REDD Methodological Module

"Estimation of carbon stocks in the dead wood pool" – CP-D

Version - April 2010

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module allows for ex ante estimation of carbon stocks in dead wood in the baseline case (for both pre- and post-deforestation stocks) and project case.

Applicability

This module is applicable to all forest types and age classes. This module is applicable if the dead wood pool is included as part of the project boundary as per applicability criteria in the framework module REDD-MF, specifically:

- Dead wood shall be included if stocks are greater in the baseline than in the project scenario (in conformance with REDD-MF), and
- Dead wood shall be included if determined to be significant (using the X-SIG module).

Parameters

This module produces the following parameter:

Parameter	SI Unit	Description
$C_{DW,i,t}$	t CO_2-e ha^{-1}	Carbon stock in dead wood in strata *i* at time *t*

II. PROCEDURES

Frequency of measurement for baseline dead wood stocks

Measurements of initial stocks employed in the baseline must take place within ±5 years of the project start date, for simplicity referred to here as stocks at t=0.

Dead wood stock estimates are valid in the baseline (i.e. treated as constant) for 10 years, after which they must be re-estimated from new field measurements (in both the project area and where applicable in the leakage belt). For each stratum, where the re-measured estimate is within the 90% confidence interval of the t=0 estimate, the t=0 stock estimate takes precedence and is re-employed, and where the re-measured estimate is outside (i.e. greater than or less than) the 90% confidence interval of the t=0 estimate, the new stock estimate takes precedence and is used for the subsequent period.

Estimation of carbon stocks of dead wood

The mean carbon stock in dead wood per unit area at time *t* is estimated based on field measurements fixed area plots or sample points using prisms or relascopes, and line transects, employing representative random or systematic sampling.

Dead wood included in the methodology comprises two components – *standing dead wood that is fully dead* (i.e. absence of green leaves and green cambium) and *lying dead wood*. Considering the differences in the two components, different sampling and estimation procedures shall be used to calculate stocks in dead wood biomass of the two components.

The methods to be followed in the measurement of the standing dead wood and the lying dead wood biomass are outlined below. Procedures are the same for estimation of baseline ($C_{BSL,DW,i,t}$) and project stocks ($C_{ACTUAL,DW,i,t}$).

Part 1: Standing Dead Wood

Step 1. Estimation of biomass of standing dead trees

Step 1.1: Standing dead trees shall be measured using the same criteria (eg minimum DBH) used for measuring live trees. Stumps must be inventoried as if they are very short standing dead trees.

Step 1.2: The decomposition class (not to be confused with dead wood density class) of the dead tree shall be recorded and the standing dead wood is categorized under two decomposition classes:

1. Tree with branches and twigs that resembles a live tree (except for leaves);
2. Tree with signs of decomposition (other than loss of leaves) including loss of twigs, branches, or crown.

Step 1.3: Biomass is estimated using an allometric equation or BCEF calculation for live trees in the decomposition class 1; with no outward signs of decomposition (i.e. twigs remaining) wood density is assumed to be comparable to live tree. Calculations are detailed in the module for aboveground biomass. In decomposition class 2, the estimate of biomass should be limited to the main trunk (bole) of the tree, in which case the biomass is calculated converting volume to biomass *using the appropriate dead wood density class*. Volume is estimated as either the volume of a cone if the top diameter cannot be measured (and is assumed to be zero), or a cylinder (using Smalian's formula) if the top diameter can be measured directly or by using an instrument such as a relascope or laser inventory instrument or estimated using a taper function. Height/length is determined as either the total height in case of a standing bole or the height at the base of the crown if the crown is persistent.

For decomposition class 2, the biomass of standing dead trees is estimated either as (where top diameter is not measured):

$$B_{SDWl,sp,i,t} = \frac{1}{3} * \pi * \left(\frac{BDia_{SDWl,sp,i,t}}{200} \right)^2 * H_{SDWl,sp,i,t} * D_{DWdc} \quad (1)$$

Where:

$B_{SDWl,sp,i,t}$	Biomass of standing dead tree *l* from sample plot/point *sp* in stratum *i* at time *t*; t d.m.
$BDia_{SDWl,sp,i,t}$	Basal diameter of standing dead tree *l* from sample plot/point *sp* in stratum *i* at time *t*; cm
$H_{SDWl,sp,i,t}$	Height of standing dead tree *l* from sample plot/point *sp* in stratum *i* at time *t*; m
$D_{DW,dc}$	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
sp	*1, 2, 3 … P_i* sample plots/points in stratum *i*
i	*1, 2, 3 … M* strata in the project scenario
t	*0, 1, 2, 3 … t* years elapsed since the start of the project activity

or (where top diameter is measured):

$$B_{SDWl,sp,i,t} = \frac{BDia_{SDWl,sp,i,t} + TD_{SDWl,sp,i,t}}{200} * H_{SDWl,sp,i,t} * D_{DWdc} \quad (2)$$

Where:

$B_{SDWl,sp,i,t}$	Biomass of standing dead tree *l* from sample plot/point *sp* in stratum *i* at time *t*; t d.m.
$BDia_{SDWl,sp,i,t}$	Basal diameter of standing dead tree *l* from sample plot/point *sp* in stratum *i* at time *t*; cm

$TD_{SDWl,sp,i,t}$	Top diameter of standing dead tree *l* from sample plot/point *sp* in stratum *i* at time *t*; cm
$H_{SDWl,sp,i,t}$	Height of standing dead tree *l* from sample plot/point *sp* in stratum *i* at time *t*; m
D_{DWdc}	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
sp	*1, 2, 3 … P_i* sample plots/points in stratum *i*
i	*1, 2, 3 … M* strata in the project scenario
t	*0, 1, 2, 3 … t* years elapsed since the start of the project activity

Step 2. Estimation of biomass stock per unit area in standing dead wood

Two methods are available for sampling: either Fixed Area Plots and Point Sampling with Prisms or Relascopes.

Step 2, Option 1. Fixed Area Plots

Step 2.1: Determine the biomass of each standing dead tree present in the sample plot *sp* in stratum *i* at time *t* ($B_{SDWl,sp,i,t}$).

Step 2.2: Calculate total biomass stock in standing dead trees present in the sample plot *sp* in stratum *i* at time *t*.

$$B_{SDWsp,i,t} = \sum_{l=1}^{N_{sp,i,t}} B_{SDWl,sp,i,t} \quad (3)$$

Where:

$B_{SDWsp,i,t}$	Biomass of standing dead wood in sample plot *sp* in stratum *i* at time *t*; t d.m.
$B_{SDWl,sp,i,t}$	Biomass of standing dead tree *l* in sample plot *sp* in stratum *i* at time *t*; t d.m.
sp	*1, 2, 3 … P_i* sample plots in stratum *i*
i	*1, 2, 3 … M* strata
t	*0, 1, 2, 3 … t* years elapsed since the start of the project activity
$N_{sp,i,t}$	Number of standing dead trees in sample plot *sp* of stratum *i* at time *t*
l	*1, 2, 3 … $N_{i,sp,t}$* standing dead trees in sample plot *sp* of stratum *i* at time *t*

Step 2.3: Calculate the mean biomass stock per unit area in standing dead wood for each stratum at time *t*:

$$B_{SDWi,t} = \frac{1}{A_{sp,i}} * \sum_{sp=1}^{P_i} B_{SDWsp,i,t} \tag{4}$$

Where:

$B_{SDWi,t}$	Mean biomass of standing dead wood in stratum *i* at time *t*; t d.m. ha^{-1}
$B_{SDWsp,i,t}$	Biomass of standing dead wood in sample plot *sp* in stratum *i* at time *t*; t d.m.
Asp_i	Total area of all sample plots in stratum *i*; ha*sp* 1, 2, 3 … P_i sample plots in stratum *i*
i	*1, 2, 3 … M* strata
t	*0, 1, 2, 3 … t* years elapsed since the start of the project activity

Step 2, Option 2. Point Sampling

Step 2.1: Determine the biomass of each standing dead tree from sample point *sp* in stratum *i* at time *t* ($B_{SDWl,sp,i,t}$).

Step 2.2: Calculate total biomass stock in standing dead trees from sample point *sp* in stratum *i* at time *t*.

$$B_{SDWsp,i,t} = \sum_{l=1}^{N_{j,sp,i,t}} \frac{B_{SDWl,sp,i,t}}{(3.1415/10000)*((DBH/100)*D:RAD)^2} \tag{5}$$

Where:

$B_{SDWsp,i,t}$	Biomass of standing dead wood per unit area at point *sp* in stratum *i* at time *t*; t d.m. ha^{-1}
$B_{SDWl,sp,i,t}$	Biomass of standing dead tree *l* from sample point *sp* in stratum *i* at time *t*; t d.m.
DBH	Diameter at breast height of standing dead tree *l* at point *sp* in stratum *i* at time *t*, cm
D:RAD	Ratio of DBH to plot radius, specific to prism Basal Area Factor (BAF) employed in point sampling
l	*1, 2, 3, …* $N_{j,sp,i,t}$ sequence number of individual standing dead trees at point *sp* in stratum *i* at time *t*
i	*1, 2, 3, …M* strata

t	*0, 1, 2, 3 …* years elapsed since start of the project activity

Step 2.3: Calculate the mean biomass stock per unit area in standing dead wood for each stratum at time *t*:

$$B_{SDWi,t} = \frac{1}{N} * \sum_{sp=1}^{P_i} B_{SDWsp,i,t} \quad (6)$$

Where:

$B_{SDWi,t}$	Mean biomass of standing dead wood in stratum *i* at time *t*; t d.m. ha^{-1}
$B_{SDWsp,i,t}$	Biomass of standing dead wood at point *sp* in stratum *i* at time *t*; t d.m. ha^{-1}
N	Number of sample points in stratum *i*; dimensionless
sp	*1, 2, 3 … P_i* sample points in stratum *i*
i	*1, 2, 3 … M* strata
t	*0, 1, 2, 3 …* years elapsed since the start of the project activity

Part 2: Lying Dead Wood

Step 1: Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996)[1]. Two 50-meter lines (164 ft) are established bisecting each sample plot and the diameters of the lying dead wood (≥ 10 cm diameter [≥ 3.9 inches]) intersecting the lines are measured. The first line is oriented along a random bearing, the second line is oriented perpendicular to the first.

Step 2: The dead wood is assigned to one of the three density states (sound, intermediate and rotten) using the 'machete test', as recommended by *IPCC Good Practice Guidance for LULUCF* (2003), Section 4.3.3.5.3. Dead wood density class (*dc*) is assessed at the point of intersection with the sample line, as per measured parameters section below.

Step 3: The volume of lying dead wood per unit area is estimated using the equation (Warren and Olsen 1964)[2] as modified by Van Wagner (1968)[3] separately for each density state:

---

[1] Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of wood detritus in forest ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

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

$$V_{LDWdc,i,t} = \frac{\pi^2 * \left(\sum_{n=1}^{N} Dia_{dc,n,i,t}{}^2 \right)}{8 * L} \tag{7}$$

Where:

$V_{LDWi,t}$	Volume of lying dead wood per unit area in density class *dc* in stratum *i* at time *t*; m^3 ha^{-1}
$Dia_{n,i,t}$	Diameter of piece n of dead wood along the transect in stratum *i* at time *t;* cm
n	*1, 2, 3, … N* sequence number of wood pieces in density class *dc* intersecting the transect
L	Length of the transect; 100 m
dc	dead wood density class – sound (1), intermediate (2), and rotten (3); dimensionless
i	*1, 2, 3 … M* strata in the project scenario
t	*0, 1, 2, 3 … t* years elapsed since the start of the project activity

Step 4: Volume of lying dead wood shall be converted into biomass using the following relationship. Density of each dead wood density class (D_{DWdc}) is estimated as per guidance in measured parameters section below.

$$B_{LDWi,t} = \sum_{dc=1}^{3} V_{LDWdc,i,t} * D_{DWdc} \tag{8}$$

Where:

$B_{LDWi,t}$	Biomass of lying dead wood per unit area in stratum *i* at time *t*; d.m. ha^{-1}
$V_{LDWdc,i,t,}$	Volume of lying dead wood per unit area in density class *dc* in stratum *i* at time *t*; m^3 ha^{-1}
D_{DWdc}	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
dc	dead wood density class – sound (1), intermediate (2), and rotten (3); dimensionless
i	*1, 2, 3 … M* strata in the project scenario
t	*0, 1, 2, 3 … t* years elapsed since the start of the project activity

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

Step 5: Mean carbon stock in dead wood for each stratum is then calculated as the sum of standing and lying dead wood components, converted to carbon dioxide equivalents

$$C_{DWi,t} = \left(\left(B_{SDWi,t} + B_{LDWi,t}\right) * CF_{DW}\right) * \frac{44}{12} \qquad (9)$$

where:

$C_{DWi,t}$	Mean carbon stock of dead wood in stratum *i* at time *t*; t CO_2-e ha^{-1}
$B_{SDWi,t}$	Biomass of standing dead wood in stratum *i* at time *t*; t d.m. ha^{-1}
$B_{LDWi,t}$	Biomass of lying dead wood in stratum *i* at time *t*; t d.m. ha^{-1}
CF_{DW}	Carbon fraction of dry matter in dead wood; t C t^{-1} d.m.
i	*1, 2, 3 … M* strata
t	0, *1, 2, 3* … years elapsed since the start of the project activity
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

III. DATA AND PARAMETERS NOT MONITORED (DEFAULT OR POSSIBLY MEASURED ONE TIME)

Data / parameter:	*CF*
Data unit:	t C t^{-1} d.m.
Used in equations:	9
Description:	Carbon fraction of dry matter in t C t^{-1} d.m.
Source of data:	Default value 0.47 t C t^{-1} d.m. (per IPCC 2006GL) can be used Species-specific values are not required due to difficulty of species determination of dead wood.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	*D:RAD*
Data unit:	Dimensionless
Used in equations:	5
Description:	Ratio of DBH to plot radius, specific to prism Basal Area Factor (BAF) employed in point sampling

Source of data:	BAF (m²/ha) / D:RAD 2 / 35.4 3 / 28.9 4 / 25.0 5 / 22.4 6 / 20.4 7 / 18.9 8 / 17.7 9 / 16.7
Measurement procedures (if any):	None
Any comment:	

Data / parameter:	D_{DWdc}
Data unit:	t d.m. m^{-3}
Used in equations:	1, 2
Description:	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) Research publications relevant to the project area; (b) National species-specific or group of species-specific (e.g. from National GHG inventory); (c) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a); (d) Global species-specific or group of species-specific (e.g. IPCC GPG-LULUCF). Species-specific dead wood densities may not always be available, and may be difficult to apply with certainty to decomposed wood and in the typically species rich forests of the humid tropics, hence it is acceptable

	practice to use dead wood densities developed for forest types.
Measurement procedures (if any):	Project-specific determination of density is most likely necessary, requiring collection of representative samples (in terms of scale and representation of forest strata/species composition similar to the inventory), from a minimum of 20-30 trees from each density class. Density classes need not be determined for specific species or species groups. Dead wood samples are cut in discs and thickness and diameter measured to calculate green volume. Samples are oven dried (70^{o} C) to a constant weight in the laboratory, and density calculated as dry weight (g) per unit green volume (cm^3), from which mean value and 90% confidence interval are calculated for each density class. For each density class, either: • If the 90% confidence interval is equal to or less than 10% of the mean, the mean density value is applied in project calculations. • If the 90% confidence interval is greater than 10% of the mean, the lower 90% confidence bound of the mean density estimate is applied in project calculations.
Any comment:	

IV. DATA AND PARAMETERS MONITORED

Data / parameter:	$Dia_{n,i,t}$
Data unit:	cm
Used in equations:	7
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*, at time *t* in *cm*
Monitoring interval:	Not more than 10 years
Source of data:	Field measurements in sample transects
Measurement procedures (if any):	Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996[4]). Two 50-meter lines are established bisecting each sample plot and the diameters of the lying dead wood (≥ 10 cm diameter) intersecting the lines are measured. The first line is oriented

4 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.

	along a random bearing, the second line is oriented perpendicular to the first.
QA/QC procedures:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management shall be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the *IPCC GPG LULUCF 2003*, is recommended.
Any comment:	

Data / parameter:	*DBH*
Data unit:	cm
Used in equations:	5
Description:	Diameter at breast height of standing dead tree in cm
Monitoring interval:	Not more than 10 years
Source of data:	Field measurements from sample plots or points
Measurement procedures (if any):	Typically measured 1.3m aboveground. Measure all standing dead trees above some minimum *DBH* in the sample plots. Minimum DBH employed in inventories is held constant for the duration of the project.
QA/QC procedures:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management shall be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the *IPCC GPG LULUCF 2003*, is recommended.
Any comment:	

Data / parameter:	*BDia*
Data unit:	cm
Used in equations:	1, 2
Description:	Basal diameter of standing dead tree in cm
Monitoring interval:	Not more than 10 years
Source of data:	Field measurements from sample plots/points
Measurement procedures (if any):	Measured at ground level.
QA/QC procedures:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management shall be applied.

	Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the *IPCC GPG LULUCF 2003*, is recommended.
Any comment:	

Data / parameter:	TD_{SDW}
Data unit:	cm
Used in equations:	2
Description:	Top diameter of standing dead tree in cm
Monitoring interval:	Not more than 10 years
Source of data:	Field measurements from sample plots/points
Measurement procedures (if any):	Measured at the top of a standing bole, or if crown persistent at the base of the crown. Measured either directly or by using an instrument such as a relascope or laser inventory instrument. Top diameter can also be estimated from measured basal diameter and height using a taper function that models diminution of diameter over the height of a tree. Taper functions should be based on empirical data relevant to the project area, but need not be species or species-group specific.
QA/QC procedures:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management shall be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the *IPCC GPG LULUCF 2003*, is recommended.
Any comment:	

Data / parameter:	H_{SDW}
Data unit:	m
Used in equations:	1, 2
Description:	Height of standing dead tree in m
Monitoring interval:	Not more than 10 years
Source of data:	Field measurements from sample plots/points
Measurement procedures (if any):	Height measured from ground level to either the top of a standing bole or to the base of crown if crown is persistent. Height is measured either directly or by using an instrument such as a clinometers, relascope or

	laser inventory instrument.
QA/QC procedures:	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management shall be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the *IPCC GPG LULUCF 2003*, is recommended.
Any comment:	

Data / parameter:	*Asp*
Data unit:	ha
Used in equations:	4
Description:	Total area of all sample plots in ha
Monitoring interval:	Not more than 10 years
Source of data:	Recording and archiving of number and size of sample plots
Measurement procedures (if any):	
QA/QC procedures:	
Any comment:	

Data / parameter:	*N*
Data unit:	Dimensionless
Used in equations:	6
Description:	Number of sample points
Monitoring interval:	Not more than 10 years
Source of data:	Recording and archiving of number of sample points
Measurement procedures (if any):	
QA/QC procedures:	
Any comment:	