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REDD Methodological Module

"Estimation of carbon stocks and changes in carbon stocks in the dead wood carbon pool"

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I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module allows for estimating carbon stocks and changes in carbon stocks in dead wood. Estimation of emissions from dead wood due to deforestation are dealt with in the baseline modules, referencing stocks calculated here.

Applicability

This module is applicable to all forest types and age classes with stable or increasing stocks in the with-project case.

Parameters

This module produces the following parameters:

Parameter	SI Unit	Description
$C_{DW,i,t}$	t CO_2-e	Carbon stock in dead wood in strata i at time t
$\Delta C_{DW,i,t}$	t CO_2-e	Carbon stock changes in dead wood in strata i at time t

II. PROCEDURES

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 in sample plots.

Dead wood included in the methodology comprises two components – *standing dead wood* 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:

(1) Standing Dead Wood

Step 1: Standing dead trees shall be measured using the same criteria used for measuring live trees. Stumps must be inventoried as if they are very short standing dead trees.

Step 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 3: Biomass is estimated using an allometric equation or BCEF calculation for live trees in the decomposition class 1. 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. 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):

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

Where:

$B_{SDWl,sp,i,t}$ Biomass of standing dead tree l in sample plot sp in stratum i at time t; t d.m.

$BDia_{SDWl,sp,i,t}$ Basal diameter of standing dead tree l in sample plot sp in stratum i at time t; cm

$H_{SDWl,sp,i,t}$ Height of standing dead tree l in sample plot 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 $1, 2, 3 \dots P_i$ sample plots in stratum i

i $1, 2, 3 \dots M$ strata in the project scenario

t $0, 1, 2, 3 \dots t$ years elapsed since the start of the project activity

or (where top diameter is measured):

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

Where:

$B_{SDWl,sp,i,t}$	Biomass of standing dead tree l in sample plot sp in stratum i at time t; t d.m.
$BDia_{SDWl,sp,i,t}$	Basal diameter of standing dead tree l in sample plot sp in stratum i at time t; cm
$TD_{SDWl,sp,i,t}$	Top diameter of standing dead tree l in sample plot sp in stratum i at time t; cm
$H_{SDWl,sp,i,t}$	Height of standing dead tree l in sample plot 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 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
$N_{i,sp,t}$	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 4: Calculate total carbon stock in standing dead trees present in the sample plot sp in stratum i at time t.

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

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* |
| I | *1, 2, 3 … $N_{i,sp,t}$* standing dead trees in sample plot *sp* of stratum *i* at time *t* |

Step 5: Calculate the mean biomass stock per unit area in standing dead wood for each stratum at time *t*:

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

Where:

$B_{SDWi,t}$	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

(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.

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.

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:

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[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.

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

$$V_{LDWi,t} = \frac{\pi^2 * \left(\sum_{n=1}^{N} Dia_{n,i,t}{}^2 \right)}{8 * L}$$ (5)

Where:

$V_{LDWi,t}$	Volume of lying dead wood per unit area 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	Total number of wood pieces intersecting the transect; dimensionless
L	Length of the transect; m
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

To convert this to a mass per unit area multiply the volumes of each density state by their respective wood densities as outlined below:

Step 4: Volume of lying dead wood shall be converted into biomass using the following relationship:

$$B_{LDWi,t} = \sum_{dc=1}^{3} V_{LDWi,t} * D_{DWdc}$$ (6)

Where:

$B_{LDWi,t}$	Biomass of lying dead wood per unit area in stratum i at time t; d.m. ha^{-1}
$V_{LDWi,t,}$	Volume of lying dead wood per unit area 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}
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

Total 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

$$C_{DWi,t} = \left(\left(B_{SDWi,t} + B_{LDWi,t} \right) * CF_{DW} \right) * \frac{44}{12}$$ (7)

where:

$C_{DWi,t}$	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}

Baseline

This module does not track increases in dead wood occurring prior to deforestation in areas deforested the baseline scenario. Stocks of dead wood in areas deforested in the baseline are assumed to be constant, or are matched and canceled by (the same) increases measured in the with-project case if the election is made to monitor change in the with-project case (see below).

For areas not deforested in the baseline stocks are conservatively assumed to be constant in either with or without project scenarios.

Post-deforestation stocks are equally treated as constant and this value may be the ultimate stocks of the designated replacement land use. Where the land use is part of a cycle, the time-weighted average of the carbon stocks can be used. Proxy measurement sites must represent the land use, site conditions and management practices identified as the most likely conversion use in the baseline, and documentation must be provided to the satisfaction of the verifier establishing that the lands are representative.

Actual change in dead wood carbon in the project

Two alternatives are provided for accounting change in dead wood carbon in the with-project case, either:

1. conservatively assume no change in dead wood in areas deforested in the baseline, and thus no monitoring required following initial quantification of stocks at *t*=0, or

2. directly monitor dead wood in the project for baseline deforested areas using permanent sample plots.

Carbon stock changes in the project, if monitoring is elected, are estimated using the stock change method:

$$\Delta C_{DWi,t} = (C_{DWi,t} - C_{DWi,t-1})/T$$

(8)

Where:

$\Delta C_{DWi,t}$	Annual net carbon stock change in dead wood for stratum *i*, at time *t*; t CO_2-e ha^{-1} yr^{-1}
$C_{DWi,t}$	Carbon stock in dead wood for stratum *i,* at time *t*; t CO_2-e ha^{-1}
$C_{DWi,t-1}$	Carbon stock in dead wood for stratum *i,* at time *t= t-1*; t CO_2-e ha^{-1}
i	1, 2, 3 …*M* strata
t	1, 2, 3, … *t* years elapsed since the start of the project activity

T Number of years between times *t* and *t-1 (T = 1)*

III. DATA AND PARAMETERS <u>NOT</u> MONITORED (DEFAULT OR POSSIBLY MEASURED ONE TIME)

Data / parameter:	*CF*
Data unit:	t C t^{-1} d.m.
Used in equations:	7
Description:	Carbon fraction of dry matter
Source of data:	Default value 0.47 t C t^{-1} d.m. can be used, or species specific values from the literature (e.g. IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.3).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	D_{DWdc}
Data unit:	t d.m. m^{-3}
Used in equations:	1, 2, 6
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 from 20-30 trees from each decomposition class.
	Dead wood samples are cut in discs and thickness and diameter measured to calculate green volume. Samples are oven dried (70° C) to a constant weight in the laboratory, and density calculated as dry weight (g) per unit green volume (cm^3).
Any comment:	

IV. DATA AND PARAMETERS MONITORED

Data / parameter:	$Dia_{n,i,t}$
Data unit:	cm
Used in equations:	5
Description:	Diameter of piece n of dead wood along the transect in stratum i, at time t
Source of data:	Field measurements in sample plots
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 ($\geq$ 10 cm diameter) intersecting the lines are measured.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	BDia
Data unit:	cm
Used in equations:	1, 2
Description:	Basal diameter of standing dead tree

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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, Univiersity of Washington, Seattle, WA, USA.

Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Measured at ground level. Measure all trees above some minimum *BDia* in the sample plots, typically $\geq$ 10 cm.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	TD_{SDW}
Data unit:	cm
Used in equations:	2
Description:	Top diameter of standing dead tree
Source of data:	Field measurements in sample plots
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.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	H_{SDW}
Data unit:	m
Used in equations:	1, 2
Description:	Height of standing dead tree
Source of data:	Field measurements in sample plots
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.

Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	*N*
Data unit:	Dimensionless
Used in equations:	5
Description:	Total number of wood pieces intersecting the transect
Source of data:	Field measurements
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	