CLEAN DEVELOPMENT MECHANISM

AR-TOOL12

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 03.1

United Nations
Framework Convention on
Climate Change

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1. Introduction

1. This tool provides a step-by-step method for estimating carbon stocks and change in carbon stocks in dead wood and/or litter in the baseline and project scenarios of an afforestation or reforestation (A/R) project activity under the clean development mechanism (CDM). The tool provides methods based on field measurements. Simplified methods based on conservative default factors are also available where certain conditions are met.

2. Scope, applicability, and entry into force

2.1. Scope

2. This tool can be used for 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.

2.2. Applicability

3. This tool has no internal applicability conditions.

4. 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.

2.3. Entry into force

5. The date of entry into force is the date of the publication of the EB 85 meeting report on 24 July 2015.

3. Normative references

6. The following documents are indispensable for the application of this tool:

    (a) Glossary of CDM terms;

    (b) Tool “Demonstrating appropriateness of volume equations for estimation of aboveground tree biomass in A/R CDM project activities”;

    (c) Tool “Demonstrating appropriateness of allometric equations for estimation of aboveground tree biomass in A/R CDM project activities”;

(d) Tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”.

4. Definitions

7. The definitions contained in the Glossary of CDM terms shall apply. Where a term is not defined in the Glossary of CDM terms, project participants should consult the definitions provided in the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC GPG-LULUCF 2003).

5. Parameters

8. This tool provides procedures to determine the following parameters:

Table 1. Parameters determined by the tool

Parameter	SI Unit	Description
$C_{DW,t}$	t CO_2e	Carbon stock in dead wood within the project boundary at a given point of time in year *t*
$\Delta C_{DW,t}$	t CO_2e	Change in carbon stock in dead wood within the project boundary in year *t*
$C_{LI,t}$	t CO_2e	Carbon stock in litter within the project boundary at a given point of time in year *t*
$\Delta C_{LI,t}$	t CO_2e	Change in carbon stock in litter within the project boundary in year *t*

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

(a) 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 $\Delta C_{LI,t}$

(b) 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 $\Delta C_{LI,t}$

6. Estimation of carbon stock and change in carbon stock in dead wood

10. 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, project participants (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.

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

6.1. Measurement-based methods for estimation of carbon stock in dead wood

12. 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.

13. 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.

6.1.1. Standing dead wood

14. 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.[2]

15. For dead trees and stumps which do not conform to the categories under paragraph 14, biomass is estimated using the method described in paragraphs 23–27.

16. For all dead trees falling in the categories mentioned under paragraph 14, 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.

17. 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.

[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.

[2] Ibid.

6.1.1.1. Estimation of standing dead tree biomass using *BEF* method

18. 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:

$$B_{DWS\_TREE,j,p,i,t} = D_j \times BEF_{2,j} \times (1 + R_j) \times \sum_{k=1}^{K} V_{TREE,j}\,(DBH_{k,}H_k) \times \alpha_k \qquad \text{Equation (1)}$$

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.
$V_{TREE,j}(DBH_{k,}H_k)$	=	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*; 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
α_k	=	Biomass reduction factor for the k^{th} dead tree, depending upon its category according to paragraph 14; 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

19. 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”.

6.1.1.2. Estimation of standing dead tree biomass using allometric method

20. 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:

$$B_{DWS\_TREE,j,p,i,t} = (1 + R_j) \times \sum_{k=1}^{K} f_j\ (DBH_{k,}H_k) \times \alpha_k \qquad \text{Equation (2)}$$

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.
α_k	=	Biomass reduction factor for the k^{th} dead tree, depending upon its condition according to paragraph 14; 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

21. 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".

6.1.1.3. Estimation of carbon stock in standing dead wood in dead trees

22. 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:

$$C_{DWS\_TREE,j,p,i,t} = \frac{44}{12} \times CF_{TREE} \times B_{DWS\_TREE,j,p,i,t} \qquad \text{Equation (3)}$$

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
CF_{TREE}	=	Carbon fraction of tree biomass; 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, …* 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

6.1.1.4. Estimation of carbon stock in standing dead wood in tree stumps

23. 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.[3]

24. 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[4] 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: (a) Sound, the density reduction factor = 1.00; for the decay class; (b) Intermediate, the density reduction factor = 0.80; for the decay class; and (c) Rotten, the density reduction factor = 0.45.

25. 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.

26. For stumps of height more than 4 m, the mid-height diameter of the stump is estimated[5] 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
DBH	=	Diameter at breast height of the dead tree stump; m

3 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.

4 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.

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

H_{STUMP}	=	Height of the stump; m
H_{DBH}	=	Height above ground level at which DBH is measured; m

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

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

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
CF_{TREE}	=	Carbon fraction of tree biomass; dimensionless
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
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
β_k	=	Density reduction factor (per paragraph 24) 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

6.1.2. Lying dead wood

28. Lying dead wood is estimated by using line transect method (Harmon and Sexton, 1996).[6] Two transect lines, of total length of at least 100 m,[7] 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.

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

[7] 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.

29. 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 23 and 24.

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

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

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
a_{PLOT}	=	Area of the sample plot p; ha
CF_{TREE}	=	Carbon fraction of tree biomass; dimensionless
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
D_n	=	Diameter of the *n^th^* piece of lying dead wood intersecting a transect line; cm
β_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

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

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

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
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*; t CO_2e
$C_{DWS\_STUMP,j,p,i,t}$	=	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
$C_{DWL,j,p,i,t}$	=	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
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

32. 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:

$$C_{DW,t} = \sum_{i} C_{DW,i,t}$$ 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
$C_{DW,i,t}$	=	Carbon stock in dead wood in stratum *i* at a given point of time in year *t*; t CO_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

6.2. Conservative default-factor based method for estimation of carbon stock in dead wood

33. If PPs 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.

34. 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

$C_{TREE,i,t}$	=	Carbon stock in trees biomass in stratum *i* at a point of time in year *t*, as calculated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO_2e
DF_{DW}	=	Conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass; per cent
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

35. 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 8 unless transparent and verifiable information can be provided to justify a different value.

6.3. Change in carbon stock in dead wood

36. 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:

$$dC_{DW,(t_1,t_2)} = \frac{C_{DW,t_2} - C_{DW,t_1}}{T}$$ Equation (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; t CO_2e yr^{-1}
C_{DW,t_2}	=	Carbon stock in dead wood within the project boundary at a point of time in year t_2; t CO_2e
C_{DW,t_1}	=	Carbon stock in dead wood within the project boundary at a point of time in year t_1; t CO_2e
T	=	Time elapsed between two successive estimations ($T=t_2 - t_1$); yr

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

$$\Delta C_{DW,t} = dC_{DW,(t_1t_2)} \times 1year \text{ for } t_1 \leq t \leq t_2$$ Equation (11)

Where:

$\Delta C_{DW,t}$	=	Change in carbon stock in dead wood within the project boundary in year *t*; t CO_2e
$dC_{DW,(t_1t_2)}$	=	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_2e yr^{-1}

7. Estimation of carbon stock and change in carbon stock in litter

38. 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.

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

7.1. Measurement-based method for estimation of carbon stock in litter

40. 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.

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

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

Where:

$C_{LI,p,i,t}$	=	Carbon stock in litter in plot *p* in stratum *i*; t CO_2e
CF_{LI}	=	Carbon fraction of dry biomass in litter; dimensionless (IPCC default value[8] 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

[8] 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 Note: The numerical factor 2.5 appears in this equation because of coversion 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

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

$$C_{LI,i,t} = \frac{A_i}{A_{PLOT,i}} \sum_{p} C_{LI,p,i,t} \qquad \text{Equation (13)}$$

Where:

$C_{LI,i,t}$	=	Carbon stock in litter in stratum *i* at a given point of time in year *t*; t CO_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_2e
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

43. 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:

$$C_{LI,t} = \sum_{i} C_{LI,i,t} \qquad \text{Equation (14)}$$

Where:

$C_{LI,t}$	=	Carbon stock in litter within the project boundary at a given point of time in year *t*; t CO_2e
$C_{LI,i,t}$	=	Carbon stock in litter in stratum *i* at a given point of time in year *t*; t CO_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

7.2. Conservative default-factor based method for estimation of carbon stock in litter

44. If PPs do not wish to make sampling based measurements for estimation of C 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 boundary through any type of anthropogenic activities.

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

$$C_{LI,i,t} = C_{TREE,i,t} \times DF_{LI} \qquad \text{Equation (15)}$$

Where:

$C_{LI,i,t}$	=	Carbon stock in litter in stratum *i* at a given point of time in year *t*; t CO_2e
$C_{TREE,i,t}$	=	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”; t CO_2e
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

46. 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 8 unless transparent and verifiable information can be provided to justify a different value.

7.3. Change in carbon stock in litter

47. 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:

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

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; t CO_2e yr^{-1}
C_{LI,t_2}	=	Carbon stock in litter within the project boundary at a point of time in year t_2; t CO_2e

C_{LI,t_1}	=	Carbon stock in litter within the project boundary at a point of time in year t_1; t CO_2e
T	=	Time elapsed between two successive estimations ($T=t_2 - t_1$); yr

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

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

Where:

$\Delta C_{LI,t}$	=	Change in carbon stock in litter within the project boundary in year t; t CO_2e
$dC_{LI,(t_1,t_2)}$	=	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; t CO_2e yr^{-1}

8. Data and parameters used in the tool

49. 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.

8.1. Data and parameters not measured

Data / Parameter table 1.

Data / Parameter:	$\mathbf{BEF_{2,j}}$
Data unit:	Dimensionless
Used in equations:	1
Description:	Biomass expansion factor for conversion of stem biomass to above-ground biomass for tree species *j*
Source of data:	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
Measurement procedures (if any):	-
Any comment:	*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 per cent

Data / Parameter table 2.

Data / Parameter:	$\mathbf{CF_{TREE}}$
Data unit:	t C t^{-1} d.m.
Used in equations:	3, 5, 6

Description:	Carbon fraction of tree biomass
Source of data:	A value of 0.5 shall be used unless transparent and verifiable information can be provided to justify a different value
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 3.

Data / Parameter:	$\mathbf{CF_{LI}}$
Data unit:	t C t^{-1} d.m.
Used in equations:	12
Description:	Carbon fraction of litter biomass
Source of data:	IPCC default value of 0.37 t C t^{-1} d.m. may be used
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 4.

Data / Parameter:	$\mathbf{D_J}$
Data unit:	t d.m. m^{-3}
Used in equations:	1, 5, 6
Description:	Basic wood density for species *j*
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
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	$\mathbf{DF_{DW}}$
Data unit:	Per cent
Used in equations:	9
Description:	Conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass

<table>
<tr><td>Source of data:</td><td>Defaults conservatively derived from Delaney et al. 1997,[9] Smith et al. 2006,[10] Glenday 2008,[11] Keller et al. 2004,[12] Eaton and Lawrence 2006,[13] Krankina and Harmon 1995,[14] and Clark et al 2002:[15]
<table>
<tr><th>Biome</th><th>Elevation</th><th>Precipitation</th><th>$\mathbf{DF_{DW}}$</th></tr>
<tr><td>Tropical</td><td><2000m</td><td><1000 mm yr^{-1}</td><td>2%</td></tr>
<tr><td>Tropical</td><td><2000m</td><td>1000-1600 mm yr^{-1}</td><td>1%</td></tr>
<tr><td>Tropical</td><td><2000m</td><td>>1600 mm yr^{-1}</td><td>6%</td></tr>
<tr><td>Tropical</td><td>>2000m</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>Measurement procedures (if any):</td><td>-</td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

Data / Parameter table 6.

Data / Parameter:	$\mathbf{DF_{LI}}$
Data unit:	Per cent
Used in equations:	15
Description:	Default factor for the relationship between carbon stock in litter and carbon stock in living trees

9 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.

10 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.

11 Glenday, J. 2008. Carbon storage and emissions offset potential in an African dry forest, the Arabuko-Sokoke Forest, Kenya. Envion. Monit. Assess 142: 85-95.

12 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.

13 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.

14 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.

15 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.

<table>
<tr><td>Source of data:</td><td>Defaults conservatively derived from sources cited above:
<table><tr><th>Biome</th><th>Elevation</th><th>Precipitation</th><th>DF_{LI}</th></tr><tr><td>Tropical</td><td><2000m</td><td><1000 mm yr^{-1}</td><td>4%</td></tr><tr><td>Tropical</td><td><2000m</td><td>1000-1600 mm yr^{-1}</td><td>1%</td></tr><tr><td>Tropical</td><td><2000m</td><td>>1600 mm yr^{-1}</td><td>1%</td></tr><tr><td>Tropical</td><td>>2000m</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>Measurement procedures (if any):</td><td>-</td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

Data / Parameter table 7.

Data / Parameter:	R_J
Data unit:	Dimensionless
Used in equations:	1, 2, 5
Description:	Root-shoot ratio for species *j*
Source of data:	The value of R_j shall be calculated as: $R = exp[-1.085+0.9256 \times ln(A)]/A$, where A is above-ground biomass (t d.m. ha^{-1}) [Source: Table 4.A.4 of IPCC GPG-LULUCF 2003] unless transparent and verifiable information can be provided to justify a different value
Measurement procedures (if any):	-
Any comment:	-

8.2. Data and parameters measured

Data / Parameter table 8.

Data / Parameter:	A_i
Data unit:	ha
Used in equations:	7, 13
Description:	Area of stratum *i*
Source of data:	Field measurement
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 IPCC GPG LULUCF 2003, 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 IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 9.

Data / Parameter:	$\mathbf{A_{PLOT,i}}$
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 (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 IPCC GPG LULUCF 2003, 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 IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 10.

Data / Parameter:	$\mathbf{a_{p,i}}$
Data unit:	m^2
Used in equations:	12
Description:	Area of litter sampling frame used in plot *p* in stratum *i*
Source of data:	Measurement
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 IPCC GPG LULUCF 2003, 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 IPCC GPG LULUCF 2003, may be applied
Any comment:	Often a litter sampling frame of 0.50 m^2 is used

Data / Parameter table 11.

Data / Parameter:	$\mathbf{B_{LI\_WET,p,i}}$
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 (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 IPCC GPG LULUCF 2003, 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 IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 12.

Data / Parameter:	$\mathbf{DBH}$
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 the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, 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 IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 13.

Data / Parameter:	$\mathbf{D}_{\boldsymbol{n}}$
Data unit:	cm
Used in equations:	6
Description:	Diameter of the n^{th} piece of lying dead wood intersecting a transect line
Source of data:	Field measurements along transect lines 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 IPCC GPG LULUCF 2003, 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 IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 14.

Data / Parameter:	**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 IPCC GPG LULUCF 2003, 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 IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 15.

Data / Parameter:	**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 (if any):	N/A
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	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

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Document information

Version	Date	Description
03.1	24 July 2015	EB 85, Annex 23 Minor revision to correct paragraph 30, equation 6, the parameter a_{PLOT} has been included.
03.0	4 October 2013	EB 75, Annex 27 The revision introduces conditions under which the conservative default-factor based method for estimation of carbon stock in dead wood and litter can be used.
02.0.0	11 May 2012	EB 67, Annex 23 The revision: • 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”; • Uses a fixed value of carbon fraction for tree biomass across all tree species; • Allows use of more specific values of the parameters DF_{DW} and DF_{LI} instead of the default values provided in the tool; and • Enhances the clarity of the text in some paragraphs.
01.1.0	26 November 2010	EB 58, Annex 14 The revision: • Excludes estimation of emissions from the scope of the tool as this is dealt with in another approved tool; • Introduces simplified methods for estimation of carbon stock in some components of dead wood; • Provides for the option of default-factor based estimation of carbon stock in dead wood and litter; • Streamlines the general presentation of the tool with the recently approved tools; and • 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	2 August 2008	EB 41, Annex 14 Initial adoption.

Decision Class: Regulatory
Document Type: Tool

Version	Date	Description

Business Function: Methodology
Keywords: afforestation reforestation, AR project activity, biomass, carbon pools