

PLAN  VIVO

PV Climate Tool

PT#WB

Estimation of Change in Woody Biomass

Version 1.0

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Developed by:

The Landscapes and Livelihoods Group
(TLLG) www.landscapesandlivelihoods.com
and Natural State www.naturalstate.org

Lead Author: Nicholas Berry
(nick@landscapesandlivelihoods.com)

Contributors: Jenny Langan-Farmer

Approved by:

Enter details of the Methodology Approval Panel
(MAP) members who approved the module/tool.

Contents

- 1 Summary..... 3
- 2 Sources..... 3
- 3 Definitions..... 4
- 4 Applicability Conditions..... 4
- 5 Procedures..... 4
 - 5.1 Estimating Change in Carbon Stock in Trees Between Two Points in Time 4
 - 5.1.1 Difference of Two Independent Stock Estimates..... 5
 - 5.1.2 Direct Estimation of Change by Remeasurement of Sample Plots..... 5
 - 5.2 Estimating Carbon Stock in Trees at a Point in Time..... 7
 - 5.2.1 Stratified Random Sampling 7
 - 5.2.2 Double Sampling..... 8
 - 5.2.3 Calculation of Average Tree Biomass Carbon Stock in Control Areas..... 9
 - 5.3 Estimating Change in Carbon Stock in Shrubs Between Two Points in Time 10
 - 5.4 Estimating Carbon Stock in Shrubs at a Point in Time..... 10
 - 5.4.1 Calculation of Average Shrub Biomass Carbon Stock in Control Areas..... 11
 - 5.5 Uncertainty..... 12
- 6 Parameters..... 13
- 7 References..... 21

1 Summary

This tool is part of the PV Climate *Agriculture and Forestry Carbon Benefit Assessment Methodology* (**PM001**), and is applied within Module **PU001** *Estimation of baseline and project GHG removals by carbon pools in Plan Vivo projects*. It provides procedures for estimating changes in woody biomass carbon stocks in PV Climate project areas under baseline and project scenarios. Procedures include using stratified random sampling or double sampling of woody biomass to determine values for the following parameters that are used to estimate baseline and project removals in non-woody biomass following **PU001**:

$C_{TREE_{BSL,t2,i}}$ Average carbon stock in tree biomass in the control plots for baseline scenario stratum *i* in year *t2* (t CO₂e/ha; see Section 5.2.3)

$C_{TREE_{BSL,t1,i}}$ Average carbon stock in tree biomass in the control plots for baseline scenario stratum *i* in year *t1* (t CO₂e/ha; see Section 5.2.3)

$C_{SHRUB_{BSL,t2,i}}$ Average carbon stock in shrub biomass in the control plots for baseline scenario stratum *i* in year *t2* (t CO₂e; see Section 5.4.1)

$C_{SHRUB_{BSL,t1,i}}$ Average carbon stock in shrub biomass in the control plots for baseline scenario stratum *i* in year *t1* (t CO₂e; see Section 5.4.1)

$\Delta C_{TREE_PROJ,t}$ Change in carbon stock in tree biomass under the project scenario within the project area in year *t* (t CO₂e; see Section 5.1)

$\Delta C_{SHRUB_PROJ,t}$ Change in carbon stock in shrub biomass under the project scenario within the project area in year *t* (t CO₂e; see Section 5.3)

The tool is applicable globally to project areas in cropland, grassland, shrubland, savanna, woodland, and forestland; and project interventions that increase carbon stored in woody biomass.

Compliance with the relevant methodology requirements is summarised in Appendix 2.

2 Sources

Procedures applied in the tool are derived from the following sources:

AR-TOOL14 Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities, Version 4.2.

3 Definitions

The tool follows all definitions in the latest versions of the PV Climate Glossary, **PM001** and **PU001**, and the following:

Species - can also refer to a species group when a species-specific biometric parameter (e.g. biomass expansion factor), or a model (e.g. allometric equation), is demonstrated to be applicable to more than one species

Tree biomass - refers to above-ground and below-ground living biomass of trees

Shrub biomass - refers to above-ground and below-ground living biomass of shrubs

Plot biomass - refers to tree biomass per hectare in a plot

Measurement of a sample plot - refers to the measurement of one or more dimensions (e.g. diameter) of the trees in a sample plot, or measurement of a plot parameter (e.g. basal area per hectare), and conversion of the measured tree dimensions, or the measured plot parameter into plot biomass by using one of the methods provided in Appendix 1

Conservative value of a parameter - refers to the value which, when used in calculations, is more likely to result in underestimation rather than overestimation of carbon benefits

4 Applicability Conditions

The tool is applicable globally to project areas and project interventions that meet applicability conditions of **PM001** and **PU001**.

5 Procedures

5.1 Estimating Change in Carbon Stock in Trees Between Two Points in Time

Change in carbon stock in trees in a year (annual change) between two successive monitoring events is estimated on the assumption of linear change. Change in carbon stock in trees in a year in the project scenario is estimated with Equation 1.

$$\Delta C_{TREE_PROJ,t} = \frac{\Delta C_{TREE}}{T}$$

Equation 1

Where:

$\Delta C_{TREE_PROJ,t}$ Change in carbon stock in tree biomass under the project scenario within the project area in year t (t CO₂e; see Equation 1)

ΔC_{TREE} Change in carbon stock in tree biomass within the project area in time period T (t CO₂e; see Sections 5.1.1 and 5.1.2)

T Time elapsed between two successive estimations ($T=t2 - t1$; years). Note that the value of T does not have to be a whole number (e.g. an interval of 4 years and 5 months implies $T= 4.417$ years).

Change in carbon stock in tree biomass (ΔC_{TREE}) can be estimated from the difference of two-independent stock estimates (see Section 5.1.1) or direct estimation of change by re-measurement of sample plots (see Section 5.1.2).

5.1.1 Difference of Two Independent Stock Estimates

Under this method, change in carbon stock in trees is estimated as the difference between two successive and independent carbon stock estimations.

This method is efficient when the correlation between the plot biomass values on the two occasions is absent or weak (e.g. when there has been harvest or disturbance in a stratum after the first estimation, resulting in spatial re-distribution of tree biomass in the stratum). Under this method, the change in aboveground carbon stock in trees is estimated with Equation 2.

$$\Delta C_{TREE} = C_{TREE,t2} - C_{TREE,t1}$$

Equation 2

Where:

ΔC_{TREE} Change in carbon stock in tree biomass within the project area in time period T (t CO₂e; see Equation 2)

$C_{TREE,t1}$ Aboveground carbon stock in trees as estimated at time $t1$ (t CO₂e; see Section 5.2)

$C_{TREE,t2}$ Aboveground carbon stock in trees as estimated at time $t2$ (t CO₂e; see Section 5.2)

5.1.2 Direct Estimation of Change by Remeasurement of Sample Plots

Under this method, the same sample plots are measured on two successive occasions, and the plot-level change in biomass is obtained by subtracting the plot biomass on the first occasion from the plot biomass on the second occasion.

This method is efficient when there is a significant correlation between the plot biomass values on the two occasions (e.g. when there has been no harvest or disturbance in a stratum and therefore no significant spatial re-distribution of biomass has occurred in the stratum after the first estimation).

Under this method, the change in carbon stock is estimated as follows:

$$\Delta C_{TREE} = \frac{44}{12} \times CF_{TREE} \times \Delta B_{TREE}$$

Equation 3

$$\Delta B_{TREE} = A \times \Delta b_{TREE}$$

Equation 4

$$\Delta b_{TREE} = \sum_{i=1}^M w_i \times \Delta b_{TREE_i}$$

Equation 5

$$\Delta b_{TREE_i} = \frac{\sum_{p=1}^{n_i} \Delta b_{TREE_{p,i}}}{n_i}$$

Equation 6

$$\Delta b_{TREE_{p,i}} = b_{TREE_{p,i,t2}} - b_{TREE_{p,i,t1}}$$

Equation 7

Where:

ΔC_{TREE} Change in carbon stock in tree biomass within the project area in time period T (t CO₂e; see Equation 3)

CF_{TREE} Carbon fraction of tree biomass (t C/t d.m; a default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value)

ΔB_{TREE} Change in tree biomass within the biomass estimation strata (t d.m.; see Equation 4)

A Sum of areas of the biomass estimation strata (ha)

Δb_{TREE}	Mean change in tree biomass per hectare within the biomass estimation strata (t d.m./ha; see Equation 5)
w_i	Ratio of the area of stratum i to the sum of areas of tree biomass estimation strata (i.e. $w_i = A_i/A$; dimensionless)
Δb_{TREE_i}	Mean change in carbon stock per hectare in tree biomass in stratum i (t d.m./ha; see Equation 6)
$\Delta b_{TREE_{p,i}}$	Change in tree biomass per hectare in plot p in stratum i (t d.m./ha; see Equation 7)
$b_{TREE_{p,i,t2}}$	Tree biomass per hectare in plot p in stratum i at time $t2$ (t d.m./ha; see Annex 1)
$b_{TREE_{p,i,t1}}$	Tree biomass per hectare in plot p in stratum i at time $t1$ (t d.m./ha; see Annex 1)
M	Total number of tree biomass estimation strata
n_i	Number of sample plots, in stratum i in which tree biomass was re-measured (see Annex 1)
$\frac{44}{12}$	Molar mass of CO ₂ used to convert to tCO ₂ e (unitless)

5.2 Estimating Carbon Stock in Trees at a Point in Time

Carbon stock in trees at a point in time ($C_{TREE,t}$) can be estimated by measurement of sample plots, using one of the following approaches:

- Stratified random sampling (see Section 5.2.1); or
- Double sampling (see Section 5.2.2).

5.2.1 Stratified Random Sampling

Under this method, random sample plots are installed in the strata (e.g. systematic sampling with a random start) and measured. Carbon stock in trees within the tree biomass estimation are estimated as follows (all time-dependent quantities relate to the time of measurement):

$$C_{TREE} = \frac{44}{12} \times C_{F_{TREE}} \times B_{TREE}$$

Equation 8

$$B_{TREE} = A \times b_{TREE}$$

Equation 9

$$b_{TREE} = \sum_{i=1}^M w_i \times b_{TREE,i}$$

Equation 10

$$b_{TREE,i} = \frac{\sum_{p=1}^{n_i} b_{TREE,p,i}}{n_i}$$

Equation 11

Where:

C_{TREE} Carbon stock in trees in the tree biomass estimation strata (t CO₂e; see Equation 8)

CF_{TREE} Carbon fraction of tree biomass (t C /t d.m; a default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value)

B_{TREE} Aboveground tree biomass in the tree biomass estimation strata (t d.m.; see Equation 9)

A Sum of areas of the tree biomass estimation strata (ha)

b_{TREE} Mean tree biomass per hectare in the tree biomass estimation strata (t d.m./ha; see Equation 10)

w_i Ratio of the area of stratum i to the sum of areas of tree biomass estimation strata (i.e. $w_i = A_i/A$; dimensionless)

$b_{TREE,i}$ Mean tree biomass per hectare in stratum i (t d.m./ha; see Equation 11)

$b_{TREE,p,i}$ Tree biomass per hectare in plot p of stratum i (t d.m./ha; see Annex 1)

n_i Number of sample plots in stratum i (see Annex 1)

$\frac{44}{12}$ Molar mass of CO₂ used to convert to tCO₂e (unitless)

5.2.2 Double Sampling

Under this method, a secondary variable is measured in all the sample plots in a stratum and tree biomass is measured in a sub-set of the same sample plots. The mean biomass is estimated from the measured plot biomass values in the sub-sample and adjusted through regression of the plot biomass values against the observed plot values of the secondary variable in the sub-sample.

This method is applicable only if there is a linear relationship between the plot biomass values and the plot values of the secondary variable (i.e. the best-fit curve is a straight line) within the range of the values. Examples of secondary variables that may be linearly related to tree biomass include in-situ measurements such as basal area and metrics derived from remote sensing data such as Normalized Difference Vegetation Index (NDVI) or canopy height.

To calculate the carbon stock in above ground tree biomass, Equation 8 to Equation 10 are applied, but Equation 11 for calculating mean tree biomass per hectare in a stratum is replaced with Equation 12.

$$b_{TREE,i} = \frac{\sum_{p=1}^{n_i} b_{TREE,p,i}}{n_i} + \beta \times (\bar{x}' - \bar{x})$$

Equation 12

Where:

$b_{TREE,i}$	Mean tree biomass per hectare in stratum i (t d.m./ha; see Equation 12)
$b_{TREE,p,i}$	Tree biomass per hectare in stratum i (t d.m./ha; see Annex 1)
n_i	Number of sample plots in the sub-sample
β	Slope of the regression line of tree biomass per hectare in a sample plot against the secondary variable value of the plot
\bar{x}'	Mean value of the secondary variable across all the sample plots
\bar{x}	Mean value of the secondary variable across the sub-sample of sample plots in which tree biomass is also measured

5.2.3 Calculation of Average Tree Biomass Carbon Stock in Control Areas

When estimating tree biomass carbon stocks in control areas, average carbon stock in tree biomass in each baseline scenario stratum at a point in time is calculated with Equation 13.

$$C_{TREE_{BSL,t,i}} = \frac{44}{12} \times CF_{TREE} \times b_{TREE,i}$$

Equation 13

Where:

$C_{TREE_{BSL,t,i}}$	Average carbon stock in tree biomass in the control plots for baseline scenario stratum i in year t (t CO ₂ e/ha; see Equation 13)
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CF_{TREE} Carbon fraction of tree biomass (t C /t d.m; a default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value)

$b_{TREE,i}$ Mean tree biomass per hectare in stratum i (t d.m./ha; see Equation 11 or Equation 12)

5.3 Estimating Change in Carbon Stock in Shrubs Between Two Points in Time

Change in carbon stock in shrubs in a year (annual change) between two successive monitoring events is estimated on the assumption of linear change. Change in carbon stock in shrubs in a year in the project scenario is estimated with Equation 14.

$$\Delta C_{SHRUB_PROJ,t} = \frac{C_{SHRUB,t2} - C_{SHRUB,t1}}{T}$$

Equation 14

Where:

$\Delta C_{SHRUB_PROJ,t}$ Change in carbon stock in shrub biomass under the project scenario within the project area in year t (t CO₂e; see Equation 14)

$C_{SHRUB,t2}$ Carbon stock in shrubs within the project area at time $t2$ (t CO₂e; see Section 5.4)

$C_{SHRUB,t1}$ Carbon stock in shrubs within the project area at time $t1$ (t CO₂e; see Section 5.4)

T Time between $t1$ and $t2$ (years)

5.4 Estimating Carbon Stock in Shrubs at a Point in Time

Carbon stock in shrubs at a point in time is estimated on the basis of shrub crown cover. The area within the project boundary is stratified by shrub crown cover. Those areas where the shrub crown cover is less than 5 per cent are treated as a single stratum, and the shrub biomass in this stratum is estimated as zero.

For the strata with a shrub crown cover of greater than 5 per cent, carbon stock in shrubs is estimated as follows:

$$C_{SHRUB,t} = \frac{44}{12} \times CF_S \times (1 + R_S) \times \sum_i A_{SHRUB,i} \times b_{SHRUB,i}$$

Equation 15

$$b_{SHRUB,i} = BDR_{SF} \times b_{FOREST} \times CC_{SHRUB,i}$$

Equation 16

Where:

$C_{SHRUB,t}$ Carbon stock in shrubs within the project area at a given point of time in year t (t CO₂e; see Equation 15)

CF_S Carbon fraction of shrub biomass (t C/t.d.m.). A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value.

R_S Root-shoot ratio for shrubs (dimensionless). The default value of 0.40 is used unless transparent and verifiable information can be provided to justify a different value.

$A_{SHRUB,i}$ Area of shrub biomass estimation stratum i (ha)

$b_{SHRUB,i}$ Shrub biomass per hectare in shrub biomass estimation stratum i , (t d.m./ha; see Equation 16)

BDR_{SF} Ratio of shrub biomass per hectare in land having a shrub crown cover of 1.0 (i.e. 100 per cent) and the default above-ground biomass content per hectare in forest in the region/country where the project is located (dimensionless). A default value of 0.10 should be used unless transparent and verifiable information can be provided to justify a different value.

b_{FOREST} Default above-ground biomass content in forest in the region/country where the project is located (t d.m./ha). Values from Table 3A.1.4 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values.

$CC_{SHRUB,i}$ Crown cover of shrubs in shrub biomass estimation stratum i at the time of estimation, expressed as a fraction (e.g. 10 per cent crown cover implies = 0.10; dimensionless)

5.4.1 Calculation of Average Shrub Biomass Carbon Stock in Control Areas

When estimating shrub biomass carbon stocks in control areas, average carbon stock in shrub biomass in each baseline scenario stratum at a point in time is calculated with Equation 17.

$$C_{SHRUB_{BSL,t,i}} = \frac{44}{12} \times CF_S \times b_{SHRUB,i}$$

Where:

$C_{SHRUB_{BSL,t,i}}$ Average carbon stock in shrub biomass in the control plots for baseline scenario stratum i in year t (t CO₂e; see Equation 17)

CF_S Carbon fraction of shrub biomass (t C/t.d.m). A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value.

$b_{SHRUB,i}$ Shrub biomass per hectare in shrub biomass estimation stratum i ; (t d.m./ha; see Equation 16)

5.5 Uncertainty

Uncertainty calculations depend on the approach used to estimate the woody biomass carbon stocks and carbon stock changes:

- Where sampling approaches are used, uncertainty must account for sampling error following the procedures in **PU005** Section 5.1.1. Measurement error is assumed to be zero provided QA/QC procedures in field procedures are applied.
- Where double sampling is used, uncertainty must account for model error following the procedures in **PU005** Section 5.1.2. Percentage uncertainty of the estimate of carbon stock in trees in the tree biomass estimation strata is calculated as follows:

$$U_{C_{TREE}} = \frac{t_{VAL} \times \sqrt{\sum_{i=1}^M w_i^2 \times \frac{s_i^2}{n_i}}}{b_{TREE}}$$

Equation 18

$$s_i^2 = \frac{n_i \times \sum_{p=1}^{n_i} b_{TREE,p,i}^2 - (\sum_{p=1}^{n_i} b_{TREE,p,i})^2}{n_i \times (n_i - 1)} \times (1 - (1 - \alpha) \times \rho^2)$$

Equation 19

Where:

$U_{C_{TREE}}$ Uncertainty in C_{TREE} at a 90% confidence level (dimensionless; see Equation 18)

t_{VAL} Two-sided Student's t-value for a confidence level of 90 per cent and degrees of freedom equal to $n - M$, where n is total number of sample plots within the tree biomass estimation strata and M is the total number of tree biomass estimation strata

w_i Ratio of the area of stratum i to the sum of areas of tree biomass estimation strata (i.e. $w_i = A_i/A$; dimensionless)

s_i^2 Variance of tree biomass per hectare across all sample plots in stratum i ((t d.m./ha)²; see Equation 19)

n_i Number of sample plots in stratum i

b_{TREE} Mean tree biomass per hectare in the tree biomass estimation strata (t d.m./ha; see Equation 10)

$b_{TREE,p,i}$ Tree biomass per hectare in plot p of stratum i (t d.m./ha; see Annex 1)

α Ratio of number of sample plots in the sub-sample to the number of sample plots in the sample ($\alpha < 1$)

ρ Coefficient of correlation between the secondary variable and the tree biomass per hectare in a sample plot, estimated across all the sample plots in the sub-sample

6 Parameters

Data/Parameter	CF_{TREE}
Units	t C/t d.m
Description	Carbon fraction of tree biomass
Equations	Equation 3; Equation 8; Equation 13
Source	IPCC 2006
Value	A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value
Justification of choice of data or description of	Default value is provided in the IPCC's 2006 National Guidelines for Greenhouse Gas Inventories. This value is not

measurement methods and procedures applied	updated in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Purpose of Data	Conversion of tree biomass to carbon stock estimate
Comments	NA

Data/Parameter	A
Units	ha
Description	Sum of areas of the biomass estimation strata
Equations	Equation 4; Equation 9
Source	Measurement of project areas from maps, satellite imagery or using handheld GPS.
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Measurements should be made following standard operating procedures with QA/QC measures in place.
Purpose of Data	Scaling change in tree biomass to the stratum level.
Comments	NA

Data/Parameter	w_i
Units	Unitless
Description	Ratio of the area of stratum <i>i</i> to the sum of areas of tree biomass estimation strata
Equations	Equation 5; Equation 10; Equation 19
Source	Calculated from the extent of each stratum and extent of all strata i.e. $w_i = A_i/A$
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Calculated as a ratio.

Purpose of Data	Combining measurements from different strata to a value for all strata.
Comments	NA

Data/Parameter	$b_{TREE,p,i,t1}; b_{TREE,p,i,t2}; b_{TREE,p,i}$
Units	t d.m./ha
Description	Tree biomass per hectare in plot p in stratum i at time $t1; t2$
Equations	Equation 7; Equation 11; Equation 12; Equation 19
Source	Measurements in sample plots following the procedures in Appendix 1.
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Sample plot measurements following the procedures in Appendix 1 can be used to accurately estimate tree biomass. Measurements should be made following standard operating procedures with QA/QC measures in place.
Purpose of Data	Calculating change in tree biomass in a plot.
Comments	NA

Data/Parameter	β
Units	Unitless
Description	Slope of the regression line of tree biomass per hectare in a sample plot against the secondary variable value of the plot
Equations	Equation 12
Source	For two linearly related data sets of equal size, the correlation coefficient and the slope of regression line are calculated as follows: $\beta = \rho \times \frac{s_y}{s_x}$ <p>Where:</p>

	<p>ρ Sample correlation coefficient between the dependent variable (y) and the independent variable (x)</p> <p>s_y, s_x Sample standard deviation of the dependent variable (y) values and the independent variable (x) values respectively</p>
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Established statistical method.
Purpose of Data	Estimation of mean tree biomass per hectare.
Comments	May also be calculated using commercial or open source computer software (e.g. statistical packages).

Data/Parameter	\bar{x}' ; \bar{x}
Units	Depends on secondary variable selected
Description	Mean value of the secondary variable across all the sample plots; Mean value of the secondary variable across the sub-sample of sample plots in which tree biomass is also measured
Equations	Equation 12
Source	Depends on secondary variable selected
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Examples of secondary variables that may be linearly related to tree biomass include in-situ measurements such as basal area and metrics derived from remote sensing data such as Normalized Difference Vegetation Index (NDVI) or canopy height.
Purpose of Data	Estimation of mean tree biomass per hectare.
Comments	NA

Data/Parameter	R_s
Units	Unitless
Description	Root-shoot ratio for shrubs
Equations	Equation 15
Source	IPCC 2006
Value	The default value of 0.40 is used unless transparent and verifiable information can be provided to justify a different value.
Justification of choice of data or description of measurement methods and procedures applied	The default value of 0.40 is provided in Table 4.4 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories. This value is not updated in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Purpose of Data	Estimation of root biomass carbon stock in shrubs
Comments	NA

Data/Parameter	$A_{SHRUB,i}$
Units	ha
Description	Area of shrub biomass estimation stratum i
Equations	Equation 15
Source	Measurement of project areas from maps, satellite imagery or using handheld GPS.
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Measurements should be made following standard operating procedures with QA/QC measures in place.
Purpose of Data	Estimation of carbon stocks in shrubs.
Comments	NA

Data/Parameter	BDR_{SF}
Units	Unitless

Description	Ratio of shrub biomass per hectare in land having a shrub crown cover of 1.0 (i.e. 100 per cent) and the default above-ground biomass content per hectare in forest in the region/country where the project is located
Equations	Equation 16
Source	AR-TOOL14
Value	A default value of 0.10 should be used unless transparent and verifiable information can be provided to justify a different value.
Justification of choice of data or description of measurement methods and procedures applied	AR-TOOL14 provides a default value of 0.10.
Purpose of Data	Estimation of shrub biomass
Comments	NA

Data/Parameter	b_{FOREST}
Units	t d.m./ha
Description	Default above-ground biomass content in forest in the region/country where the project is located
Equations	Equation 16
Source	Values from Table 3A.1.4 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values.
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Default values from IPCC GPG-LULUCF 2003 describe average biomass content of forest by region.
Purpose of Data	Estimation of shrub biomass
Comments	NA

Data/Parameter	$CC_{SHRUB,i}$
Units	Unitless
Description	Crown cover of shrubs in shrub biomass estimation stratum i at the time of estimation, expressed as a fraction (e.g. 10 per cent crown cover implies = 0.10)
Equations	Equation 16
Source	Field measurement.
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Considering that the biomass in shrubs is smaller than the biomass in trees, a simplified method of measurement may be used for estimating shrub crown cover. Ocular estimation of crown cover may be carried out or any other method such as the line transect method or the relascope method may be applied
Purpose of Data	Estimation of shrub biomass
Comments	When land is subjected to periodic cycles (e.g. slash-and-burn, or clearing-regrowing cycles) so that the shrub crown cover oscillates between a minimum and maximum values in the baseline, an average shrub crown cover equal to 0.5 is used unless transparent and verifiable information can be provided to justify a different value

Data/Parameter	t_{VAL}
Units	Unitless
Description	Two-sided Student's t-value for a confidence level of 90 per cent and degrees of freedom equal to $n - M$, where n is total number of sample plots within the tree biomass estimation strata and M is the total number of tree biomass estimation strata
Equations	Equation 18
Source	Statistical tables.
Value	NA

Justification of choice of data or description of measurement methods and procedures applied	Established statistical method.
Purpose of Data	Calculation of variance of tree biomass.
Comments	NA

Data/Parameter	α
Units	Unitless
Description	Ratio of number of sample plots in the sub-sample to the number of sample plots in the sample ($\alpha < 1$)
Equations	Equation 19
Source	Field measurements
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Ratio calculation.
Purpose of Data	Calculation of variance of tree biomass.
Comments	NA

Data/Parameter	ρ
Units	Unitless
Description	Coefficient of correlation between the secondary variable and the tree biomass per hectare in a sample plot, estimated across all the sample plots in the sub-sample.
Equations	Equation 19
Source	For two linearly related data sets of equal size, the correlation coefficient and the slope of regression line are calculated as follows:

	$\rho = \frac{\sum_{i=1}^n \{(x_i - \bar{x})(y_i - \bar{y})\}}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \times \sum_{i=1}^n (y_i - \bar{y})^2}}$ <p>Where:</p> <p>x_i, y_i Independent variable (x) and dependent variable (y) values</p> <p>\bar{x}, \bar{y} Mean of the independent variable (x) and dependent variable (y) values</p> <p>n Number of data values in each data set</p>
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Established statistical method.
Purpose of Data	Calculation of variance of tree biomass.
Comments	May also be calculated using commercial or open source computer software (e.g. statistical packages).

7 References

AR-TOOL14 Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities, Version 4.2. CDM Tool. Available from:

https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v2.1.0.pdf/history_view

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