurements. The stem volume is expanded to the above-ground tree biomass using biomass expansion factor (*BEF*) and basic wood

density (*D*). Total tree biomass is then obtained by multiplying the above-ground tree biomass by (1+*R*) where *R* is the root-shoot ratio.

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

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

Step 1 (a): *Ex ante* estimation

> (i) For each tree species or group of species under the project scenario, select a tree growth model from existing data or literature. Available growth models could be in form of yield tables, growth curves/equations, or growth simulation models. See paragraph 8 of this section for exact guidance on selecting the growth model applicable;

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

Step 1 (b): *Ex post* estimation

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

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

> (i) Select the volume tables (these could be in form of equations or curves) applicable to the tree species or group of species planted under the project. See paragraph 8 of this section for exact guidance on selecting the volume tables applicable;

> (ii) Depending on the volume tables selected in the sub-step above, measure the diameter at breast height (*DBH*) and/or tree height (*H*) of all trees in the permanent sample plots;

> (iii) Insert the above field measurements into the selected volume tables and calculate the stem volume of all trees in each sample plot.

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

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

$$C_{TREE,j,p,i} = V_{TREE,j,p,i} * D_j * BEF_{2,j} * (1+R_j) * CF_j \qquad \text{(17)}$$

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^{-1} d.m.
j	*1, 2, 3, …* tree species or group of species in the project scenario
p	*1, 2, 3, …* sample plots in stratum i
i	*1, 2, 3, …* strata in the project scenario

(b) Allometric method

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

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

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

Step 1 (a): *Ex ante* estimation

    (i)   For each tree species or group of species, select an allometric equation from existing data or literature. See paragraph 8 of this section for exact guidance on selecting the allometric equation applicable;

    (ii)   For each tree species or group of species, select a tree growth model from existing data and literature, as explained in sub-step 1(a)(i) of the *BEF* method above;

    (iii)   Obtain the diameter at breast height (*DBH*) and/or tree height (*H*) corresponding to the age of tree at a given time from the tree growth model selected above;

    (iv)   Insert the diameter at breast height (*DBH*) and/or tree height (*H*) into the allometric equation and calculate the total above-ground tree biomass per unit area according to the project planting/management plan.

Step 1 (b): *Ex post* estimation

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

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

<ol type="i">
Select an allometric equation for the tree species or group of species as described in sub-step 1(a)(i) above;

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;

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:

$$C_{TREE,j,p,i} = f_j(DBH,H) * (1 + R_j) * CF_j \qquad \text{(18)}$$

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.)$^{-1}$

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

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

j *1, 2, 3, … tree species or group of species in the project scenario*

p *1, 2, 3, … sample plots in stratum i*

i *1, 2, 3, … strata in the project scenario*

For both the BEF method and the allometric equation method

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

$$C_{TREE,i} = \frac{A_i}{A_{p,i}} \sum_{p=1}^{P_i} \sum_{j=1}^{J_i} C_{TREE,j,p,i} \qquad \text{(19)}$$

where:

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

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

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

A_i Total area of stratum i; ha

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

p 1, 2, 3, … P_i sample plots in stratum i in the project scenario

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

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

(c) FVS method

The FVS method uses the Forest Vegetation Simulator (FVS) to calculate aboveground and belowground tree biomass. For *ex ante* estimation, carbon estimates for initial and future years can be obtained from an FVS simulation done for each stratum. For *ex post* estimation, measurements from permanent sample plots can be entered into FVS and carbon estimates obtained for the year the plot data was collected with an FVS simulation for each stratum. 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". In both cases, the units for the FVS stand carbon report must be changed to metric tons per hectare.

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

$$C_{TREE,i} = A_i * C_{TREE,i\_FVS} \tag{20}$$

where:

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

C_{TREE,i_FVS} Carbon stock in trees for stratum i using FVS. This is estimated by summing the Aboveground Live Total Carbon and the Belowground Live Carbon in the FVS stand carbon report for a particular year. Units must be changed to metric tons per hectare; t C/ha

A_i Total area of stratum i; ha

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

Equation 20 when applied at two consecutive years t_1 and t_2 provides two values C_{TREE,i,t_1} and C_{TREE,i,t_2} which are then inserted in equation 15.

Note: At start of the project activity (that is for t_1=1) the baseline tree biomass is equal to initial biomass under the project, that is, the value of C_{TREE,i,t_1} in equation 15 is set equal to the baseline C stock as calculated in equation 4.

5.1.2 Dead wood (if selected in Table 1)

For *ex ante* estimates, if values for carbon stocks of dead wood are readily available (for example, from the Forest Vegetation Simulator) those values may be used. If values are not readily available, the changes in carbon stocks of dead wood shall be conservatively neglected.

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

For the *ex post* situation, the rate of change in C stock in dead wood is estimated as follows:

$$dC_{DW,i,t} = \frac{C_{DW,i,t_2} - C_{DW,i,t_1}}{T} \tag{21}$$

where:

$dC_{DW,i,t}$	Rate of change in carbon stock in dead wood in stratum *i*, for the period between year t_1 and year t_2; t C yr^{-1}
$C_{DW,i,t}$	Carbon stock of dead wood in stratum *i*, at time *t*; t C
T	Number of years between monitoring time t_2 and t_1 ($T = t_2 - t_1$); yr
i	1, 2, 3, … M_{PS} strata in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

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

$$\Delta C_{DW,i,t} = dC_{DW,i,(t_1,t_2)} * 1 year \tag{22}$$

where:

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

Carbon stock of dead wood in stratum *i*, at time *t* is estimated by one of the following methods:

(a) $C_{DW,i,t} = (B_{SDW,i,t} + B_{LDW,i,t}) * CF_{DW}$ $\tag{23a}$

(b) $C_{DW,i,t} = C_{SDW,i,t,FVS} * A_i + (B_{LDW,i,t}) * CF_{DW}$ $\tag{23b}$

where:

$C_{DW,i,t}$	Carbon stock of dead wood biomass in stratum i, at a point of time in year t; t C
$B_{SDW,i,t}$	Biomass of standing dead wood in stratum i, at a point of time in year t; t d.m.
$B_{LDW,i,t}$	Biomass of lying dead wood in stratum i, at a point of time in year t; t d.m.
CF_{DW}	Carbon fraction of dead wood biomass; dimensionless
i	1, 2, 3, … M_{PS} strata in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity
$C_{SDW,i,t,FVS}$	Carbon of standing dead wood in stratum i, in year t from FVS. This is from the Standing Dead Carbon column in the FVS stand carbon report. Units must be changed to metric tons per hectare; t C/ha
A_i	Total area of stratum i; ha

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

(1) Standing dead wood

Step 1: Standing dead trees shall be measured on permanent sample plots (established for estimating tree biomass - see paragraph 5.1.1 above) using the same criteria and monitoring frequency used for measuring living trees. The decomposed portion that corresponds to the original above-ground and below-ground biomass is discounted.

Step 2: The decomposition class of the dead tree and the diameter at breast height shall be recorded and the standing dead wood is categorized under the following four decomposition classes:

    (1)   Tree with branches and twigs that resembles a live tree (except for leaves);

    (2)   Tree with no twigs, but with persistent small and large branches;

    (3)   Tree with large branches only;

    (4)   Bole only, no branches.

Step 3a: For tree in the decomposition class 1 biomass should be estimated using the allometric equation for living trees.

Step 3b: When the bole is in decomposition classes 2, 3 or 4, it is recommended to limit the estimate of the biomass to the main trunk of the tree. Usually, there are no allometric equations applicable for such boles and their biomass is estimated based on volume assessment. The volume of dead wood is converted to biomass using the dead wood density appropriate for the decomposition class.

(2) Lying dead wood

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

Step 1: Lying dead wood should be sampled using the line intersect method (Harmon and Sexton, 1996).[6] Two 50-m lines bisecting each plot are established and the diameters of the lying dead wood (≥5 cm diameter) intersecting the lines are measured.

Step 2: The dead wood is assigned to one of the three density states ds=1 (sound), ds=2 (intermediate), and ds=3 (rotten) using the 'machete test', as recommended by IPCC Good Practice Guidance for LULUCF (2003), Section 4.3.3.5.3.

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

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

(24)

where:

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

$D_{n,i,t}$ Diameter of piece n of dead wood along the transect in stratum i, at time t; cm

N Total number of wood pieces intersecting the transect; dimensionless

L Length of the transect; m

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

t 1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

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

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

(25)

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

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

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

where:

$B_{LDW,i,t}$ Biomass of lying dead wood in stratum *i* at time *t*; t d.m.

$V_{LDW,i,t}$ Volume of lying dead wood in stratum *i*, at time *t*; m^3 ha^{-1}

$D_{DW,ds}$ Basic wood density of dead wood in the density class *ds*; t d.m. m^{-3}
     Note: To estimate density of each class, follow the procedure described in IPCC Good Practice Guidance for LULUCF (2003), Section 4.3.3.5.3.

A_i Area of stratum *i*; ha

ds   Index for density state: 1 (sound), 2 (intermediate) or 3 (rotten)

i   *1, 2, 3, … M$_{PS}$* strata in the project scenario

t   *1, 2, 3, … t** years elapsed since the start of the AR ACR project activity

5.1.3 Litter (if selected in Table 1)

For *ex ante* estimates, if values for carbon stocks of litter are readily available (for example, from the Forest Vegetation Simulator) those values may be used. If values are not readily available, the changes in carbon stocks of litter shall be conservatively neglected.

For *ex post* estimates, four litter samples shall be collected per sample plot and well mixed into one composite sample. Samples shall be taken at the same time of the year in order to account for natural and anthropogenic influences on the litter accumulation and to eliminate seasonal effects.

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

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

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

(26)

where:

$B_{LI,i,p}$ Biomass of dry litter for plot *p* in stratum *i*; t d.m. ha^{-1}

$B_{LI\_WET,i,p}$ Wet weight (field) of the litter in plot *p* of stratum *i*; kg

MP_{LI} Dry-to-wet weight ratio of the litter (dry weight/wet weight); dimensionless

$a_{i,p}$ Area of sampling frame for plot *p* in stratum *i*; m^2

i   *1, 2, 3, … M$_{PS}$* strata in the project scenario

p   Index for sample plots

The average annual rate of change in the carbon stock of litter from the data at two monitoring intervals shall be calculated. As recommended in the Good Practice Guidance on LULUCF (Chapter 3.2, p 3.35), the dry mass of litter is converted into carbon using 0.370 t C t^{-1} d.m. as a default value for the carbon fraction.[9] Thus:

$$dC_{LI,i,t} = \frac{B_{LI,i,t_2} - B_{LI,i,t_1}}{T} * CF_{LI}$$
(27)

where:

$dC_{LI,i,t}$ Rate of change in the litter carbon pool in stratum *i* (averaged over a monitoring period); t C yr^{-1}

$B_{LI,i,t}$ Biomass of litter in stratum *i* at time *t*; t d.m.

T Number of years between monitoring time t_2 and t_1 ($T = t_2 - t_1$); yr

CF_{LI} Carbon fraction of litter (default value 0.370 t C t^{-1} d.m.); t C t^{-1} d.m.

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

t 1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

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

$$\Delta C_{LI,i,t} = dC_{LI,i,(t_1,t_2)} * 1 year$$
(28)

where:

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

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

5.1.4 Soil Organic Carbon (if selected in Table 1)

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

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

$$\Delta C_{SOC,i,t} = \Delta SOC_{AL,t}$$
(29)

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[9] Smith and Heath, 2002.

where:

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

$\Delta SOC_{AL,t}$ Change in carbon stock in the SOC pool as estimated in the tool "Tool for estimation of change in soil organic carbon stocks due to the implementation of AR ACR project activities" applied to stratum *i*; t C

5.1.5 Wood Products (if selected in Table 1)

Wood products may be excluded from the project as this carbon stock is considered to be zero in the baseline scenario (see Section 4.3) and omission is thus always conservative. However, if included in the project scenario, wood products (if any) must also be included in accounting for the baseline scenario.

The change in carbon stock in wood products is estimated on the basis of harvested volume and ratios of long-term wood products of time in year t_1 and again at a point of time in year t_2 for each stratum. If harvesting boundaries extend across stratum boundaries, harvest volumes should be allocated to each stratum proportionally to the area harvested in each stratum and documentation thereof presented for verification. The rate of change of carbon stock in wood products is calculated as:

$$\Delta C_{WP,i,t} = \frac{C_{WP,i,t_2} - C_{WP,i,t_1}}{T}$$
(30)

where:

$\Delta C_{WP,i,t}$ Rate of change in long-term wood products from stratum *i*, averaged for the period between year t_1 and year t_2; t C yr^{-1}

C_{WP,i,t_2} Carbon stock in wood products from stratum *i*, up to year t_2; t C

C_{WP,i,t_1} Carbon stock in wood products from stratum *i*, up to 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

t 1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

To calculate wood products two methodologies are available. The direct (*1605b*) method is only applicable within the 48 contiguous United States and for limited vegetation types. The less direct (*Winjum et al.*) method can be applied to any vegetation types throughout the world.

5.1.5.A The 1605b method

This method calculates the carbon extracted from the start of the project to date and then calculates the proportion of that carbon sequestered long term in wood products.

Step 1: Calculate the biomass of the total volume extracted from the start of the project to date from within the project boundary with extracted timber differentiated into sawnwood

and pulpwood classes (if necessary convert volumes in ft^3 to m^3 by multiplying by 0.0283). When using the Forest Vegetation Simulator to estimate the change in carbon stock in wood products, this step can be skipped since these calculations are built into FVS.

$$EXC_{WP,i,t,s/p} = \sum_{h=1}^{H_{PS}} \sum_{j=1}^{S_{PS}} \left(V_{ex,i,h,s/p,j} * D_j * CF_j \right) \qquad \text{(31)}$$

where:

$EXC_{WP,i,t,s/p}$ The summed stock of extracted biomass carbon from stratum i up to year t by wood product disposition (sawnwood/pulpwood) s/p; t C

$V_{ex,i,h,s/p,j}$ The volume of timber extracted from stratum i during harvest h by species j and wood product disposition (sawnwood/pulpwood) s/p; m^3

D_j Basic wood density of species j; t d.m. m^{-3}

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.)

h 1, 2, 3 …H_{PS} number of harvests since the start of the AR ACR project activity up to year t

j 1, 2, 3 … S_{PS} tree species in the baseline scenario

s/p Wood product disposition – defined here as sawnwood or pulpwood

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

t 1, 2, 3, … t* years elapsed since the start of the AR ACR project activity

Step 2: Calculate the carbon in extracted timber that remains sequestered after 100 years. This can be done in one of two ways. Option (a) below uses Table 1.6 from the Forestry Appendix of the Technical Guidelines of the US Department of Energy's Voluntary Reporting of Greenhouse Gases Program (known as Section 1605b)[10]. PPs will determine the region the project is located in (using Figure 1.1 of the same document) and whether the timber is softwood or hardwood. Instead of tracking annual emissions through retirement, burning and decomposition, the methodology calculates the proportion of wood products that have not been emitted to the atmosphere 100 years after harvest and assumes that this proportion is permanently sequestered. The proportions defined as "In Use" and "Landfill" 100 years after production will be used here.

Option (b) uses the Forest Vegetation Simulator to estimate the carbon sequestered over time in extracted timber.

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[10] http://www.eia.doe.gov/oiaf/1605/Forestryappendix[1].pdf; also available as a US Forest Service General Technical Report at: http://www.fs.fed.us/ne/durham/4104/papers/ne_gtr343.pdf

$$(a) \qquad C_{WP,i,t} = \sum_{s,p}^{s/p} EXC_{WP,i,t,s/p} * 1605b \qquad (32a)$$

$$(b) \qquad C_{WP,i,t} = C_{WP,i,t,FVS} * A_i \qquad (32b)$$

where:

$C_{WP,i,t}$ Carbon stock in wood products from stratum i up to year t; t C

$EXC_{WP,i,t,s/p}$ The summed stock of extracted biomass carbon from stratum i up to year t by wood product disposition (sawnwood/pulpwood) s/p; t C

$1605b$ The proportions of extracted timber still "in use" or sequestered in a "landfill" as wood products 100 years after production from Table 1.6 of the Forestry Appendix to the Technical Guidelines; t C in products permanently sequestered t C-1 extracted biomass carbon

s/p Wood product disposition – defined here as sawnwood (s) or pulpwood (p)

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

t 1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

$C_{WP,i,t,FVS}$ The carbon in wood products from stratum i up to year t as estimated by FVS. This is obtained from the Merchantable Carbon Stored column of the FVS harvested products carbon report and includes the carbon in wood products still in use and sequestered in a landfill. Because FVS is estimating the amount of carbon currently stored for a given year, and not necessarily the amount that is permanently sequestered, values used from the FVS report should be for the year 100 years after the harvest immediately preceding year t and the simulation should not include any harvests or thinnings that are planned to occur after year t. Units must be changed to metric tons per hectare; t C/ha

A_i Total area of stratum i; ha

5.1.5.B The Winjum et al. method

Step 1: Calculate the biomass of the total volume extracted from the start of the project to date from within the project boundary (if necessary convert volumes in ft^3 to m^3 by multiplying by 0.0283):

$$EXC_{WP,i,t,ty} = \sum_{h=1}^{H_{PS}} \sum_{j=1}^{S_{PS}} \left(V_{ex,i,h,ty,j} * D_j * CF_j \right) \qquad (33)$$

where:

$EXC_{WP,i,t,ty}$ The summed stock of extracted biomass carbon from stratum i up to year t by class of wood product ty; t C

$V_{ex,i,h,ty,j}$	The volume of timber extracted from stratum i during harvest h by species j and wood product class ty; m^3
D_j	Basic wood density of species j; t d.m. m^{-3}
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.)
h	$1, 2, 3 …H_{PS}$ number of harvests since the start of the AR ACR project activity up to year t.
j	$1, 2, 3 … S_{PS}$ tree species in the baseline scenario
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other
i	$1, 2, 3, … M_{PS}$ strata in the project scenario
t	$1, 2, 3, … t^*$ years elapsed since the start of the AR ACR project activity

Step 2: Calculate the proportion of extracted timber that remains sequestered after 100 years. Instead of tracking annual emissions through retirement, burning and decomposition, the methodology calculates the proportion of wood products that have not been emitted to the atmosphere 100 years after harvest and assumes that this proportion is permanently sequestered. Default factors listed below are derived from Winjum et al.1998[11]. Alternatively, Project Proponents may use specific factors in equations 34a to 34d from local, regional or national sources that can be validated by peer-reviewed literature.

$$C_{WP,i,t} = \sum_{s,w,oir,p,o}^{ty} \left(\left(\left(EXC_{WP,i,t,ty} - WW_{i,t} \right) - SLF_{i,t} \right) - OF_{i,t} \right) \tag{34a}$$

where:

$C_{WP,i,t}$	Carbon stock in wood products from stratum i up to year t; t C
$EXC_{WP,i,t,ty}$	The summed stock of extracted biomass carbon from stratum i up to year t by class of wood product ty; t C
$WW_{i,t}$	Wood waste. The fraction of biomass extracted from stratum i up to year t immediately emitted through mill inefficiency; t C
$SLF_{i,t}$	Fraction of wood products up to year t that will be emitted to the atmosphere within 5 years of timber harvest; t C

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[11] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

$OF_{i,t}$ Fraction of wood products up to year t that will be emitted to the atmosphere between 5 and 100 years of timber harvest; t C

ty Wood product class – defined here as sawnwood (s), wood-based panels (w), other industrial roundwood (oir), paper and paper board (p), and other (o)

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

t 1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

Wood waste fraction (WW):

Winjum et al 1998 indicate that the proportion of extracted biomass that is oxidized (burning or decaying) from the production of commodities to be equal to 19% for developed countries, 24% for developing countries.

WW is therefore equal to:

$$WW_{i,t} = EXC_{WP,i,t,ty} * wf \qquad \text{(34b)}$$

where:

$WW_{i,t}$ Wood waste. The fraction of biomass extracted from stratum i up to year t immediately emitted through mill inefficiency; t C

$EXC_{WP,i,t,ty}$ The summed stock of extracted biomass carbon from stratum i up to year t by class of wood product ty; t C

ty Wood product class – defined here as sawnwood (s), wood-based panels (w), other industrial roundwood (oir), paper and paper board (p), and other (o)

wf Wood waste fraction – 0.19 for developed countries, 0.24 for developing countries; t C t C^{-1}

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

t 1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

Short-lived fraction (SLF)

Winjum et al 1998 give the following proportions for wood products with short-term (<5 yr) uses (applicable internationally):

Sawnwood	0.2
Woodbase panels	0.1
Other industrial roundwood	0.3
Paper and Paperboard	0.4

The methodology makes the assumption that all other classes of wood products are 100% oxidized within 5 years.

SLF is therefore equal to:

$$SLF_{i,t} = \left(EXC_{WP,i,t,ty} - WW_{i,t}\right) * slp \tag{34c}$$

where:

$SLF_{i,t}$ Fraction of wood products extracted from stratum i up to year t that will be emitted to the atmosphere within 5 years of timber harvest; t C

$EXC_{WP,i,t,ty}$ The summed stock of extracted biomass carbon from stratum i up to year t by class of wood product ty; t C

$WW_{i,t}$ Wood waste. The fraction of biomass extracted from stratum i up to year t immediately emitted through mill inefficiency; t C

slp Short-lived proportion - 0.2 for sawnwood, 0.1 for woodbase panels, 0.3 for other industrial roundwood, 0.4 for paper and paperboard and 1 for other; t C t C^{-1}

ty Wood product class – defined here as sawnwood (s), wood-based panels (w), other industrial roundwood (oir), paper and paper board (p), and other (o)

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

t 1, 2, 3, … t^* years elapsed since the start of the AR ACR project activity

Additional oxidized fraction (OF)

Winjum et al 1998 gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate and tropical). This methodology projects these fractions over 95 years to give the additional proportion that is oxidized between the 5th and 100th years after initial harvest (Table 3):

Table 3: Proportion of remaining wood products oxidized between 5 and 100 years after initial harvest by wood product class and forest region Wood Product Class

Wood Product Class	Boreal	Temperate	Tropical
Sawnwood	0.36	0.60	0.84
Woodbase panels	0.60	0.84	0.97
Other industrial roundwood	0.84	0.97	0.99
Paper and paperboard	0.36	0.60	0.99

OF is therefore equal to:

$$OF_{i,t} = \left(\left(EXC_{WP,i,t,ty} - WW_{i,t} \right) - SLF_{i,t} \right) * fo \qquad \textbf{(34d)}$$

where:

$OF_{i,t}$ — Fraction of wood products extracted from stratum *i* up to year *t* that will be emitted to the atmosphere between 5 and 100 years of timber harvest; t C

$EXC_{WP,i,t,ty}$ — The summed stock of extracted biomass carbon from stratum *i* up to year *t* by class of wood product *ty*; t C

$WW_{i,t}$ — Wood waste. The fraction of biomass extracted from stratum *i* up to year *t* immediately emitted through mill inefficiency; t C

$SLF_{i,t}$ — Fraction of wood products extracted from stratum *i* up to year *t* that will be emitted to the atmosphere within 5 years of timber harvest; t C

fo — Fraction oxidized – see Table 3 for defaults; t C t C^{-1}

ty — Wood product class – defined here as sawnwood (*s*), wood-based panels (*w*), other industrial roundwood (*oir*), paper and paper board (*p*), and other (*o*)

i — *1, 2, 3, … M$_{PS}$* strata in the project scenario

t — *1, 2, 3, … t** years elapsed since the start of the AR ACR project activity

5.2 Estimation of GHG emissions within the project boundary

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

$$GHG_E = \sum_{t=1}^{t^*} E_{BIOMASS\_BURN,t} \qquad \textbf{(35)}$$

where:

GHG_E — Increase in GHG emissions as a result of the implementation of the proposed AR ACR project activity within the project boundary; t CO$_2$-e

$E_{BIOMASS\_BURN,t}$ — Non-CO$_2$ emissions due to burning of biomass of existing woody vegetation as part of site preparation during the year *t*, as estimated in the tool "Estimation of GHG emissions due to clearing, burning and decay of existing vegetation attributable to a CDM A/R project activity"; t CO$_2$-e

t — *1, 2, 3, … t** years elapsed since the start of the AR ACR project activity

6. Leakage

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

$$LK = \sum_{t=1}^{t^*} LK_{AGRIC,t}$$

(36)

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*, as calculated in the tool "Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity"; t CO_2-e

7. Net anthropogenic GHG removals by sinks

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

$$C_{AR-ACR} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK$$

(37)

where:

C_{AR-ACR} — 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

In addition an uncertainty deduction, if required per the *Forest Carbon Project Standard* (i.e. if the precision target of ±10% of the mean at 90% confidence, applied to the final calculation of emission reductions/removal enhancements, is not achieved), must be applied to the result from equation 37 to give an adjusted value of C_{AR-ACR} accounting for uncertainty.

7.1 Calculation of ERTs

To estimate the ERTs at time $t^* = t_2$ (the date of verification) for the monitoring period $T = t_2 - t_1$, this methodology uses the equation provided by ACR[12], which uses a buffer pool and other approved mechanisms to mitigate the risk of reversals. ACR does not award temporary credits.

ERTs shall be calculated by applying the buffer deduction, if applicable:

$$ERT_t = \left(C_{AR-ACR,t_2} - C_{AR-ACR,t_1}\right) * \left(1 - BUF\right) \tag{38}$$

where:

ERT_t	Number of Emission Reduction Tonnes at time $t=t2-t1$
C_{AR-ACR,t_2}	Cumulative total net GHG emission reductions up to time t_2; t CO_2e
C_{AR-ACR,t_1}	Cumulative total net GHG emission reductions up to time t_1; t CO_2e
BUF	Percentage of project ERTs contributed to the ACR buffer pool, if applicable

Per the *Forest Carbon Project Standard*, *BUF* is determined using an ACR-approved risk assessment tool.[13] If the Project Proponent elects to make the buffer contribution in non-project ERTs, or elects to mitigate the assessed reversal risk using an alternate risk mitigation mechanism approved by ACR, *BUF* shall be set equal to zero.

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

In addition to the parameters listed in the tables below, the provisions on data and parameters in the tools referred to in this methodology apply.

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

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[12] ACR clarifications for AR-ACM0001 v5, available at
http://www.americancarbonregistry.org/carbon-accounting/AR-ACM0001%20v5%20clarificaitons%20for%20use%20on%20ACR.pdf
[13] As described in the ACR Standard v2.1, unless/until ACR publishes its own Tool for Risk Analysis and Buffer Determination, the Project Proponent shall use the latest version of the VCS AFOLU Non-Permanence Risk Tool, available at http://v-c-s.org/program-documents.

Data / Parameter:	$BEF_{2,j}$
Data unit:	Dimensionless
Used in equations:	17
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)[14]
Measurement procedures:	N/A
Comments:	*BEFs* in IPCC literature and national forest inventories are usually applicable to closed canopy forests. If applied to individual trees growing in open field, it is recommended that the selected BEF_2 be increased by 30%

Data / Parameter:	$BEF_{1,j}$
Data unit:	Dimensionless
Used in equations:	3
Description:	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total above-ground tree biomass increment for species j
Source of data:	(a) Local sources of species or group of species-specific data; (b) National sources of species or group of species-specific data (e.g. national forest inventory or national GHG inventory); (c) Species or group of species-specific data from neighbouring countries with similar conditions; (d) Globally available data applicable to species or group of species; (e) IPCC default values (e.g. Table 3A.1.10 of IPCC GPG-LULUCF 2003)[15]
Measurement procedures:	N/A

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

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

Comments:	*BEFs* in IPCC literature and national inventory data are usually applicable to closed canopy forest. If applied to individual trees growing in open field it is recommended that the selected *BEF* be increased by a further 30%

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

Data / Parameter:	BD_{TREE_BSL}
Data unit:	t d.m. ha^{-1}
Used in equations:	5
Description:	Tree biomass density per unit area of the project area (obtained from published literature)
Source of data:	Published data may relate to the project area or to another area similar to the project area. If published data is in terms of volume and not in terms of biomass, or the biomass data does not include the below-ground biomass, then transparent and verifiable method using suitable parameters may be used for calculating the tree biomass per unit area from the available data
Measurement procedures:	N/A

Data / Parameter:	B_{FOREST}
Data unit:	t d.m. ha^{-1}
Used in equations:	6
Description:	Default above-ground biomass content in forest in the region/country where the AR ACR project activity is located

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

Data / Parameter:	CF_j
Data unit:	t C t^{-1} d.m.
Used in equations:	17, 18
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.
Measurement procedures:	N/A

Data / Parameter:	CF_{DW}
Data unit:	t C t^{-1} d.m.
Used in equations:	23a, 23b
Description:	Carbon fraction of dry matter in dead wood biomass
Source of data:	Default value 0.5 t C t^{-1} d.m. shall be used
Measurement procedures:	N/A

Data / Parameter:	CF_{LI}
Data unit:	t C t^{-1} d.m.
Used in equations:	27
Description:	Carbon fraction of dry matter in litter biomass
Source of data:	Default value 0.37 t C t^{-1} d.m. shall be used
Measurement procedures:	N/A

Data / Parameter:	CF_{TREE_BSL}
Data unit:	t C t^{-1} d.m.
Used in equations:	2a
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
Measurement procedures:	N/A

Data / Parameter:	D_j
Data unit:	t d.m. m^{-3}
Used in equations:	3, 17
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 forest inventory or 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)
Measurement procedures:	N/A

Data / Parameter:	$D_{DW,ds}$
Data unit:	t d.m. m^{-3}
Used in equations:	25
Description:	Basic wood density of dead wood in the density state: 1 (sound), 2 (intermediate) or 3 (rotten)
Source of data:	The source of data, in order of preference, shall be any of the following: (a) National and species-specific or group of species-specific data (e.g. from national GHG inventory); (b) Species-specific or group of species-specific data from neighbouring countries with similar conditions. Sometimes (b) might be preferable to (a); (c) Globally species-specific or group of species-specific (e.g. IPCC GPG-LULUCF 2003)
Measurement procedures:	Project specific determination of the density is allowed
Comments:	

Data / Parameter:	$f_i(DBH, H)$
Data unit:	t d.m. tree^{-1}
Used in equations:	18

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)
Measurement procedures:	N/A

Data / Parameter:	$I_{V,j,t}$
Data unit:	$m^3\ ha^{-1}\ yr^{-1}$
Used in equations:	3
Description:	Average annual increment in stem volume of species *j*, in year *t*
Source of data:	The source of data, in order of preference, shall be the following: (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
Measurement procedures:	N/A
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:	$OF_{i,t}, SLF_{i,t}, WW_{i,t}$
Data unit:	t C

Used in equations:	34a – 34d
Description:	$OF_{i,t}$ = Fraction of wood products extracted from stratum i up to year t that will be emitted to the atmosphere between 5 and 100 years after production; $SLF_{i,t}$ = Fraction of wood products extracted from stratum i up to year t that will be emitted to the atmosphere within 5 years of production; $WW_{i,t}$ = Fraction of biomass extracted from stratum i up to year t effectively emitted to the atmosphere during production.
Source of data:	The source of the data is the published paper of Winjum et al. 1998: Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284
Measurement procedures:	N/A

Data / Parameter:	R_j
Data unit:	Dimensionless
Used in equations:	17, 18
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]
Measurement procedures:	N/A

Data / Parameter:	R_{1j}
Data unit:	kg d.m.yr^{-1} (kg d.m.yr^{-1})$^{-1}$
Used in equations:	3
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
Measurement procedures:	N/A
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:	R_{TREE_BSL}
Data unit:	Dimensionless
Used in equations:	6
Description:	Root-shoot ratio for the trees in the baseline
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_{TREE_BSL} 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]
Measurement procedures:	N/A

Data / Parameter:	$V_{TREE,j,p,i}$
Data unit:	m^3
Used in equations:	17
Description:	Stem volume of trees of species or group of species *j* in plot *p* in stratum *i*
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
Measurement procedures:	N/A
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. If such age-diameter curves are not available then average growing stock values from Table 3A.1.4 of IPCC GPG-LULUCF 2003 may be multiplied by the fractional value of estimated crown cover of trees. For example, if crown cover of trees is estimated as 10% and the project is located in Cameroon (growing stock volume of 135 m^3/ha), then the stem volume of trees may be estimated as 0.10×135 = 13.50 m^3/ha

Data / Parameter:	$1605b$
Data unit:	Dimensionless
Used in equations:	32a
Description:	Proportion of wood products still "in use" 100 years after production

Source of data:	The source is the Forestry Appendix of US Department of Energy's Technical Guidelines for The Voluntary Reporting of Greenhouse Gas Program (Section 1605b): http://www.eia.doe.gov/oiaf/1605/Forestryappendix[1].pdf; also available as a US Forest Service General Technical Report at: http://www.fs.fed.us/ne/durham/4104/papers/ne_gtr343.pdf
Measurement procedures:	N/A

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 GHG Project Plan, 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 GHG Project Plan an *ex ante* stratification of the project area or justify the lack of it. The number and boundaries of the strata defined *ex ante* may change during the crediting period (*ex post*).

2.1 Updating of strata

The *ex post* stratification shall be updated because of the following reasons:

- Unexpected disturbances occurring during the crediting period (e.g. due to fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;

- Forest management activities (cleaning, planting, thinning, harvesting, coppicing, re-replanting) that are implemented in a way that affects the existing stratification.

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

2.2 Precision requirements

The targeted precision level for biomass estimation shall be ±10% of the mean at a 90% confidence level. Given the correlation between biomass and volume, assessing the precision level with a confidence interval for cubic foot volume is sufficient. 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. Regeneration Monitoring Areas

To ensure that the natural (without planting) regeneration rates assumed in the baseline scenario remain valid over the Crediting Period, the Project Proponent shall establish a Regeneration Monitoring Area for each of the strata in the project. Each Regeneration Monitoring Area must be at least 1/4 hectare in size and must be designated outside the project boundary in an area similar to the project area in soil type, slope, aspect, and distance to seed sources. Regeneration Monitoring Areas should be near the project area, but it is suggested they be located far enough away to avoid regeneration due to seeds from the trees planted in the project area.

Each Regeneration Monitoring Area must be examined close to the project start date to determine initial regeneration values. Each Regeneration Monitoring Area must then be re-assessed at intervals not to exceed ten (10) years for the duration of the Crediting Period.

At each re-assessment, regeneration (number of seedlings per hectare) in the Regeneration Monitoring Areas shall be compared to the regeneration assumptions used for the baseline to determine whether the number of seedlings per hectare varies significantly from assumptions. If the observed number of seedlings per hectare exceeds the baseline estimate by more than 10% and by more than 10 trees per hectare, the baseline scenario (including the baseline scenario simulated by FVS, if used) must be modified to better reflect the observed values.

Note that although the required reassessment of natural regeneration based on Regeneration Monitoring Areas may require revision of the baseline regeneration assumptions, this only applies to the current and future calculation of net emission reductions. Baseline revisions will not be applied retroactively to credits already verified and issued in earlier years.

4. Data and parameters monitored

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

Data / Parameter:	A_i
Data unit:	ha
Used in equations:	19, 25
Description:	Area of tree biomass stratum i
Source of data:	Monitoring of strata and stand boundaries shall be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data)
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

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

Data / Parameter:	$a_{i,p}$
Data unit:	m^2
Used in equations:	26
Description:	Area of sampling frame for plot p in stratum i
Source of data:	Simple measurement or manufacturer's data
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III
Comments:	Once selected, the size of the sampling frame shall be fixed until the end of the last crediting period

Data / Parameter:	$A_{p,i}$
Data unit:	ha
Used in equations:	19
Description:	Total area of all sample plots in stratum i

Source of data:	Field measurement
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	$B_{LI\_WET,i,p}$
Data unit:	kg
Used in equations:	26
Description:	Wet weight (field) of the litter in plot *p* of stratum *i*
Source of data:	Field measurements in sample plots
Measurement procedures:	Step 1: Litter shall be sampled using a sampling frame. The frame is placed at four locations within the sample plot. Step 2: At each location, all litter (leaves, fruits, small wood, etc.) falling inside the frame shall be collected and the litter from four locations is mixed to get a representative sample for measuring the wet weight of the biomass
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	$D_{n,i,t}$
Data unit:	cm
Used in equations:	24
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*, at time *t*
Source of data:	Field measurements in sample plots
Measurement procedures:	Lying dead wood should be sampled using the line intersect method (Harmon and Sexton, 1996).[16] Two 50-m lines bisecting each plot are established, and the diameters of the lying dead wood (≥5 cm diameter) intersecting the lines are measured
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	*DBH*

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

Data unit:	inch/cm or any unit of length used in the model or data source used
Used in equations:	Implicitly used in equation 17, 18
Description:	Usually the diameter at breast height of the tree; but it could be any other diameter or dimensional measurement used in the model or data source used, e.g. basal diameter, root-collar diameter, basal area, etc.
Source of data:	Field measurements in sample plots. For *ex ante* estimations, *DBH* values should be estimated using a growth curve, a growth model, or a yield table that gives the expected tree dimensions as a function of tree age
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	H
Data unit:	m or any other unit of length
Used in equations:	Implicitly used in equation 17, 18
Description:	Height of tree
Source of data:	Field measurements in sample plots. For *ex ante* estimations, *H* values should be estimated using a growth curve, a growth model, or a yield table that gives the expected tree dimensions as a function of tree age
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III
Comments:	Models used may be based on units of length other than metre (e.g. feet), in which case the appropriate unit of length only should be used

Data / Parameter:	L
Data unit:	m
Used in equations:	24
Description:	Length of the transect to determine volume of lying dead wood
Source of data:	Field measurements
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	MP_{LI}
Data unit:	Dimensionless
Used in equations:	26
Description:	Dry-to-wet weight ratio of the litter (dry weight/wet weight)
Source of data:	Laboratory measurement of field samples
Measurement procedures:	Litter samples shall be collected and well mixed into one composite sample at the same time of year in order to account for natural and anthropogenic influences on the litter accumulation and to eliminate seasonal effects. A subsample from the composite sample of litter is taken, oven dried and weighed to determine the dry weight
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	N
Data unit:	Dimensionless
Used in equations:	24
Description:	Total number of wood pieces intersecting the transect
Source of data:	Field measurements
Measurement procedures:	See paragraph 1(b) of Section III
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	See paragraph 1(b) of Section III

Data / Parameter:	T
Data unit:	Year
Used in equations:	15, 21, 27
Description:	Time period elapsed between two successive estimations of carbon stock in a carbon pool
Source of data:	Recorded time
Measurement procedures:	N/A
Comments:	If the two successive estimations of carbon stock in a carbon pool are carried out at different points of time in year t_2 and t_1, (e.g. in the month of April in year t_1 and in the month of September in year t_2), then a fractional value shall be assigned to T

5. Conservative approach and uncertainties

While applying this methodology, PPs shall ensure that "Guidelines on conservative choice and application of default data in estimation of the net anthropogenic GHG removals by sinks"[17] are followed for addressing uncertainty.

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

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[17] See http://cdm.unfccc.int/Reference/Guidclarif/ar/methAR_guid26.pdf.

IV. ESTIMATES USING THE FOREST VEGETATION SIMULATOR (FVS)

Some sections of this methodology refer to the Forest Vegetation Simulator (FVS) as a tool to estimate carbon stock changes. FVS is the U.S. Forest Service's (USFS) national forest growth model. The FVS software package is free and available on the internet (http://www.fs.fed.us/fmsc/fvs/).

When following this methodology, the version of the FVS software used shall always be at least as recent as the version available at the project start date. If a model user would like to update their FVS software mid-project, this is acceptable as long as consistency is maintained; in this case both the baseline and project calculations must be done with the updated software.

Care and attention to detail must be exercised when using FVS with this methodology. To ensure the best estimates possible, Project Proponents shall follow these guidelines:

1. FVS may only be used for projects located within the United States, and only using variants maintained by the FVS staff. Variants for outside the U.S. are available, but are not maintained by the USFS. As a result, USFS cannot verify the biomass and carbon calculation methods used in those variants.

2. Select the appropriate geographic variant of FVS. A map and associated GIS shapefiles depicting the suggested FVS variants are available on the FVS website (http://www.fs.fed.us/fmsc/fvs/whatis/index.shtml). If an FVS variant other than the one suggested by the variant map is used, the reasoning behind this substitution must be documented.

3. Use current inventory data for model projections. Inventory data older than 10 years may not be used to estimate current carbon stocks.

4. Provide as much information with the input data set as possible. As an example, FVS variants often use variables such as slope, aspect, elevation, and a measure of site quality (e.g., site index, habitat type, or plant association) to estimate forest growth over time. Provide this information wherever possible to help ensure accurate predictions. The information relevant to the selected variant is described in the variant overview document available from the FVS website. It is highly recommended that site index or other measures of site quality used by the variant are included as input in FVS simulations. Also, measured growth data (e.g., large tree diameter growth and small tree height growth) can be used to calibrate the growth estimates built into each variant. Including growth sample measurements with simulations will improve model results. Tree records for species not modelled within a specific variant are mapped within FVS to a similar species. If model users change the species designation on input (and hence create their own personally designated species mapping), the reasoning behind this substitution must be documented.

5. Be aware of how regeneration is being handled with the variant. Some variants have a full-regeneration model, where regeneration is predicted and added to the model over time. Other variants have a partial-regeneration model that adds in sprouts after fire or harvest, but does not automatically include any other types of regeneration. Understand what the model is doing so you can adjust or add additional regeneration as needed. In addition, the assumptions about baseline regeneration used in FVS must be evaluated through the periodic assessment of Regeneration Monitoring Areas as described in section III.3.

6. Describe which biomass calculation method was selected for the simulations. The FFE method (the default) is the preferred method as it uses more localized volume/biomass equations for each variant and uses species-specific lbs/cubic foot conversion factors. A full description can be found in the FVS Fire and Fuels Extension Guide[19]. The Jenkins' equations, a national set of equations that predict biomass based on species group and dbh, may only be used if it can be demonstrated to the validation/verification body that these are more accurate than the FFE method for the project area.

7. Identical settings and model assumptions shall be used to compare project conditions or multiple projects. As an example, make sure the units selected for the carbon calculations are metric tons of carbon/hectare for all simulations. If biomass is calculated using the FFE method, then this method shall be used for all conditions and projects. Similarly, if regeneration has been adjusted, then appropriate adjustments shall be made for all conditions and projects.

8. Provide the FVS keyword file (*.key), FVS main output file (*.out) as well as the input data files for review by ACR and/or the validation/verification body.

For additional information about FVS and its carbon calculations, see the Essential FVS Guide[18] and the FVS Fire and Fuels Extension Guide[19]. Variant overviews that describe each individual geographic variant are also available on the FVS website.

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[18] Dixon, Gary E. comp. 2002. Essential FVS: A user's guide to the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 226p. (http://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf)

[19] Rebain, Stephanie A. comp. 2010 . The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 396p. (http://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/FFEguide.pdf).

V. REFERENCES AND ANY OTHER INFORMATION

All references are quoted in footnotes.

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History of the document

Version	Date	Nature of revision(s)
1.1	12 June 2013	Modification, adding Forest Vegetation Simulator (FVS) as an approved tool to estimate carbon stock changes, following approval by ACR AFOLU Technical Committee.
1.0	08 March 2011	Initial adoption under ACR, following approval by ACR AFOLU Technical Committee.
AR-ACM0001 v05.0.0	EB56, Annex 12 17 September 2010	Adoption by the CDM Executive Board of version 5.0.0 of methodology AR-ACM0001, "Afforestation and reforestation of degraded land," on which the ACR methodology is based.