

**A/R Methodological Tool****“Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities”**(Version **02.0.0**)**I. SCOPE, APPLICABILITY AND ASSUMPTIONS****Scope**

1. This tool can be used for *ex post* estimation of carbon stocks and change in carbon stocks in dead wood and/or litter in the baseline and project scenarios of an A/R CDM project activity.

**Applicability**

2. This tool has no internal applicability conditions.

**Assumptions**

3. 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.

**Parameters**

4. This tool provides an approach to determine the following parameters:

**Table 1: Parameters determined by the tool**

<b>Parameter</b>	<b>SI Unit</b>	<b>Description</b>
$C_{DW,t}$	tCO <sub>2</sub> e	Carbon stock in dead wood within the project boundary at a given point of time in year <i>t</i>
$\Delta C_{DW,t}$	tCO <sub>2</sub> e	Change in carbon stock in dead wood within the project boundary in year <i>t</i>
$C_{LL,t}$	tCO <sub>2</sub> e	Carbon stock in litter within the project boundary at a given point of time in year <i>t</i>
$\Delta C_{LL,t}$	tCO <sub>2</sub> e	Change in carbon stock in litter within the project boundary in year <i>t</i>



5. While applying this tool in a methodology, the following notation should be used:

In the baseline scenario:

$C_{DW\_BSL,t}$  for  $C_{DW,t}$  and  $C_{LI\_BSL,t}$  for  $C_{LI,t}$ ;

$\Delta C_{DW\_BSL,t}$  for  $\Delta C_{DW,t}$  and  $\Delta C_{LI\_BSL,t}$  for  $\Delta C_{LI,t}$ .

In the project scenario:

$C_{DW\_PROJ,t}$  for  $C_{DW,t}$  and  $C_{LI\_PROJ,t}$  for  $C_{LI,t}$ ;

$\Delta C_{DW\_PROJ,t}$  for  $\Delta C_{DW,t}$  and  $\Delta C_{LI\_PROJ,t}$  for  $\Delta C_{LI,t}$ .

## II. ESTIMATION OF C STOCK AND CHANGE IN C STOCK IN DEAD WOOD

### Estimation of carbon stock in dead wood ( $C_{DW}$ )

6. 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, PPs applying this tool may use a different stratification for the purpose of estimation of carbon stock in dead wood if transparent and verifiable information can be given for justification of such a choice.

7. Two methods are offered for estimation of carbon stock in dead wood: a measurement-based method and a conservative default-factor based method.

#### *Measurement based method for estimation of carbon stock in dead wood ( $C_{DW}$ )*

8. 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.

9. For the purpose of this tool a biometric parameter (such as bole shape/form factor, biomass expansion factor, root shoot ratio, basic wood density, carbon fraction, etc) applicable to a species may also be applied to a group of species having similar biometric characteristics.

10. For the purpose of this tool an allometric equation or volume table applicable to a species may also be applied to a group of species having similar allometric characteristics.

9. 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;
- (b) Lying dead wood.

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

*Standing dead wood*

10. 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;<sup>1</sup>

- (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.<sup>2</sup>

11. For dead trees and stumps which ~~have no branches, twigs, and leaves, the dead wood do not conform to the categories in paragraphs 10(a) and 10(b)~~ biomass is calculated using the method indicated in paragraphs 19-22 ~~and following~~ below.

12. For all dead trees falling in the categories mentioned in paragraphs 10 (a) and 10 (b) above, measurement of tree dimensions (i.e. diameter and/or height) are carried out in sample plots laid down in each stratum. In exceptional situations, measurements may be carried out on all such dead trees in the stratum where trees are few and scattered out.

13. 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; or  
(b) The allometric method.

*Estimation of standing dead tree biomass using BEF method*

14. Under this method volume tables (or volume functions/curves) are used to convert tree dimensions to stem volume of trees. Stem volume of trees is converted to above-ground tree biomass using basic wood density and biomass expansion factors 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:

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

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.

$V_{TREE,j}(DBH_k, H_k)$  Stem volume of the *k*<sup>th</sup> 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<sup>3</sup>

<sup>1</sup> Adapted from IPCC GPG-LULUCF 2003: p. 4.105, section 4.3.3.5.3 DEAD ORGANIC MATTER.

<sup>2</sup> Ibid.



$DBH_k$	Diameter of the $k^{th}$ dead tree of species $j$ in plot $p$ of stratum $i$ at a point of time in year $t$ ; metre 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 $t$ ; metre or any other unit of length used by the volume function
$\alpha_k$	Biomass reduction factor for the $k^{th}$ dead tree, depending upon its category according to paragraph 11 (a) or 11 (b); dimensionless
$D_j$	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
$j$	1, 2, 3, ... tree species in plot $p$
$k$	1, 2, 3, ... dead trees of species $j$ in plot $p$ in stratum $i$
$p$	1, 2, 3, ... sample plots in stratum $i$
$i$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

15. The volume table or volume function used must be demonstrated to be appropriate for the purpose of estimation of tree biomass by applying the tool “Demonstrating appropriateness of volume equations for estimation of aboveground tree biomass in A/R CDM project activities”.

*Estimation of standing dead tree biomass using allometric method*

16. Under this method allometric equations are used to convert tree dimensions to above-ground 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:

$$B_{DWS\_TREE,j,p,i,t} = (1 + R_j) * \sum_{k=1}^K f_j(DBH_k, H_k) * \alpha_k \quad (2)$$

where:

$B_{DWS\_TREE,j,p,i,t}$	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.
$f_j(DBH_k, H_k)$	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.
$\alpha_k$	Biomass reduction factor for the $k^{th}$ dead tree, depending upon its condition according to paragraph 11(a) or 11(b); dimensionless
$R_j$	Root-shoot ratio for tree species $j$ ; dimensionless
$j$	1, 2, 3, ... tree species in plot $p$
$k$	1, 2, 3, ... dead trees of species $j$ in plot $p$ in stratum $i$



$p$	$1, 2, 3, \dots$ sample plots in stratum $i$
$i$	$1, 2, 3, \dots$ biomass estimation strata within the project boundary
$t$	$1, 2, 3, \dots$ years elapsed since the start of the A/R CDM project activity

17. The allometric equation used must be demonstrated to be appropriate for the purpose of estimation of tree biomass by applying the tool “Demonstrating appropriateness of allometric equations for estimation of aboveground tree biomass in A/R CDM project activities”.

*Estimation of carbon stock in standing dead wood in dead trees*

18. 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:

$$C_{DWS\_TREE,j,p,i,t} = \frac{44}{12} * CF_{TREE} * B_{DWS\_TREE,j,p,i,t} \quad (3)$$

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 $t$ ; tCO <sub>2</sub> e
$CF_{TREE}$	Carbon fraction of tree biomass of species $j$ ; dimensionless
$B_{DWS\_TREE,j,p,i,t}$	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.
$j$	$1, 2, 3, \dots$ tree species in plot $p$
$p$	$1, 2, 3, \dots$ sample plots in stratum $i$
$i$	$1, 2, 3, \dots$ biomass estimation strata within the project boundary
$t$	$1, 2, 3, \dots$ years elapsed since the start of the A/R CDM project activity

*Estimation of carbon stock in standing dead wood in tree stumps*

19. Each dead tree stump in a sample plot is categorized into a decay class as: (i) Sound; (ii) Intermediate; or (iii) Rotten, on the basis of a machete test.<sup>3</sup>

20. 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<sup>4</sup> of the density reduction factors for the three decay classes are used, unless PPs have more specific data available with them: for the decay class: (i) Sound, the density reduction factor = 1.00; for the decay class; (ii) Intermediate, the density reduction factor = 0.80; for the decay class; and (iii) Rotten, the density reduction factor = 0.45.

<sup>3</sup> 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.

<sup>4</sup> 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.



21. 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.

22. For stumps of height more than 4-m, the mid-height diameter of the stump is estimated<sup>5</sup> as:

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

where:

$D_{MID\_STUMP}$	Mid-height diameter of the dead tree stump; m
$DBH$	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

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

$$C_{DWS\_STUMP,j,p,i,t} = \frac{44}{12} * CF_{TREE} * D_j * (1 + R_j) * \frac{\pi}{4} \sum_k D_{MID\_STUMP,k}^2 * H_k * \beta_k \quad (5)$$

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 $t$ ; tCO <sub>2</sub> e
$CF_{TREE}$	Carbon fraction of tree biomass of species $j$ ; dimensionless
$D_j$	Basic wood density of species $j$ ; t d.m. m <sup>-3</sup>
$R_j$	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
$H_k$	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
$\beta_k$	Density reduction factor 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
$j$	1, 2, 3, ... tree species in plot $p$
$k$	1, 2, 3, ... dead trees of species $j$ in plot $p$ in stratum $i$
$p$	1, 2, 3, ... sample plots in stratum $i$
$i$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

<sup>5</sup> Adapted from Ormerod, D W, 1973. A simple bole model. *Forestry Chronicle*. 49:136-138.

### Estimation of lying dead wood

24. Lying dead wood is estimated by using line transect method (Harmon and Sexton, 1996).<sup>6</sup> Two transect lines, of total length of at least 100 m,<sup>7</sup> 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  $\geq 10$  cm) intersecting a transect line is measured.

25. 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 paragraphs 19 and 20 above.

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

$$C_{DWL,j,p,i,t} = \frac{44}{12} * CF_{TREE} * D_j * \frac{\pi^2}{8L} * \sum_{n=1}^N D_n^2 * \beta_n \quad (6)$$

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 $t$ ; tCO <sub>2</sub> e
$CF_{TREE}$	Carbon fraction of tree biomass of species $j$ ; dimensionless
$D_j$	Basic wood density of species $j$ ; t d.m. m <sup>-3</sup>
$L$	Sum of the lengths of the transect lines approximately orthogonally bisecting each other at the centre of the plot $p$ ; m
$D_n$	Diameter of the $n^{th}$ piece of lying dead wood intersecting a transect line; cm
$\beta_n$	Density reduction factor applicable to the $n^{th}$ piece of lying dead wood intersecting a transect line; dimensionless
$j$	1, 2, 3, ... tree species in plot $p$
$p$	1, 2, 3, ... sample plots in stratum $i$
$i$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

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

$$C_{DW,i,t} = \frac{A_i}{A_{PLOT,i}} \sum_p \sum_j (C_{DWS\_TREE,j,p,i,t} + C_{DWS\_STUMP,j,p,i,t} + C_{DWL,j,p,i,t}) \quad (7)$$

<sup>6</sup> 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.

<sup>7</sup> 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 20m.



where:

$C_{DW,i,t}$	Carbon stock in dead wood in stratum $i$ at a given point of time in year $t$ ; tCO <sub>2</sub> e
$A_i$	Total area of stratum $i$ ; ha
$A_{PLOT,i}$	Total area of sample plots in stratum $i$ ; ha
$C_{DWS\_TREE,j,p,i,t}$	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 $t$ ; tCO <sub>2</sub> e
$C_{DWS\_STUMP,j,p,i,t}$	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 $t$ ; tCO <sub>2</sub> e
$C_{DWL,j,p,i,t}$	Carbon stock in lying dead wood of species $j$ in sample plot $p$ in stratum $i$ at a given point of time in year $t$ ; tCO <sub>2</sub> e
$j$	1, 2, 3, ... tree species in plot $p$
$p$	1, 2, 3, ... sample plots in stratum $i$
$I$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

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

$$C_{DW,t} = \sum_i C_{DW,i,t} \quad (8)$$

where:

$C_{DW,t}$	Carbon stock in dead wood within the project boundary at a given point of time in year $t$ ; tCO <sub>2</sub> e
$C_{DW,i,t}$	Carbon stock in dead wood in stratum $i$ at a given point of time in year $t$ ; tCO <sub>2</sub> e
$i$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

***Conservative default-factor based method for estimation of carbon stock in dead wood ( $C_{DW}$ )***

29. If PPs do not wish to make sampling based measurements for estimation of C stock in dead wood, instead of the method described in paragraphs 8-29 above they may use the default method described here.

30. For all strata to which this default method is applied, the carbon stock in dead wood is estimated as:

$$C_{DW,i,t} = C_{TREE,i,t} * DF_{DW} \quad (9)$$



where:

$C_{DW,i,t}$	Carbon stock in dead wood in stratum $i$ at a given point of time in year $t$ ; tCO <sub>2</sub> e
$C_{TREE,i,t}$	Carbon stock in trees biomass in stratum $i$ at a point of time in year $t$ , as calculated in tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”; tCO <sub>2</sub> e
$DF_{DW}$	Conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass; percent
$i$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

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 III **unless transparent and verifiable information can be provided to justify a different value.**

#### Estimation of change in carbon stock in dead wood ( $\Delta C_{DW}$ )

31. The rate of change of dead wood biomass over a period of time is calculated assuming a linear change (see assumptions under Section I). Therefore, the rate of change in carbon stock in dead wood over a period of time is calculated as:

$$dC_{DW,(t_1,t_2)} = \frac{C_{DW,t_2} - C_{DW,t_1}}{T} \quad (10)$$

where:

$dC_{DW,(t_1,t_2)}$	Rate of change in carbon stock in dead wood within the project boundary during the period between a point of time in year $t_1$ and a point of time in year $t_2$ ; tCO <sub>2</sub> e yr <sup>-1</sup>
$C_{DW,t_2}$	Carbon stock in dead wood within the project boundary at a point of time in year $t_2$ ; tCO <sub>2</sub> e
$C_{DW,t_1}$	Carbon stock in dead wood within the project boundary at a point of time in year $t_1$ ; tCO <sub>2</sub> e
$T$	Time elapsed between two successive estimations ( $T=t_2 - t_1$ ); yr

32. Change in carbon stock in dead wood within the project boundary in year  $t$  ( $t_1 \leq t \leq t_2$ ) is given by:

$$\Delta C_{DW,t} = dC_{DW,(t_1,t_2)} * 1year \text{ for } t_1 \leq t \leq t_2 \quad (11)$$



where:

$\Delta C_{DW,t}$  Change in carbon stock in dead wood within the project boundary in year  $t$ ;  
t CO<sub>2</sub>-e

$dC_{DW,(t_1,t_2)}$  Rate of change in carbon stock in dead wood 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 CO<sub>2</sub>-e yr<sup>-1</sup>

### III. ESTIMATION OF C STOCK AND CHANGE IN C STOCK IN LITTER

33. 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, PPs applying this tool may use a different stratification for the purpose of estimation of carbon stock in litter if transparent and verifiable information can be given for justification of such a choice.

34. Two methods are offered for estimation of carbon stock in litter: a measurement-based method and a conservative default-based approach.

#### *Measurement based method for estimation of carbon stock in litter ( $C_{LI}$ )*

35. 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.

36. Carbon stock in litter biomass in plot  $p$  is then calculated as:

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

where:

$C_{LI,p,i,t}$  Carbon stock in litter in plot  $p$  in stratum  $i$ ; tCO<sub>2</sub>e

$CF_{LI}$  Carbon fraction of dry biomass in litter; dimensionless (IPCC default value<sup>8</sup> of 0.37 is used)

$B_{LI\_WET,p,i}$  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

Note: 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

$A_{p,i}$  Area of sample plot  $p$  of stratum  $i$ ; ha

<sup>8</sup> IPCC GPG for LULUCF, 2003, page 3.35, section 3.2.1.2.1.1 Choice of Method.

$a_{p,i}$	Area of sampling frame for plot $p$ in stratum $i$ ; $m^2$  <u>Note:</u> 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
$i$	1, 2, 3, ... biomass estimation strata within the project boundary
$p$	1, 2, 3, ... sample plots in stratum $i$
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

37. Carbon stock in litter in stratum  $i$  is then calculated as:

$$C_{LI,i,t} = \frac{A_i}{A_{PLOT,i}} \sum_p C_{LI,p,i,t} \quad (13)$$

where:

$C_{LI,i,t}$	Carbon stock in litter in stratum $i$ at a given point of time in year $t$ ; $tCO_2e$
$A_i$	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 $i$ ; $t CO_2-e$
$p$	1, 2, 3, ... sample plots in stratum $i$
$i$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

38. 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  $C_{LI,i,t}$  over all the strata, that is:

$$C_{LI,t} = \sum_i C_{LI,i,t} \quad (14)$$

where:

$C_{LI,t}$	Carbon stock in litter within the project boundary at a given point of time in year $t$ ; $t CO_2-e$
$C_{LI,i,t}$	Carbon stock in litter in stratum $i$ at a given point of time in year $t$ ; $tCO_2e$
$I$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

**Conservative default-factor based method for estimation of carbon stock in litter ( $C_{LI}$ )**

39. If the PPs do not wish to make sampling based measurements for estimation of C stock in litter, instead of the method described in paragraphs 36–39 above they may use the default method described here.

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

$$C_{LI,i,t} = C_{TREE,i,t} * DF_{LI} \quad (15)$$

where:

$C_{LI,i,t}$	Carbon stock in litter in stratum $i$ at a given point of time in year $t$ ; tCO <sub>2</sub> e
$C_{TREE,i,t}$	Carbon stock in trees biomass in stratum $i$ at a point of time in year $t$ , as calculated in tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”; tCO <sub>2</sub> e
$DF_{LI}$	Conservative default factor expressing carbon stock in litter as a percentage of carbon stock in tree biomass; percent
$i$	1, 2, 3, ... biomass estimation strata within the project boundary
$t$	1, 2, 3, ... years elapsed since the start of the A/R CDM project activity

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 III unless transparent and verifiable information can be provided to justify a different value.

**Estimation of change in carbon stock in litter ( $\Delta C_{LI}$ )**

41. The rate of change of litter biomass over a period of time is calculated assuming a linear change (see assumptions under Section I). Therefore, the rate of change in carbon stock in litter over a period of time is calculated as:

$$dC_{LI,(t_1,t_2)} = \frac{C_{LI,t_2} - C_{LI,t_1}}{T} \quad (16)$$

where:

$dC_{LI,(t_1,t_2)}$	Rate of change in carbon stock in litter within the project boundary during the period between a point of time in year $t_1$ and a point of time in year $t_2$ ; tCO <sub>2</sub> e yr <sup>-1</sup>
$C_{LI,t_2}$	Carbon stock in litter within the project boundary at a point of time in year $t_2$ ; tCO <sub>2</sub> e
$C_{LI,t_1}$	Carbon stock in litter within the project boundary at a point of time in year $t_1$ ; tCO <sub>2</sub> e
$T$	Time elapsed between two successive estimations ( $T=t_2 - t_1$ ); yr



42. Change in carbon stock in litter within the project boundary in year  $t$  ( $t_1 \leq t \leq t_2$ ) is given by:

$$\Delta C_{LL,t} = dC_{LL,(t_1,t_2)} * 1 \text{ year} \text{ for } t_1 \leq t \leq t_2 \quad (17)$$

where:

$\Delta C_{LL,t}$  Change in carbon stock in litter within the project boundary in year  $t$ ; tCO<sub>2</sub>e

$dC_{LL,(t_1,t_2)}$  Rate of change in carbon stock in litter within the project boundary during the period between a point of time in year  $t_1$  and a point of time in year  $t_2$ ; tCO<sub>2</sub>e yr<sup>-1</sup>

#### IV. DATA AND PARAMETERS USED IN THE TOOL

43. The following tables describe the data and parameters used in this tool. The guidelines contained in these tables regarding selection of data sources, and procedures to be followed in measurement, where applicable, should be treated as an integral part of this tool.

##### Data and parameters not measured

<b>Data/Parameter:</b>	$BEF_{2,j}$
<b>Data unit:</b>	Dimensionless
<b>Used in equations:</b>	1
<b>Description:</b>	Biomass expansion factor for conversion of stem biomass to above-ground biomass for tree species $j$
<b>Source of data:</b>	Values from Table 3A.1.10 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values. The source of data shall be selected, in order of preference, from the following: Local sources of species-specific data; National sources of species-specific data (e.g. national forest inventory or national GHG inventory); Species-specific data from neighbouring countries with similar conditions; Globally available data applicable to the species; IPCC default values (e.g. Table 3A.1.10 of IPCC GPG-LULUCF 2003) <sup>9</sup>
<b>Comments:</b>	$BEFs$ 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%

<sup>9</sup>—Although the  $BEFs$  in Table 3A.1.10 apply to biomass, the dimensionless factors can be equally applied for wood volume expansions.



<b>Data/Parameter:</b>	$CF_{TREE}$
Data unit:	t C t <sup>-1</sup> d.m.
Used in equations:	3, 5, 6
Description:	Carbon fraction of tree biomass for species <i>j</i>
Source of data:	A value of 0.5 shall be used unless transparent and verifiable information can be provided to justify a different value. The source of data, in order of preference, shall be the following: National level species-specific data (e.g. from national GHG inventory); Species-specific data from neighbouring countries with similar conditions; Globally available species-specific data (e.g. IPCC GPG-LULUCF 2003); The IPCC default value of 0.5 t C t <sup>-1</sup> d.m.

<b>Data/Parameter:</b>	$CF_{LI}$
Data unit:	t C t <sup>-1</sup> d.m.
Used in equations:	12
Description:	Carbon fraction of litter biomass
Source of data:	IPCC default value of 0.37 t C t <sup>-1</sup> d.m. may be used

<b>Data/Parameter:</b>	$D_j$
Data unit:	t d.m. m <sup>-3</sup>
Used in equations:	1, 5, 6
Description:	Basic wood density for species <i>j</i>
Source of data:	Values from Table 3A.1.9 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values. The source of data, in order of preference, shall be any of the following: (a) National and species-specific data (e.g. from national GHG inventory); (b) Species-specific data from neighbouring countries with similar conditions; (c) Globally available species-specific data (e.g. Table 3A.1.9 IPCC GPG-LULUCF 2003)



<b>Data/Parameter:</b>	$DF_{DW}$																								
Data unit:	percent																								
Used in equations:	9																								
Description:	Conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass																								
Source of data:	Defaults conservatively derived from Delaney et al. 1997, <sup>10</sup> Smith et al. 2006, <sup>11</sup> Glenday 2008, <sup>12</sup> Keller et al. 2004, <sup>13</sup> Eaton and Lawrence 2006, <sup>14</sup> Krankina and Harmon 1995, <sup>15</sup> and Clark et al 2002. <sup>16</sup>																								
	<table border="1"> <thead> <tr> <th>Biome</th> <th>Elevation</th> <th>Precipitation</th> <th><math>DF_{DW}</math></th> </tr> </thead> <tbody> <tr> <td>Tropical</td> <td>&lt;2000m</td> <td>&lt;1000 mm yr<sup>-1</sup></td> <td>2%</td> </tr> <tr> <td>Tropical</td> <td>&lt;2000m</td> <td>1000-1600 mm yr<sup>-1</sup></td> <td>1%</td> </tr> <tr> <td>Tropical</td> <td>&lt;2000m</td> <td>&gt;1600 mm yr<sup>-1</sup></td> <td>6%</td> </tr> <tr> <td>Tropical</td> <td>&gt;2000m</td> <td>All</td> <td>7%</td> </tr> <tr> <td>Temperate / boreal</td> <td>All</td> <td>All</td> <td>8%</td> </tr> </tbody> </table>	Biome	Elevation	Precipitation	$DF_{DW}$	Tropical	<2000m	<1000 mm yr <sup>-1</sup>	2%	Tropical	<2000m	1000-1600 mm yr <sup>-1</sup>	1%	Tropical	<2000m	>1600 mm yr <sup>-1</sup>	6%	Tropical	>2000m	All	7%	Temperate / boreal	All	All	8%
Biome	Elevation	Precipitation	$DF_{DW}$																						
Tropical	<2000m	<1000 mm yr <sup>-1</sup>	2%																						
Tropical	<2000m	1000-1600 mm yr <sup>-1</sup>	1%																						
Tropical	<2000m	>1600 mm yr <sup>-1</sup>	6%																						
Tropical	>2000m	All	7%																						
Temperate / boreal	All	All	8%																						

<b>Data/Parameter:</b>	$DF_{LI}$																								
Data unit:	%																								
Used in equations:	15																								
Description:	Default factor for the relationship between carbon stock in litter and carbon stock in living trees																								
Source of data:	Defaults conservatively derived from sources cited above:																								
	<table border="1"> <thead> <tr> <th>Biome</th> <th>Elevation</th> <th>Precipitation</th> <th><math>DF_{LI}</math></th> </tr> </thead> <tbody> <tr> <td>Tropical</td> <td>&lt;2000m</td> <td>&lt;1000 mm yr<sup>-1</sup></td> <td>4%</td> </tr> <tr> <td>Tropical</td> <td>&lt;2000m</td> <td>1000-1600 mm yr<sup>-1</sup></td> <td>1%</td> </tr> <tr> <td>Tropical</td> <td>&lt;2000m</td> <td>&gt;1600 mm yr<sup>-1</sup></td> <td>1%</td> </tr> <tr> <td>Tropical</td> <td>&gt;2000m</td> <td>All</td> <td>1%</td> </tr> <tr> <td>Temperate / boreal</td> <td>All</td> <td>All</td> <td>4%</td> </tr> </tbody> </table>	Biome	Elevation	Precipitation	$DF_{LI}$	Tropical	<2000m	<1000 mm yr <sup>-1</sup>	4%	Tropical	<2000m	1000-1600 mm yr <sup>-1</sup>	1%	Tropical	<2000m	>1600 mm yr <sup>-1</sup>	1%	Tropical	>2000m	All	1%	Temperate / boreal	All	All	4%
Biome	Elevation	Precipitation	$DF_{LI}$																						
Tropical	<2000m	<1000 mm yr <sup>-1</sup>	4%																						
Tropical	<2000m	1000-1600 mm yr <sup>-1</sup>	1%																						
Tropical	<2000m	>1600 mm yr <sup>-1</sup>	1%																						
Tropical	>2000m	All	1%																						
Temperate / boreal	All	All	4%																						

<sup>10</sup> Delaney, M., Brown, S., Lugo, A.E., Torres-Lezama, A. and Bello Quintero, N. 1997. The distribution of organic carbon in major components of forests located in five life zones of Venezuela. *Journal of Tropical Ecology* 13: 697-708.

<sup>11</sup> Smith, James E.; Heath, Linda S.; Skog, Kenneth E.; Birdsey, Richard A. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States*. Forest Service, Northeastern Research Station, General Technical Report NE-343. 216 p.

<sup>12</sup> Glenday, J. 2008. Carbon storage and emissions offset potential in an African dry forest, the Arabuko-Sokoke Forest, Kenya. *Environ. Monit. Assess* 142: 85-95.

<sup>13</sup> Keller, M., Palace, M., Asner, G., Pereira Jr, R. and Silva, JNM. 2004. Coarse woody debris in undisturbed and logged forests in eastern Brazilian Amazon. *Global Change Biology* 10: 784-795.

<sup>14</sup> Eaton, J.M. and Lawrence, D. 2006. Woody debris stocks and fluxes during succession in a dry tropical forest. *Forest Ecology and Management* 232: 46-55.

<sup>15</sup> Krankina, O.N., Harmon, M.E., 1995. Dynamics of the dead wood carbon pool in northwestern Russian boreal forests. *Water Air Soil Pollut.* 82,227–238.

<sup>16</sup> Clark, D.B., Clark, D.A., Brown, S., Oberbauer, S.F., Veldkamp, E., 2002. Stocks and flows of coarse woody debris across a tropical rain forest nutrient and topography gradient. *Forest Ecol. Manage.* 5646, 1-112.



<b>Data/Parameter:</b>	$R_j$
Data unit:	Dimensionless
Used in equations:	1, 2, 5
Description:	Root-shoot ratio for species $j$
Source of data:	<p>The source of data, in order of preference, shall be any of the following:</p> <p>(a) Existing local species-specific data;</p> <p>(b) National species-specific data (e.g. national forest inventory or national GHG inventory);</p> <p>(c) Species-specific data from neighbouring countries with similar conditions;</p> <p>(d) Globally available species-specific data.</p> <p>If none of the above sources are available, then the value of <math>R_j</math> may shall be calculated as <math>R = \exp[-1.085 + 0.9256 \cdot \ln(A)]/A</math>, where <math>A</math> is above-ground biomass (t d.m. ha<sup>-1</sup>) [Source: Table 4.A.4 of IPCC GPG-LULUCF 2003] unless transparent and verifiable information can be provided to justify a different value</p>

#### Data and parameters measured

<b>Data/Parameter:</b>	$A_i$
Data unit:	ha
Used in equations:	7, 13
Description:	Area of stratum $i$
Source of data:	Field measurement
Measurement procedures:	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied

<b>Data/Parameter:</b>	$A_{PLOT,i}$
Data unit:	ha
Used in equations:	7, 12, 13
Description:	Total area of sample plots in stratum $i$
Source of data:	Field measurement
Measurement procedures:	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied





<b>Data/Parameter:</b>	$a_{p,i}$
Data unit:	m <sup>2</sup>
Used in equations:	12
Description:	Area of litter sampling frame used in plot $p$ in stratum $i$
Source of data:	Measurement
Measurement procedures:	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In absence of these, SOPs from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied
Comments:	Often a litter sampling frame of 0.50 m <sup>2</sup> is used

<b>Data/Parameter:</b>	$B_{LI\_WET,p,i}$
Data unit:	Kg
Used in equations:	12
Description:	Wet weight of the composite litter sample collected from plot $p$ of stratum $i$ ; kg
Source of data:	Field measurements in sample plots
Measurement procedures:	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied

<b>Data/Parameter:</b>	$DBH$
Data unit:	cm or any unit of length as specified
Used in equations:	1, 2, 4
Description:	Diameter at breast height of a tree. For the purpose of Equations (1) and (2), $DBH$ could be any other diameter or dimensional measurement (e.g. basal diameter, root-collar diameter, basal area, etc.) applicable for the model or data source used
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In absence of these, SOPs from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied



Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied

<b>Data/Parameter:</b>	$D_n$
Data unit:	cm
Used in equations:	6
Description:	Diameter of the $n^{\text{th}}$ piece of lying dead wood intersecting a transect line
Source of data:	Field measurements along transect lines in sample plots
Measurement procedures:	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In absence of these, SOPs from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied

<b>Data/Parameter:</b>	$H$
Data unit:	m or any other unit of length as specified
Used in equations:	1, 2, 4, 5
Description:	Height of tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the <i>IPCC GPG LULUCF 2003</i> , may be applied

<b>Data/Parameter:</b>	$T$
Data unit:	Year
Used in equations:	10, 16
Description:	Time period elapsed between two successive estimations of carbon stock
Source of data:	Recorded time
Measurement procedures :	N/A
Comments:	If the two successive estimations of carbon stock 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 $T$

**IV. References**

All references are quoted in footnotes.

-----

**History of the document**

<b>Version</b>	<b>Date</b>	<b>Nature of revision</b>
02.0.0	EB 67, Annex # 11 May 2012	The revision: (i) Incorporates the use of the tools “Demonstrating appropriateness of allometric equations for estimation of aboveground tree biomass in A/R CDM project activities” and “Demonstrating appropriateness of volume equations for estimation of aboveground tree biomass in A/R CDM project activities”; (ii) Uses a fixed value of carbon fraction for tree biomass across all tree species; (iii) Allows use of more specific values of the parameters $DF_{DW}$ and $DF_{LJ}$ instead of the default values provided in the tool; and (iv) Enhances the clarity of the text in some paragraphs.
01.1.0	EB 58, Annex 14 26 November 2010	The revision: (i) excludes estimation of emissions from the scope of the tool as this is dealt with in another approved tool; (ii) introduces simplified methods for estimation of carbon stock in some components of dead wood; (iii) provides for the option of default-factor based estimation of carbon stock in dead wood and litter; (iv) streamlines the general presentation of the tool with the recently approved tools; and (v) changes the title to “Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities” from the previous title “Tool for estimation of Carbon Stocks, Removals and Emissions for the Dead Organic Matter Pools due to Implementation of a CDM A/R Project Activity”. Due to overall modification of the document, no highlights of the changes are provided.
01	EB 41, Annex 14 02 August 2008	Initial adoption.
<b>Decision Class:</b> Regulatory <b>Document Type:</b> Tool <b>Business Function:</b> Methodology		