PLAN VIVO

PV Climate Tool

PT#DWL

Estimation of Change in Dead Wood and Litter Carbon Stocks

Version 1.0

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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 dead wood and litter carbon stocks in PV Climate project areas under baseline and project scenarios. Procedures include using in-situ measurements and conservative default factors to determine values for the following parameters that are used to estimate baseline and project removals in dead wood and litter following **PU001**:

$\Delta C_{DW\_BSL,t}$ Change in carbon stock in dead wood under the baseline scenario within the project area in year *t* (t CO_2e; see Sections 5.1.2 and 5.1.3)

$\Delta C_{LI\_BSL,t}$ Change in carbon stock in litter under the baseline scenario within the project area in year *t* (t CO_2e; see Section 5.2.2 and 5.2.3)

$C_{DW_{BSL,t2,i}}$ Average carbon stock in dead wood in the control plots for baseline scenario stratum *i* in year *t2* (t CO_2e/ha; see Section 5.1.4)

$C_{DW_{BSL,t1,i}}$ Average carbon stock in dead wood in the control plots for baseline scenario stratum *i* in year *t1* (t CO_2e/ha; see Section 5.1.4)

$C_{LI_{BSL,t2,i}}$ Average carbon stock in litter in the control plots for baseline scenario stratum *i* in year *t2* (t CO_2e; see Section 5.2.4)

$C_{LI_{BSL,t1,i}}$ Average carbon stock in litter in the control plots for baseline scenario stratum *i* in year *t1* (t CO_2e; see Section 5.2.4)

$\Delta C_{DW\_PROJ,t}$ Change in carbon stock in dead wood under the project scenario within the project area in year *t* (t CO_2e; see Section 5.1.3)

$\Delta C_{LI\_PROJ,t}$ Change in carbon stock in litter under the project scenario within the project area in year *t* (t CO_2e; see Section 5.2.3)

The tool is applicable globally to project areas in cropland, grassland, shrubland, savanna, woodland, and forestland; and project interventions that increase or decrease carbon stored in dead wood and litter.

2 Sources

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

AR-TOOL12 Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities, Version 3.1.

3 Definitions

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

Standing dead wood = Trees that have died but remain upright, including dead branches, trunks, and stumps, that are not on the forest floor.

Lying dead wood = Dead tree material - such as logs, limbs, and branches - that has fallen and lies on the ground.

4 Applicability Conditions

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

This tool makes the following assumptions:

a) Linearity of change of biomass in dead wood and litter over a period of time - Change of biomass in dead wood and litter may be assumed to proceed, on average, at an approximately constant rate between two points of time at which the biomass is estimated;
b) Appropriateness of root-shoot ratios - Root-shoot ratios appropriate for estimation of below-ground biomass from above-ground biomass of living trees are also appropriate for dead trees.

5 Procedures

5.1 Estimation of Carbon Stock and Change in Carbon Stock in Dead Wood

If the project measures woody biomass in sample plots, carbon stock in dead wood is estimated on the basis of the same strata, and the same sample plots, which are used for the purpose of estimation of living tree biomass. However, projects applying this tool may use a different stratification for the purpose of estimation of carbon stock in dead wood if transparent and verifiable information from peer-reviewed literature, official national data, or project-specific data can be given for justification of such a choice.

Change in carbon stock in dead wood (ΔC_{DW}) can be estimated with the measurement-based method (see Section 5.1.1) or a conservative default-factor (see Section 5.1.2).

5.1.1 Measurement-based Methods for Estimation of Carbon Stock in Dead Wood

For the purpose of this tool, the term "species" also implies a group of species when a biometric parameter (e.g. biomass expansion factor, root-shoot ratio, basic wood density) or a model (e.g. allometric equation, volume equation or table) is applicable to more than one species.

Biomass of dead wood of species j in sample plot p in stratum i at a given point of time in year t is calculated separately for the following two types of dead wood:

a) Standing dead wood (see Section 5.1.1.1);
b) Lying dead wood (see Section 5.1.1.2).

Note: Uprooted trees lying on the ground, if not extracted, shall be treated as "standing dead wood" for estimation of dead wood biomass.

5.1.1.1 Standing Dead Wood

For the following two categories of standing dead wood, the biomass of standing dead wood is estimated by applying a biomass reduction factor to whole tree biomass:

a) Dead trees which have lost only leaves and twigs - Dead wood biomass is equal to whole tree biomass multiplied by a biomass reduction factor equal to 0.975[1];
b) Dead trees which have lost leaves, twigs and small branches (diameter < 10 cm).- Dead wood biomass is equal to whole tree biomass multiplied by a biomass reduction factor equal to 0.80[1];

For dead trees and stumps which do not conform to the categories above, biomass is estimated using the method described in Section 5.1.1.1.4.

For all dead trees falling in the categories mentioned above, measurement of tree dimensions (i.e. diameter and/or height) are carried out in sample plots laid down in each stratum. In exceptional

[1] Adapted from the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG-LULUCF 2003): p. 4.105, section 4.3.3.5.3 DEAD ORGANIC MATTER.

situations, measurements may be carried out on all such dead trees in the stratum where trees are few and scattered out.

Tree dimensions (i.e. diameter and/or height as measured) are converted to dead wood biomass in standing dead trees by applying one of the following two methods:

a) The biomass expansion factor (*BEF*) method (see Section 5.1.1.1.1); or
b) The allometric method (see Section 5.1.1.1.2).

5.1.1.1.1 Estimation of Standing Dead Tree Biomass using BEF Method

Under this method volume tables (or volume functions/curves) are used to convert tree dimensions to the stem volume of trees. Stem volume of trees is converted to aboveground tree biomass using basic wood density and biomass expansion factors, and the aboveground tree biomass is expanded to total tree biomass using root-shoot ratios. Thus, dead wood biomass in standing dead trees of species *j* in sample plot *p* is calculated as:

$$B_{DWS_{TREE},j,p,i,t} = D_j \times BEF_{2,j} \times (1 + R_j) \times \sum_{k=1}^{K} V_{TREE,j}(DBH_k, H_k) \times \alpha_k$$

Equation 1

Where:

$B_{DWS_{TREE},j,p,i,t}$ Biomass of dead wood in dead trees of species *j* in sample plot *p* of stratum *i* at a point of time in year *t* (t d.m.; see Equation 1)

D_j Basic wood density of species *j* (t d.m./m^3)

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

R_j Root-shoot ratio for tree species *j* (dimensionless)

$V_{TREE,j}(DBH_k, H_k)$ Stem volume of the k^{th} dead tree of species *j* in plot *p* of stratum *i* as returned by the volume function for species *j* using the tree dimension(s) as entry data (m^3)

DBH_k Diameter of the k^{th} dead tree of species *j* in plot *p* of stratum *i* at a point of time in year *t* (meter or any other unit of length used by the volume function)

H_k Height of the k^{th} dead tree of species *j* in plot *p* of stratum *i* at a point of time in year *t* (meter or any other unit of length used by the volume function)

α_k Biomass reduction factor for the k^{th} dead tree, depending upon its decay category according to Section 5.1.1.1 (dimensionless)

The volume table or volume function used must be demonstrated to be appropriate for the purpose of estimating tree biomass.

5.1.1.1.2 Estimation of Standing Dead Tree Biomass using Allometric Method

Under this method allometric equations are used to convert tree dimensions to aboveground biomass of trees and the above-ground tree biomass is expanded to total tree biomass using root-shoot ratios. Thus, dead wood biomass in standing dead trees of species *j* in sample plot *p* is calculated as:

$$B_{DWS_{TREE},j,p,i,t} = (1 + R_j) \times \sum_{k=1}^{K} f_j(DBH_k, H_k) \times \alpha_k$$

Equation 2

Where:

$B_{DWS_{TREE},j,p,i,t}$ $B_{DWS_{TREE},j,p,i,t}$ Biomass of dead wood in dead trees of species *j* in sample plot *p* of stratum *i* at a point of time in year *t* (t d.m.; see Equation 2)

R_j Root-shoot ratio for tree species *j* (dimensionless)

$f_j(DBH_k, H_k)$ Above-ground biomass of the k^{th} dead tree of species *j* in sample plot *p* of stratum *i* returned by the allometric function for species *j* using the tree dimension(s) as entry data (t d.m)

DBH_k Diameter of the k^{th} dead tree of species *j* in plot *p* of stratum *i* at a point of time in year *t* (meter or any other unit of length used by the allometric function)

H_k Height of the k^{th} dead tree of species *j* in plot *p* of stratum *i* at a point of time in year *t* (meter or any other unit of length used by the allometric function)

α_k Biomass reduction factor for the k^{th} dead tree, depending upon its category according to Section 5.1.1.1 (dimensionless)

The allometric equation used must be demonstrated to be appropriate for the purpose of estimating tree biomass.

5.1.1.1.3 Estimation of Standing Dead Wood in Dead Trees

In both the *BEF* method and the allometric method, the carbon stock in dead wood biomass in standing dead trees of species *j* in sample plot *p* of stratum *i* is calculated as follows:

$$C_{DWS_{TREE},j,p,i,t} = \frac{44}{12} \times CF_{TREE} \times B_{DWS_{TREE},j,p,i,t}$$

Equation 3

Where:

$C_{DWS_{TREE},j,p,i,t}$ Carbon stock in dead wood in standing dead trees of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 3)

CF_{TREE} Carbon fraction of tree biomass (t C/t d.m)

$B_{DWS_{TREE},j,p,i,t}$ Biomass of dead wood in standing dead trees of species *j* in sample plot *p* of stratum *i* at a point of time in year *t* (t d.m; see Equation 1 or Equation 2)

5.1.1.1.4 Estimation of Carbon Stock in Standing Dead Wood in Tree Stumps

Each dead tree stump in a sample plot is categorized into a decay class as:

a) Sound;
b) Intermediate; or
c) Rotten, on the basis of a machete test.[2]

A density reduction factor is assigned to each of the decay classes, which is to be multiplied by the basic wood density of the species of the stump to obtain its estimated wood density. The following default values[3] of the density reduction factors for the three decay classes are used, unless projects have more specific data available to them:

a) Sound = 1.00;
b) Intermediate = 0.80; and
c) Rotten = 0.45.

[2] The stump wood is struck with a machete - if the blade bounces off it is sound; if it enters slightly into the wood, is it intermediate; and if it causes the wood to fall apart, it is rotten. IPCC GPG LULUCF 2003, section 4.3.3.5.3 DEAD ORGANIC MATTER.

[3] Adapted from 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.

For each dead tree stump of height less than 4 m the mid-height diameter is measured. For each dead tree stump of height 4 m and above, the diameter at breast height (DBH) is measured. For stumps of height more than 4 m, the mid-height diameter of the stump is estimated[4] as:

$$D_{MID\_STUMP} = 0.57 \times DBH \times \left(\frac{H_{STUMP}}{H_{STUMP} - H_{DBH}}\right)^{0.80} \text{ for } H_{STUMP} > 4\text{m}$$

Equation 4

Where:

D_{MID_STUMP}	Mid-height diameter of the dead tree stump (m; see Equation 4)
DBH	Diameter at breast height of the dead tree stump (m)
H_{STUMP}	Height of the stump (m)
H_{DBH}	Height above ground level at which DBH is measured (m)

Carbon stock in dead wood in dead tree stumps of species *j* in plot *p* is calculated as:

$$C_{DWS_{STUMP},j,p,i,t} = \frac{44}{12} \times CF_{TREE} \times D_j \times (1 + R_j) \times \frac{\pi}{4} \sum_k D_{MID\_STUMP,k}{}^2 \times H_k \times B_k$$

Equation 5

Where:

$C_{DWS_{STUMP},j,p,i,t}$ Carbon stock in dead wood in dead tree stumps of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 5)

CF_{TREE} Carbon fraction of tree biomass (t C/t d.m)

D_j Basic wood density of species *j* (t d.m/m^3)

R_j Root-shoot ratio for tree species *j* (dimensionless)

$D_{MID\_STUMP,k}$ Mid-height diameter of the k^{th} dead tree stump of species *j* in plot *p* in stratum *i* at a given point of time in year *t* (m; see Equation 4)

H_k Height of the k^{th} dead tree stump of species *j* in plot *p* in stratum *i* at a given point of time in year *t*; m

[4] Adapted from Ormerod, D W, 1973. A simple bole model. *Forestry Chronicle*. 49:136-138.

B_k Density reduction factor (per decay class) applicable to the k^{th} dead tree stump of species j in plot p in stratum i at a given point of time in year t (dimensionless)

5.1.1.2 Lying Dead Wood

Lying dead wood is estimated by using line transect method (Harmon and Sexton, 1996).[5] Two transect lines, of total length of at least 100 m[6], approximately orthogonally bisecting each other at the centre of the plot are established and the diameter of each piece of lying dead wood (with diameter ≥10 cm) intersecting a transect line is measured.

Each piece of dead wood is assigned to one of three decay classes and each of the three decay classes are assigned a density reduction factor as explained in Section 5.1.1.1.4.

Based on these measurements and categorization into decay classes, carbon stock in lying dead wood of species j in plot p is calculated as:

$$C_{DWL,j,p,i,t} = a_{PLOT} \times \frac{44}{12} \times CF_{TREE} \times D_j \times \frac{\pi^2}{8L} \times \sum_{n=1}^{N} D_n^2 \times B_n$$

Equation 6

Where:

$C_{DWL,j,p,i,t}$ Carbon stock in lying dead wood of species j in sample plot p in stratum i at a given point of time in year t (t CO_2e; see Equation 6)

a_{PLOT} Area of the sample plot p (ha)

CF_{TREE} Carbon fraction of tree biomass (t C/t d.m.)

D_j Basic wood density of species j (t d.m./m^3)

L Sum of the lengths of the transect lines approximately orthogonally bisecting each other at the centre of the plot p (m)

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[5] 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.

[6] If the parcel area does not allow for the required length in two lines, then more than two lines are permissible. However, where lines are obliged to run in parallel they should be separated by at least 20 m.

D_n Diameter of the n^{th} piece of lying dead wood intersecting a transect line (cm)

B_n Density reduction factor (per decay class) applicable to the n^{th} piece of lying dead wood intersecting a transect line (dimensionless)

5.1.1.3 Total Carbon Stock in Dead Wood

The carbon stock in dead wood in a stratum is then calculated as:

$$C_{DW,i,t} = \frac{A_i}{A_{PLOT,i}} \sum_p \sum_j \left(C_{DWS\_TREE,j,p,i,t} + C_{DWS\_STUMP,j,p,i,t} + C_{DWL,j,p,i,t}\right)$$

Equation 7

Where:

$C_{DW,i,t}$ Carbon stock in dead wood in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 7)

A_i Total area of stratum *i* (ha)

$A_{PLOT,i}$ Total area of sample plots in stratum *i* (ha)

$C_{DWS\_TREE,j,p,i,t}$ $C_{DWS_{TREE},j,p,i,t}$ Carbon stock in dead wood in standing dead trees of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 3)

$C_{DWS\_STUMP,j,p,i,t}$ Carbon stock in dead wood in dead tree stumps of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 5)

$C_{DWL,j,p,i,t}$ Carbon stock in lying dead wood of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 6)

Finally, the carbon stock in dead tree biomass within the project boundary at a given point in time in year t is calculated by summing up $C_{DW,i,t}$ over all the strata, that is:

$$C_{DW,t} = \sum_i C_{DW,i,t}$$

Equation 8

Where:

$C_{DW,t}$ Carbon stock in dead wood within the project boundary at a given point of time in year *t* (t CO_2e; see Equation 8)

$C_{DW,i,t}$ Carbon stock in dead wood in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 7)

5.1.2 Conservative Default-factor Based Method for Estimation of Carbon Stock in Dead Wood

If projects do not wish to make sampling based measurements for estimation of C stock in dead wood, they may use the default-factor based method described in this section. The default-factor based method is applicable only if dead wood remains in situ and is not removed from the project boundary through any type of anthropogenic activities.

For all strata to which the default-factor based method is applied, the carbon stock in dead wood is estimated as:

$$C_{DW,i,t} = C_{TREE,i,t} \times DF_{DW}$$

Equation 9

Where:

$C_{DW,i,t}$ Carbon stock in dead wood in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 9)

$C_{TREE,i,t}$ Carbon stock in trees biomass in stratum *i* at a point of time in year *t*, as calculated in the tool **PT#WB** (t CO_2e)

DF_{DW} Conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass (%)

Value of the conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass (DF_{DW}) is selected according to the guidance provided in the relevant table in Section 6 unless transparent and verifiable information from peer-reviewed literature, official national data, or project-specific data can be provided to justify a different value.

5.1.3 Change in Carbon Stock in Dead Wood

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

$$dC_{DW,(t1,t2)} = \frac{C_{DW,t2} - C_{DW,t1}}{T}$$

Equation 10

Where:

$dC_{DW,(t1,t2)}$ Rate of change in carbon stock in dead wood within the project area during the period between a point of time in year *t1* and a point of time in year *t2* (t CO_2e/yr; see Equation 10)

$C_{DW,t2}$ Carbon stock in dead wood within the project area at a point of time in year *t2* (t CO_2e; see Equation 8)

$C_{DW,t1}$ Carbon stock in dead wood within the project area at a point of time in year *t1* (t CO_2e; see Equation 8)

T Time elapsed between two successive estimations ($T = t2 - t1$; years)

Change in carbon stock in dead wood under the project scenario (i.e. $\Delta C_{DW\_PROJ,t}$) or baseline scenario (i.e. $\Delta C_{DW\_BSL,t}$) within the project area in year t ($t1 \leq t \leq t2$) is given by:

$$\Delta C_{DW,t} = dC_{DW,(t1,t2)}$$

Equation 11

Where:

$\Delta C_{DW,t}$ Change in carbon stock in dead wood within the project area in year t (t CO_2e; see Equation 11)

$dC_{DW,(t1,t2)}$ Rate of change in carbon stock in dead wood within the project area during the period between a point of time in year *t1* and a point of time in year *t2* (t CO_2e/yr; see Equation 10)

5.1.4 Average Dead Wood Carbon Stock in Control Areas

When estimating dead wood carbon stocks in control areas, average carbon stock in dead wood in each baseline scenario stratum at a point in time is calculated with Equation 12.

$$C_{DW\_BSL,t,i} = \frac{C_{DW,i,t}}{A_i}$$

Equation 12

Where:

$C_{DW\_BSL,t,i}$ Average carbon stock in dead wood in the control plots for baseline scenario stratum *i* in year *t* (t CO_2e/ha; see Equation 12)

$C_{DW,i,t}$ Carbon stock in dead wood in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 7 or Equation 9)

A_i Total area of stratum *i* (ha)

5.2 Estimation of Carbon Stock and Change in Carbon Stock in Litter

If the project measures woody biomass in sample plots, carbon stock in litter is estimated on the basis of the same strata, and the same sample plots, which are used for the purpose of estimation of living tree biomass. However, projects applying this tool may use a different stratification for the purpose of estimation of carbon stock in litter if transparent and verifiable information from peer-reviewed literature, official national data, or project-specific data can be given for justification of such a choice.

Two methods are offered for estimation of carbon stock in litter: a measurement-based method (see Section 5.2.1) and a conservative default-based approach (see Section 5.2.2).

5.2.1 Measurement-based Methods for Estimation of Carbon Stock in Litter

For estimating carbon stock in litter, four litter samples are collected from each sample plot, using a sampling frame which is placed in four randomly selected positions within the plot. The four samples are well mixed into one composite sample and its wet weight is taken. A sub-sample taken from the composite sample is weighed, oven dried, and weighed again to determine its dry weight. The dry-to-wet weight ratio of the sub-sample is calculated and used for estimating the dry weight of the composite litter sample.

Carbon stock in litter biomass in plot *p* is then calculated as:

$$C_{LI,p,i,t} = \frac{44}{12} \times CF_{LI} \times 2.5 \times \frac{A_{p,i}}{a_{p,i}} \times B_{LI\_WET,p,i} \times DWR_{LI,p,i}$$

Equation 13

Where:

$C_{LI,p,i,t}$ Carbon stock in litter in plot *p* in stratum *i* (t CO_2e; see Equation 13)

CF_{LI} Carbon fraction of dry biomass in litter (dimensionless; IPCC default value[7] of 0.37 is used)

$A_{p,i}$ Area of sample plot *p* of stratum *i* (ha)

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

$B_{LI\_WET,p,i}$ Wet weight of the composite litter sample collected from plot *p* of stratum *i* (kg)

$DWR_{LI,p,i}$ Dry-to-wet weight ratio of the litter sub-sample collected from plot *p* in stratum *i* (dimensionless). it is acceptable to determine this ratio for three randomly selected sample plots in a stratum and then apply the average ratio to all plots in that stratum.

Note: The numerical factor 2.5 appears in this equation because of conversion of units from *kg* to *tonne* and from m^2 to *ha*, as well as because of the fact that $B_{LI\_WET,p,i}$ is the wet weight of litter collected from an area equal to four times the area of the sampling frame.

Carbon stock in litter in stratum *i* is then calculated as:

$$C_{LI,i,t} = \frac{A_i}{A_{PLOT,i}} \sum_{p} C_{LI,p,i,t}$$

Equation 14

Where:

$C_{LI,i,t}$ Carbon stock in litter in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 14)

A_i Area of stratum *i* (ha)

$A_{PLOT,i}$ Area of sample plots in stratum *i* (ha)

$C_{LI,p,i,t}$ Carbon stock in litter in plot *p* in stratum *i* (t CO_2e; see Equation 13)

Finally, the carbon stock in litter biomass within the project boundary at a given point of time in year *t* is calculated by summing up ($C_{LI,i,i}$) over all the strata, that is:

[7] IPCC GPG for LULUCF, 2003, page 3.35, section 3.2.1.2.1.1 Choice of Method.

$$C_{LI,t} = \sum_{i} C_{LI,i,i}$$

Equation 15

Where:

$C_{LI,t}$ Carbon stock in litter within the project area at a given point of time in year *t*; (t CO_2e; see Equation 15)

$C_{LI,i,t}$ Carbon stock in litter in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 14)

5.2.2 Conservative Default-factor Based Method for Estimation of Carbon Stock in Litter

If projects do not wish to make sampling based measurements for estimation of carbon stock in litter, they may use the default-factor based method described in this section. The default-factor based method is applicable only if litter remains in situ and is not removed from the project area through any type of anthropogenic activities.

For all strata to which this default method is applied, the carbon stock in litter is estimated as:

$$C_{LI,i,t} = C_{TREE,i,t} \times DF_{LI}$$

Equation 16

Where:

$C_{LI,i,t}$ Carbon stock in litter in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 16)

$C_{TREE,i,t}$ Carbon stock in trees biomass in stratum *i* at a point of time in year *t*, as calculated in the tool **PT#WB**

DF_{LI} Conservative default factor expressing carbon stock in litter as a percentage of carbon stock in tree biomass (%)

Value of the conservative default factor expressing carbon stock in litter as a percentage of carbon stock in tree biomass (DF_{LI} is selected according to the guidance provided in the relevant table in Section 6 unless transparent and verifiable information from peer-reviewed literature, official national data, or project-specific data can be provided to justify a different value.

5.2.3 Change in Carbon Stock in Litter

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

$$dC_{LI,(t1,t2)} = \frac{C_{LI,t2} - C_{LI,t1}}{T}$$

Equation 17

$dC_{LI,(t1,t2)}$ Rate of change in carbon stock in litter within the project area during the period between a point of time in year *t1* and a point of time in year *t2* (t CO_2e/yr; see Equation 17)

$C_{LI,t2}$ Carbon stock in litter within the project area at a point of time in year *t2* (t CO_2e; see Equation 15)

$C_{LI,t1}$ Carbon stock in litter within the project area at a point of time in year *t1* (t CO_2e; see Equation 15)

T Time elapsed between two successive estimations ($T = t2 - t1$; years)

Change in carbon stock in litter under the project scenario (i.e. $\Delta C_{LI\_PROJ,t}$) or baseline scenario (i.e. $\Delta C_{LI\_BSL,t}$) within the project area in year *t* ($t1 \leq t \leq t2$) is given by:

$$\Delta C_{LI,t} = dC_{LI,(t1,t2)}$$

Equation 18

Where:

$\Delta C_{LI,t}$ Change in carbon stock in litter within the project area in year *t* (t CO_2e; see Equation 18)

$dC_{LI,(t1,t2)}$ Rate of change in carbon stock in litter within the project area during the period between a point of time in year *t1* and a point of time in year *t2* (t CO_2e/yr; see Equation 17)

5.2.4 Average Litter Carbon Stock in Control Areas

When estimating litter carbon stocks in control areas, average carbon stock in litter in each baseline scenario stratum at a point in time is calculated with Equation 19.

$$C_{LI\_BSL,t,i} = \frac{C_{LI,i,t}}{A_i}$$

Equation 19

Where:

$C_{LI\_BSL,t,i}$ Average carbon stock in litter in the control plots for baseline scenario stratum *i* in year *t* (t CO_2e/ha; see Equation 19)

$C_{LI,i,t}$ Carbon stock in litter in stratum *i* at a given point of time in year *t* (t CO_2e; see Equation 14 or Equation 16)

A_i Total area of stratum *i* (ha)

5.3 Estimation of Carbon Stock and Change in Carbon Stock in Litter

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 conservative defaults are used, uncertainty is assumed to be zero since the most conservative default values must be used.

6 Parameters

Data/Parameter	D_j
Units	t d.m./m^3
Description	Basic wood density of species *j*
Equations	Equation 1; Equation 5; Equation 6
Source	Values from Table 3A.1.9 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information from peer-reviewed literature, official national data, or project-specific data can be provided to justify different values.
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	IPCC 2003 provides conservative default values if species specific values are not available.
Purpose of Data	Estimation of biomass in dead wood

Comments	Where density (specific gravity) of the bark of a tree species is different from the density of the wood, suitable correction should be applied to estimate a conservative value of the overall (over-bark) density of tree stem.

Data/Parameter	$BEF_{2,j}$
Units	Unitless
Description	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass, for species *j*
Equations	Equation 1
Source	Values from Table 3A.1.10 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information from peer-reviewed literature, official national data, or project-specific data can be provided to justify different values
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	IPCC 2003 provides conservative default values if species specific values are not available.
Purpose of Data	Estimation of biomass in dead wood
Comments	*BEFs* in IPCC literature and national inventory are usually applicable to closed canopy forest. If applied to individual trees growing in an open field it is recommended that the selected *BEF* be increased by 30 percent.

Data/Parameter	R_j
Units	Unitless
Description	Root-shoot ratio for tree species *j*
Equations	Equation 1; Equation 2; Equation 5
Source	Table 4.A.4 of IPCC GPG-LULUCF 2003 unless transparent and verifiable information from peer-reviewed literature, official

	national data, or project-specific data can be provided to justify a different value
Value	Default value shall be calculated as: $$R_j = \frac{e^{(-1.085+0.9256\times\ln b)}}{b}$$ Where b is above-ground tree biomass per hectare (t d.m./ha)
Justification of choice of data or description of measurement methods and procedures applied	IPCC 2003 provides conservative default values if species specific values are not available.
Purpose of Data	Estimation of belowground biomass in dead wood
Comments	If trees have grown as coppice regeneration after a harvest, then the value of should be multiplied by a factor equal to $^{v_{HARVEST}}/_{v_{TREE}}$ or 1, whichever is greater, where $v_{HARVEST}$ is the volume per hectare of trees harvested and v_{TREE} is the volume per hectare of trees standing in the plot at the time of measurement.

Data/Parameter	DBH_k; DBH
Units	meter or any other unit of length used by the volume function or allometric function
Description	Diameter of the k^{th} dead tree of species *j* in plot *p* of stratum *i* at a point of time in year *t*; Diameter at breast height of the dead tree stump
Equations	Equation 1; Equation 2; Equation 4
Source	Measurements in sample plots
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 stem volume or aboveground biomass of standing dead trees.
Comments	NA

Data/Parameter	H_k
Units	meter or any other unit of length used by the volume function or allometric function
Description	Height of the k^{th} dead tree of species j in plot p of stratum i at a point of time in year t
Equations	Equation 1; Equation 2, Equation 5
Source	Measurements in sample plots
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 stem volume, aboveground biomass and carbon stock of standing dead trees.
Comments	NA

Data/Parameter	α_k
Units	Unitless
Description	Biomass reduction factor for the k^{th} dead tree, depending upon its decay category
Equations	Equation 1; Equation 2
Source	Adapted from the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG-LULUCF 2003): p. 4.105, section 4.3.3.5.3 DEAD ORGANIC MATTER.
Value	Dead trees which have lost only leaves and twigs: 0.975 Dead trees which have lost leaves, twigs and small branches (diameter < 10 cm): 0.80.

Justification of choice of data or description of measurement methods and procedures applied	Conservative default value from IPCC GPG.
Purpose of Data	Estimation of biomass in dead wood
Comments	NA

Data/Parameter	CF_{TREE}
Units	t C/t d.m.
Description	Carbon fraction of tree biomass
Equations	Equation 3; Equation 5; Equation 6
Source	IPCC 2006 National Guidelines for Greenhouse Gas Inventories
Value	A default value of 0.47 is used unless transparent and verifiable information from peer-reviewed literature, official national data, or project-specific data can be provided to justify a different value
Justification of choice of data or description of measurement methods and procedures applied	Default value is provided in the IPCC's 2006 National Guidelines for 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 carbon stock in deadwood
Comments	NA

Data/Parameter	H_{STUMP}
Units	m
Description	Height of the stump
Equations	Equation 4
Source	Field measurements in sample plots
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 mid-height diameter of dead tree stumps > 4m in height.
Comments	NA

Data/Parameter	H_{DBH}
Units	m
Description	Height above ground level at which DBH is measured
Equations	Equation 4
Source	Field measurements in sample plots
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 mid-height diameter of dead tree stumps > 4m in height.
Comments	NA

Data/Parameter	$B_k; B_n$
Units	Unitless
Description	Density reduction factor (per decay class) applicable to the k^{th} dead tree stump of species j in plot p in stratum i at a given point of time in year t; Density reduction factor (per decay class) applicable to the n^{th} piece of lying dead wood intersecting a transect line
Equations	Equation 5; Equation 6
Source	Default values adapted from Harmon and Sexton (1996), unless projects have more specific data available to them.

Value	Default values per decay class: a) Sound = 1.00; b) Intermediate = 0.80; and c) Rotten = 0.45. See Section 5.1.1.1.4 for details of decay classes.
Justification of choice of data or description of measurement methods and procedures applied	Default value from AR-TOOL12.
Purpose of Data	Estimation of carbon stock in tree stumps.
Comments	NB

Data/Parameter	a_{PLOT}; $A_{p,i}$; $A_{PLOT,i}$
Units	ha
Description	Area of the sample plot *p;* Area of sample plot *p* of stratum *i;* Total area of sample plots in stratum *i*
Equations	Equation 6; Equation 7; Equation 13; Equation 14
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 stock in dead wood and litter.
Comments	NA

Data/Parameter	L
Units	m
Description	Sum of the lengths of the transect lines approximately orthogonally bisecting each other at the centre of the plot *p*
Equations	Equation 6

Source	Field measurements in sample plots
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 stock in lying dead wood.
Comments	NA

Data/Parameter	D_n
Units	cm
Description	Diameter of the n^{th} piece of lying dead wood intersecting a transect line
Equations	Equation 6
Source	Field measurements along transect lines in sample plots.
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 stock in lying dead wood.
Comments	NA

Data/Parameter	A_i
Units	ha
Description	Total area of stratum *i*
Equations	Equation 7; Equation 12; Equation 14; Equation 19
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 dead wood and litter.
Comments	NA

Data/Parameter	$C_{TREE,i,t}$
Units	t CO_2e
Description	Carbon stock in trees biomass in stratum *i* at a point of time in year *t*
Equations	Equation 9; Equation 16
Source	**PT#WB**
Value	NA
Justification of choice of data or description of measurement methods and procedures applied	Procedures in **PT#WB** can be used to assess carbon stock in trees.
Purpose of Data	Estimation of carbon stocks in dead wood and litter.
Comments	NA

Data/Parameter	DF_{DW}
Units	%
Description	Conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass
Equations	Equation 9
Source	Defaults conservatively derived from Delaney et al. (1997), Smith et al. (2006),Glenday (2008),Keller et al. (2004), Eaton and Lawrence (2006), Krankina and Harmon (1995), and Clark et al (2002).

<table>
<tr><td>Value</td><td>
<table>
<tr><th>Biome</th><th>Elevation (m)</th><th>Precipitation (mm/yr)</th><th>DF_{DW}</th></tr>
<tr><td>Tropical</td><td><2000</td><td><1000</td><td>2%</td></tr>
<tr><td>Tropical</td><td><2000</td><td>1000-1600</td><td>1%</td></tr>
<tr><td>Tropical</td><td><2000</td><td>>1600</td><td>6%</td></tr>
<tr><td>Tropical</td><td>>2000</td><td>All</td><td>7%</td></tr>
<tr><td>Temperate/ Boreal</td><td>All</td><td>All</td><td>8%</td></tr>
</table>
</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td>Default values from AR-TOOL12.</td></tr>
<tr><td>Purpose of Data</td><td>Estimation of carbon stock in dead wood.</td></tr>
<tr><td>Comments</td><td>The default-factor based method is applicable only if dead wood remains in situ and is not removed from the project boundary through any type of anthropogenic activities.</td></tr>
</table>

Data/Parameter	CF_{LI}
Units	Unitless
Description	Carbon fraction of dry biomass in litter
Equations	Equation 13
Source	IPCC GPG for LULUCF, 2003, page 3.35, section 3.2.1.2.1.1 Choice of Method.
Value	0.37
Justification of choice of data or description of measurement methods and procedures applied	Default values from IPCC 2003.
Purpose of Data	Estimation of carbon stock in litter.
Comments	NA

Data/Parameter	$a_{p,i}$

Units	m^2
Description	Area of sampling frame for plot *p* in stratum *i*
Equations	Equation 13
Source	Field measurements
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 stock in litter.
Comments	Often a litter sampling frame of 0.50 m^2 is used.

Data/Parameter	$B_{LI\_WET,p,i}$
Units	Kg
Description	Wet weight of the composite litter sample collected from plot *p* of stratum *i*
Equations	Equation 13
Source	Field measurements in sample plots
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 stock in litter.
Comments	NA

Data/Parameter	$DWR_{LI,p,i}$
Units	Unitless
Description	Dry-to-wet weight ratio of the litter sub-sample collected from plot *p* in stratum *i*
Equations	Equation 13

Source	Field and laboratory measurements.
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 stock in litter.
Comments	It is acceptable to determine this ratio for three randomly selected sample plots in a stratum and then apply the average ratio to all plots in that stratum.

<table>
<tr><td>Data/Parameter</td><td>DF_{LI}</td></tr>
<tr><td>Units</td><td>%</td></tr>
<tr><td>Description</td><td>Conservative default factor expressing carbon stock in litter as a percentage of carbon stock in tree biomass</td></tr>
<tr><td>Equations</td><td>Equation 16</td></tr>
<tr><td>Source</td><td>Defaults conservatively derived from Delaney et al. (1997), Smith et al. (2006),Glenday (2008),Keller et al. (2004), Eaton and Lawrence (2006), Krankina and Harmon (1995), and Clark et al (2002).</td></tr>
<tr><td>Value</td><td>
<table>
<tr><th>Biome</th><th>Elevation (m)</th><th>Precipitation (mm/yr)</th><th>DF_{LI}</th></tr>
<tr><td>Tropical</td><td><2000</td><td><1000</td><td>4%</td></tr>
<tr><td>Tropical</td><td><2000</td><td>1000-1600</td><td>1%</td></tr>
<tr><td>Tropical</td><td><2000</td><td>>1600</td><td>1%</td></tr>
<tr><td>Tropical</td><td>>2000</td><td>All</td><td>1%</td></tr>
<tr><td>Temperate/ Boreal</td><td>All</td><td>All</td><td>4%</td></tr>
</table>
</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td>Default values from AR-TOOL12.</td></tr>
<tr><td>Purpose of Data</td><td>Estimation of carbon stock in litter.</td></tr>
</table>

Comments	The default-factor based method is applicable only if litter remains in situ and is not removed from the project area through any type of anthropogenic activities.

7 References

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