American Carbon Registry®

Trusted solutions for the carbon market

Tool for Estimation of Stocks in Carbon Pools and Emissions from Emission Sources

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WINROCK INTERNATIONAL

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INTRODUCTION

The American Carbon Registry® (ACR) is a voluntary, online greenhouse gas (GHG) registration and emissions tracking system used by members to transparently register verified, project-based emissions reductions and removals as serialized offsets; record the purchase, sale, banking and retirement of tradable offsets, branded Emission Reduction Tons ("ERTs"); and optionally report, in a separate account, verified GHG inventories. ACR was founded in 1997 by the Environmental Defense Fund and Environmental Resources Trust, and joined Winrock International in 2007.

Winrock International, a non-profit public benefit corporation founded in 1984, works with people in the U.S. and around the world to empower the disadvantaged, increase economic opportunity, and sustain natural resources. Key to this mission is building capacity for climate change mitigation and adaptation and leveraging the power of environmental markets. Since the 1990s, Winrock has been working to develop science-based GHG measurement and monitoring protocols.

Purpose

This tool provides procedures for the estimation of carbon stocks and GHG emissions, for those pools and emission sources identified as significant and selected for inclusion in the GHG assessment boundary of forest carbon project activities.

It includes procedures for all the carbon pools and emission sources required for ACR Reducing Emissions from Deforestation and Forest Degradation (REDD) methodologies, including Avoiding Planned Deforestation (APD), Avoiding Unplanned Deforestation and Degradation (AUDD), and Avoiding Degradation through Fuelwood and Charcoal Production.

In the future the tool may be referenced and/or modified for use in other ACR forest carbon project methodologies.

Project Proponents and other interested parties should refer to www.americancarbonregistry.org for the latest version of this tool, the *ACR Standard,* ACR sector standards, and other relevant methodologies, tools, and templates.

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CARBON POOLS

A. Above- and Below-Ground Biomass Pools

This section provides procedures for *ex ante* estimation of carbon stocks in above- and belowground tree and non-tree woody biomass in the baseline case (for both pre- and post-deforestation stocks) and project case, and for *ex post* estimation of change in carbon stocks in above- and belowground tree biomass in the project case.

Inclusion of the aboveground tree biomass pool in the project boundary is mandatory.

Non-tree aboveground biomass must be included in the project boundary if:

- Stocks of non-tree aboveground biomass are greater in the baseline than in the project scenario, and
- Non-tree aboveground biomass is determined to be significant.

Belowground (tree and non-tree) biomass are not required for inclusion in the project boundary because omission is conservative.

1. Output parameter(s)

Parameter	SI Unit	Description
$C_{AB_tree,\ i,\ t}$	t CO_2-e ha^{-1}	Carbon stock in aboveground tree biomass in strata *i* at time *t*
$C_{BB_tree,\ i,\ t}$	t CO_2-e ha^{-1}	Carbon stock in belowground tree biomass in strata *i* at time *t*
$C_{AB_non\text{-}tree,\ i,\ t}$	t CO_2-e ha^{-1}	Carbon stock in aboveground non-tree biomass in strata *i* at time *t*
$C_{BB_non\text{-}tree,\ i,\ t}$	t CO_2-e ha^{-1}	Carbon stock in belowground non-tree biomass in strata *i* at time *t*

2. Procedure

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. Above- and belowground biomass 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. 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. 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.

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Part 1: Estimation of carbon stocks in aboveground tree biomass ($C_{AB_tree\ i}$)

The mean carbon stock in aboveground tree biomass per unit area is estimated based on field measurements in sample fixed area plots or sample points using prisms employing representative random or systematic sampling.

Two methods are available for sampling: Fixed Area Plots and Point Sampling with Prisms, both using Allometric Equations method to estimate biomass from measured tree dimensions.

Part 1, Option 1. Fixed Area Plots with Allometric Equation method

Step 1: Determine the tree dimensions such as diameter at breast height (*DBH*, at typically 1.3 m [4.3 ft] above ground level or above buttress where they exist, and total height H), of all the trees above some minimum *DBH* in the sample plots. The exact tree dimensions and minimum size tree to be measured in sample plots will be specified by the allometric equation selected in Step 2. Any minimum values employed in inventories are held constant for the duration of the project.

Step 2: Select or develop an appropriate and validated allometric equation for forest type/group of species *j* (e.g. tropical humid forest or tropical dry forest) or for each species or family *j* (group of species) found in the inventory (hereafter referred to as species group). Any equation selected may only be used if applicability has been demonstrated and validated per guidance in the parameters section below.

Step 3: Estimate carbon stock in aboveground biomass for each individual tree of species group *j* in the sample plot located in stratum *i* using the selected or developed allometric equation applied to the tree dimensions resulting from Step 1 and sum the carbon stocks in the sample plot:

$$C_{AB_tree,j,sp,i,t} = \sum_{l=1}^{N_{j,sp,i,t}} f_j(X, Y...) * CF_j \quad (1)$$

Where:

$C_{AB_tree,j,sp,i,t}$	Carbon stock in aboveground biomass of trees of species group *j* in plot *sp* in stratum *i* at time *t*; t C
CFj	Carbon fraction of biomass for tree group *j*; t C t^{-1} d.m.
$f_j(X,Y..)$	Aboveground biomass of trees based on allometric equation for species group *j* based on measured tree variable(s); t. d.m. $tree^{-1}$
i	*1, 2, 3, …M* strata
j	*1, 2, 3 … S* tree species
l	*1, 2, 3, …* $N_{j,sp,i,t}$ sequence number of individual trees in sample plot *sp* in

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stratum *i* at time *t*

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

Step 4: Calculate total carbon stock in the aboveground biomass of all trees present in sample plot *sp* in stratum *i* at time *t*:

$$C_{AB_tree,sp,i,t} = \sum_{j=1}^{S} C_{AB_tree,l,sp,i,t} \quad (2)$$

Where:

$C_{AB_tree,sp,i,t}$ — Aboveground biomass carbon stock of all trees in sample plot *sp* of stratum *i* at time *t*, t C

$C_{AB_tree,,,sp,i,t}$ — Carbon stock in aboveground biomass of trees in sample plot *sp* in stratum *i* at time *t*; t C

i — *1, 2, 3, …M* strata

l — *1, 2, 3, …* $N_{j,sp,i,t}$ sequence number of individual trees in sample plot *sp* in stratum *i* at time *t*

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

Step 5: Calculate the mean carbon stock in aboveground biomass for each stratum, converted to carbon dioxide equivalents:

$$C_{AB_tree,i,t} = \sum_{sp=1}^{P_i} \frac{C_{AB_tree,sp,i,t}}{A_{sp,i}} * \frac{44}{12} \quad (3)$$

Where:

$C_{AB_tree,i,t}$ — Mean aboveground biomass carbon stock in stratum *i* at time *t*; t CO_2-e ha^{-1}

$C_{AB_tree,sp,i,t}$ — Aboveground biomass carbon stock of trees in sample plot *sp* of stratum *i* at time *t*, t C

A_{spi} — Area of sample plot *sp* in stratum *i*; ha

Sp — *1, 2, 3 … Pi* sample plots in stratum *i*

l — *1, 2, 3 … M* strata

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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}

Part 1, Option 2: Point Sampling with Allometric Equation method

Step 1: Determine the tree dimensions such as diameter at breast height (*DBH*, at typically 1.3 m [4.3 ft] above ground level and total height H), of all the trees above some minimum *DBH* in the sample plots. The exact tree dimensions and minimum size tree to be measured at sample points will be specified by the allometric equation selected in Step 2. Any minimum values employed in inventories are held constant for the duration of the project.

Step 2: Select or develop an appropriate and validated allometric equation for each species group *j* found in the inventory. Any equation selected may only be used if applicability has been demonstrated and validated per guidance in the parameters section below.

Step 3: Estimate carbon stock in aboveground biomass for each individual tree *l* of species group *j* at the sample point located in stratum *i* using the selected or developed allometric equation applied to the tree dimensions resulting from Step 1, and sum the carbon stocks for the sample point:

$$C_{AB_tree,j,sp,i,t} = \sum_{l=1}^{N_{j,sp,i,t}} \frac{f_j(X,Y...) * CF_j}{(3.1415/10000) * ((DBH/100) * D:RAD)^2} \quad (4)$$

Where:

$C_{AB_tree,j,sp,i,t}$	Carbon stock in aboveground biomass of trees of species group *j* at point *sp* in stratum *i* at time *t*; t C
CFj	Carbon fraction of biomass for tree species group *j*; t C t^{-1} d.m.
$f_j(X,Y…)$	Allometric equation for species *j* linking measured tree variable(s) to aboveground biomass of trees; t. d.m. $tree^{-1}$
DBH	Diameter at breast height of tree *l* of species group *j* 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 trees of species *j* at point *sp* in stratum *i* at time *t*
i	*1, 2, 3, …M* strata
j	*1, 2, 3 … S* tree species

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

Step 4: Calculate total carbon stock in the aboveground biomass of all trees at sample point *sp* in stratum *i* at time *t*:

$$C_{AB_tree,sp,i,t} = \sum_{j=1}^{S} C_{AB_tree,j,sp,i,t} \quad (5)$$

Where:

$C_{AB_tree,sp,i,t}$	Aboveground biomass carbon stock of trees at sample point *sp* of stratum *i* at time *t*, t C
$C_{AB_tree,,j,sp,i,t}$	Carbon stock in aboveground biomass of trees of species group *j* at sample point *sp* in stratum *i* at time *t*; t C
i	*1, 2, 3, …M* strata
j	*1, 2, 3* … *S* tree species
t	*0, 1, 2, 3* … years elapsed since the start of the project activity

Step 5: Calculate the mean carbon stock in aboveground biomass for each stratum, converted to carbon dioxide equivalents:

$$C_{AB_tree,i,t} = \frac{1}{N} * \sum_{sp=1}^{P_i} C_{AB_tree,sp,i,t} * \frac{44}{12} \quad (6)$$

Where:

$C_{AB_tree,i,t}$	Mean aboveground biomass carbon stock in stratum *i* at time *t*; t CO_2-e ha^{-1}
$C_{AB_tree_sp,i\,t}$	Mean aboveground biomass carbon stock of trees at point *sp*, in stratum *i* at time *t*; t C
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
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

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Part 2: Estimation of carbon stocks in belowground tree biomass ($C_{BB_tree\ i,t}$)

The mean carbon stock in belowground tree biomass per unit area is estimated based on field measurements in sample fixed area plots or sample points using prisms, employing representative random or systematic sampling. The mean carbon stock in belowground tree biomass per unit area is estimated based on field measurements of aboveground parameters in sample plots. Root:shoot ratios are coupled with the Allometric Equations method Part 1 options 1 and 2, to calculate belowground from aboveground biomass.

Part 2, Option 1: Fixed area plots with root:shoot ratio

Step 1: Calculate the belowground tree biomass carbon stock for each plot. The aboveground tree biomass carbon stocks in each plot can be estimated by allometric equation method described in Part 1 Option 1.

$$C_{BB_tree,sp,i,t} = R * C_{AB_tree,sp,i,t} \quad (7)$$

Where:

$C_{BB_tree,sp,i\ t}$	Belowground tree biomass carbon stock of trees in plot *sp*, in stratum *i* at time *t*; t C
$C_{AB_tree,sp,i\ t}$	Aboveground tree biomass carbon stock of trees in plot *sp*, in stratum *i* at time *t*; t C
R	Root:shoot ratio; t root d.m. t^{-1} shoot d.m.
i	*1, 2, 3, …M* strata
t	*0, 1, 2, 3 …* years elapsed since start of the project activity

Step 2: Calculate the mean belowground tree biomass carbon stock for each stratum, converted to carbon dioxide equivalents:

$$C_{BB_tree,i,t} = \sum_{sp=1}^{P_i} \frac{C_{BB_tree_sp,i,t}}{A_{sp,i}} * \frac{44}{12} \quad (8)$$

Where:

$C_{BB_tree,i,t}$	Mean belowground tree biomass carbon stock in stratum *i* at time *t*; t CO_2-e ha^{-1}
$C_{BB_tree_sp,i\ t}$	Mean belowground tree biomass carbon stock of trees in plot *sp*, in stratum *i* at time *t*; t C

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Asp_i	Area of sample plot *sp* 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 …* 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}

Part 2, Option 2. Point Sampling with root:shoot ratio

Step 1: Calculate the belowground tree biomass carbon stock for each point sampled. The aboveground tree biomass carbon stocks in each point sampled can be found using the allometric equation method described in Part 1 Option 2 above.

$$C_{BB_tree,sp,i,t} = R * C_{AB_tree,sp,i,t} \quad (9)$$

Where:

$C_{BB_tree,sp,i\,t}$	Belowground tree biomass carbon stock of trees in point *sp*, in stratum *i* at time *t*; t C
$C_{AB_tree,sp,i\,t}$	Aboveground tree biomass carbon stock of trees in point *sp*, in stratum *i* at time *t*; t C
R	Root:shoot ratio; t root d.m. t^{-1} shoot d.m
i	*1, 2, 3, …M* strata
t	*0, 1, 2, 3 …* years elapsed since start of the project activity

Step 2: Calculate the mean belowground tree biomass carbon stock for each stratum, converted to carbon dioxide equivalents:

$$C_{BB_tree,i,t} = \frac{1}{N} * \sum_{sp=1}^{P_i} C_{BB_tree_sp,i,t} * \frac{44}{12} \quad (10)$$

Where:

$C_{BB_tree,i,t}$	Mean belowground tree biomass carbon stock in stratum *i* at time *t*; t CO_2-e ha^{-1}
$C_{BB_tree_sp,i\,t}$	Mean belowground tree biomass carbon stock of trees at point *sp*, in stratum

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	i at time *t*; t C
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
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

Part 3: Estimation of carbon stocks in aboveground non-tree woody biomass ($C_{AB_nontree,i,t}$)

The mean carbon stocks in non-tree aboveground biomass pool per unit area are estimated based on previously published or default data or field measurements. Non-tree woody aboveground biomass pool includes trees smaller than the minimum tree size measured in the tree biomass pool, all shrubs, and all other non-herbaceous live vegetation[1].

Non-tree vegetation can be sampled using destructive sampling frames and/or, where suitable, in sampling plots in combination with an appropriate allometric equation for shrubs.

Calculate the mean carbon stock in aboveground non-tree biomass for each stratum by adding the mean carbon stock in aboveground biomass calculated using the sampling frame method to the mean carbon stock in aboveground biomass calculated using the allometric equation method.

$$C_{AB_nontree,i,t} = C_{AB_nontree_sample,i,t} + C_{AB_nontree_allometric,i,t} \quad (11)$$

Where:

$C_{AB_nontree,i,t}$	Mean aboveground non-tree biomass carbon stock in stratum *i* at time *t*; t CO_2-e ha^{-1}
$C_{AB_nontree_sample,i,t}$	Mean aboveground non-tree biomass carbon stock in stratum *i* at time *t* from sample frame method; t CO_2-e ha^{-1}
$C_{AB_nontree_allometric,i,t}$	Mean aboveground non-tree biomass carbon stock in stratum *i* at time *t* from allometric equation method; t CO_2-e ha^{-1}

[1] Pursuant to AR-WG 21, the GHG emissions from removal of herbaceous vegetation are insignificant in A/R CDM project activities and therefore these emissions can be neglected in A/R baseline and monitoring methodologies.

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Part 3, Option1. Sampling Frame Method

In a stratum where non-tree vegetation is spatially variable, large frames should be used (e.g. 1-2 m radius). Where non-tree vegetation is homogeneous, smaller frames can be used (e.g. 30 cm radius).

Generally, the frame is placed at a randomly or systematically selected GPS point or tree plot. At each location, all vegetation originating from inside the frame is cut at the base and weighed. One representative subsample of the cut material is weighed to obtain its wet mass. The collected subsample is taken to a laboratory, oven-dried and weighed to determine the dry mass. The wet to dry ratio of the subsample is then used to estimate the dry mass of the original sample.

To estimate the mean carbon stock per unit area in the above ground non-tree biomass for each stratum:

$$C_{AB_nontree_sample,i,t} = \sum_{sfp=1}^{SFP_i} \frac{C_{AB_nontree_sample,sf,i,t}}{A_{sfp,i,t}} * CF * \frac{44}{12} \quad (12)$$

Where:

$C_{AB_nontree_sample,,i,,t}$	Carbon stock in aboveground non-tree vegetation in sampling plot in strata *i* at time *t* from sample method; t CO_2-e ha^{-1}
$C_{AB_,nontree_sample,sp,i,t}$	Carbon stock in aboveground non-tree vegetation in sample plot *sfp* in stratum *i* at time *t* from sampling frame method; kg d.m.
CF_j	Carbon fraction of dominant non-tree vegetation *j*; dimensionless
A_{sfpi}	Area of non-tree sampling plot *s fp* in stratum i; ha
Sfp	*1, 2, 3 … SFP_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
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

Part 3, Option 2. Allometric Equation Method

This method may be used for shrubs, bamboo, or other vegetation types where individuals can be clearly delineated.

Step 1: Select or develop an appropriate allometric equation (if possible species-specific; if not, from a similar species).

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Step 2: Estimate carbon stock in aboveground biomass for each individual *I* in the sample plot *r* located in stratum *i* using the selected or developed allometric equation:

$$C_{AB_{nontree_{allometric}},i,r,t} = \sum_{j=1}^{N_{r,i,t}} f_j\left(vegetation_{parameters}\right) * CF_j \quad (13)$$

Where:

$C_{AB_nontree_allometric,i,r,t}$	Carbon stock in aboveground biomass of non-tree sample plot *r* in stratum *i* at time *t* from allometric equation method; t C
CFj	Carbon fraction of biomass for species *j*; t C t^{-1} d.m.
f_j*(vegetation parameters)*	Aboveground biomass from allometric equation for species *j* linking parameters such as stem count, diameter of crown, height, or others ; t. d.m. $individual^{-1}$
i	*1, 2, 3, …M* strata
R	*1,2,3, …R* non-tree allometric method sample plots in stratum *i*
j	*1, 2, 3 … j* non-tree species
I	*1, 2, 3, …* $N_{I,i,sp,t}$ sequence number of individuals in sample plot *r* in stratum *i* at time *t*
t	*0,1,2,3 …t* years elapsed since start of the project activity

Step 3: Calculate the mean carbon stock in aboveground biomass for each stratum, converted to carbon dioxide equivalents:

$$C_{AB_nontree_allometric,i,t} = \sum_{r=1}^{R_i} \frac{C_{AB_nontree_allometric,r,i,t}}{A_{r,i}} * \frac{44}{12} \quad (14)$$

Where:

$C_{AB_nontree_allometric,i,t}$	Mean aboveground biomass carbon stock in stratum *i* at time *t* from allometric equation method; t CO_2-e ha^{-1}
$C_{AB_nontree_allometric,i,sp,t}$	Aboveground biomass carbon stock in non-tree vegetation in sample plot *r* of stratum *i* at time *t* from non-tree allometric sample plots, t C
Ar_i	Area of non-tree allometric method sample plot in stratum *i*; ha
R	*1,2,3, …R* non-tree allometric method sample plots in stratum *i*

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i	*1, 2, 3 … M* strata
t	*0,1,2,3, …t* 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}

Part 4: Estimation of belowground carbon stocks in non-tree vegetation ($C_{BBnontree,i,t}$)

The mean carbon stock in belowground biomass per unit area is estimated based on field measurements of aboveground parameters in sample plots. Root:shoot ratios are coupled with the aboveground biomass estimate to calculate belowground from aboveground biomass.

Step 1: Select an appropriate root:shoot ratio for non-tree biomass.

Step 2: Use the appropriate root:shoot ratio to estimate the belowground biomass from aboveground biomass carbon stock in nontree vegetation in sample plot *sp* of stratum *i* at time *t*, t C:

$$C_{BB_{nontree},i,sp,t} = C_{AB_{nontree},i,sp,t} * R \quad (15)$$

Where:

$C_{AB_nontree,i,sp,t}$	Aboveground biomass carbon stock in non-tree vegetation in sample plot *sp* of stratum *i* at time *t*, t C
$C_{BB_nontree,i,sp,t}$	Belowground biomass carbon stock in non-tree vegetation in sample plot *sp* of stratum *i* at time *t*, t C
R	Root:shoot ratio; t root d.m. t^{-1} shoot d.m.

Step 3: Calculate the mean carbon stock in belowground biomass for each stratum, converted to carbon dioxide equivalents:

$$C_{BB_nontree,i,t} = \sum_{sp=1}^{P_i} \frac{C_{BB_nontree,sp,i,t}}{A_{sp,i}} * \frac{44}{12} \quad (16)$$

Where:

$C_{BB_nontree,i,t}$	Mean belowground biomass carbon stock in stratum *i* at time *t*; t CO_2-e ha^{-1}
$C_{BB_nontree,i,sp,t}$	Belowground biomass carbon stock in nontree vegetation in sample plot *sp* of stratum *i* at time *t*, t C

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A_{spi}	Area of sample plot *sp* in stratum *i*; ha
Sp	*1, 2, 3 … Pi* 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
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

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B. Dead Wood Pool

This procedure 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.

Dead wood shall be included in the project boundary if stocks are greater in baseline than project scenario and determined to be significant; otherwise can be conservatively omitted.

1. Output parameter(s)

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*

2. Procedure

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.

The mean carbon stock in dead wood per unit area at time *t* is estimated based on field measurements of 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 (e.g. minimum DBH) used for measuring live trees. Stumps must be inventoried as if they are very short standing dead trees.

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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 Biomass Conversion and Expansion Factor (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 Section A of this Tool. 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):

$$B_{SDWl,sp,i,t} = \frac{1}{3} * \pi * \left(\frac{BDia_{SDWl,sp,i,t}}{200} \right)^2 * H_{SDWl,sp,i,t} * D_{DWdc} \quad (17)$$

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

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Or, where top diameter is measured:

$$B_{SDWl,sp,i,t} = \frac{BDia_{SDWl,sp,i,t} + TD_{SDWl,sp,i,t}}{200} * H_{SDWl,sp,i,t} * D_{DWdc} \quad (18)$$

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, or 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*.

$$B_{SDWsp,i,t} = \sum_{l=1}^{N_{sp,i,t}} B_{SDWl,sp,i,t} \quad (19)$$

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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*:

$$B_{SDWi,t} = \frac{1}{A_{sp,i}} * \sum_{sp=1}^{P_i} B_{SDWsp,i,t} \quad (20)$$

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*.

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$$B_{SDWsp,i,t} = \sum_{l=1}^{N_{j,sp,i,t}} \frac{B_{SDWl,sp,i,t}}{(3.1415/10000) * ((DBH/100) * D:RAD)^2} \quad (21)$$

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*:

$$B_{SDWi,t} = \frac{1}{N} * \sum_{sp=1}^{P_i} B_{SDWsp,i,t} \quad (22)$$

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

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Part 2: Lying Dead Wood

Step 1: Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996)[2]. 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)[3] as modified by Van Wagner (1968)[4] separately for each density state:

$$V_{LDWdc,i,t} = \frac{\pi^2 * \left(\sum_{n=1}^{N} Dia_{dc,n,i,t}^{\ 2} \right)}{8 * L} \quad (23)$$

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

[2] 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.

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

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

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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.

$$B_{LDWi,t} = \sum_{dc=1}^{3} V_{LDWdc,i,t} * D_{DWdc} \quad (24)$$

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

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

$$C_{DWi,t} = \left(\left(B_{SDWi,t} + B_{LDWi,t}\right) * CF_{DW}\right) * \frac{44}{12} \quad (25)$$

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}

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C. *Litter Pool*

This procedure allows for *ex ante* estimation of carbon stocks in forest litter in the baseline case (for both pre- and post-deforestation stocks) and project case.

The litter pool is considered an insignificant source in REDD projects. Inclusion of the litter pool as part of the project boundary is optional.

1. Output parameter(s)

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

2. Procedure

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

Part 1. *Ex ante* estimation of carbon stocks in litter

To estimate the mean carbon stock per unit area in litter for each project area stratum:

$$C_{LIi,t} = \frac{10}{A_{sp,i}} * \sum_{sp=1}^{P_i} B_{LIsp,i,t} * CF * \frac{44}{12} \qquad (26)$$

Where:

$C_{LI,i,t}$	Mean carbon stock in litter for stratum *i,* at time *t*; t CO_2-e ha^{-1}
$B_{LI,sp,i,t}$	Biomass of litter in sample plot *sp* in stratum *i* at time *t*; kg d.m.
CF	Carbon fraction; t C t^{-1} d.m.
Asp_i	Total area of all sample plots in stratum *i*; m^{-2}
Sp	*1, 2, 3 …* P_i sample plots in stratum *i*

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i	*1, 2, 3* … *M* strata
t	*0, 1, 2, 3* … *t* 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}

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D. Soil Organic Carbon Pool

This procedure for *ex ante* estimation of carbon stocks in soil organic carbon in the baseline case (for both pre- and post-deforestation stocks) and project case.

This procedure is applicable to non-organic soils under all forest types and age classes. This procedure is applicable if the soil organic carbon pool is included as part of the GHG assessment boundary, specifically:

- *Ex ante* determination that stocks are greater in the baseline than in the project scenario can be made on the basis of IPCC 2006GL Relative Stock Change Factors (F_{LU}, F_{MG}, and F_I)[5] – if the average combined stock change factor for the baseline (area-weighted by post conversion land use) is greater than or equal to 1, then soil organic carbon must be included, otherwise it can be conservatively omitted, and
- Soil organic carbon shall be included if determined to be significant.

1. Output parameter(s)

Parameter	SI Unit	Description
$C_{SOC,i,t}$	t CO_2-e ha^{-1}	Mean carbon stock in soil organic carbon in stratum *i* at time *t*
$C_{SOC,PD\text{-}BSLi,t}$	t CO_2-e ha^{-1}	Mean post-deforestation stock in soil organic carbon in the post deforestation baseline stratum *i,* at time *t*;

2. Procedure

Measurements of initial stocks employed in the baseline must take place within 5 years prior to the project start date, for simplicity referred to here as stocks at t=0. Soil organic carbon 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. For each strata, 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.

Part 1: *Ex ante* estimation of pre-deforestation stocks of soil organic carbon

The procedure to be followed in the measurement of soil organic carbon is outlined below. Strata employed for soil organic carbon will conform to the same strata employed for all other included pools. To estimate the carbon stock in soil organic carbon per unit area for sample plot *sp*, stratum *i*, at time *t*:

[5] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf.

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$$C_{SOCsp,i,t} = C_{SOCsample,sp,i,t} * BD_{sample,sp,i,t} * Dep_{sample,sp,i,t} * 100 \quad (27)$$

Where:

$C_{SOCsp,i,t}$	Carbon stock in soil organic carbon for sample plot *sp*, stratum *i,* at time *t*; t C ha^{-1}
$C_{SOCsample,sp,i,t}$	Soil organic carbon of the sample in sample plot *sp*, stratum *i,* at time *t*; determined in the laboratory in g C/100 g soil (fine fraction <2 mm)
$BD_{sample,sp,i,t}$	Bulk density of fine (<2 mm) fraction of mineral soil in sample plot *sp*, stratum *i,* at time *t* ; determined in the laboratory in g fine fraction cm^{-3} total sample volume
$Dep_{sample,sp,i,t}$	Depth to which soil sample is collected in sample plot *sp* in stratum *i* at time *t*; cm
Sp	*1, 2, 3 … P_i* sample plots in stratum *i*
i	*1, 2, 3 … M* strata
t	*0, 1, 2, 3 …* years elapsed since the start of the project activity

To estimate the mean carbon stock in soil organic carbon, converted to carbon dioxide equivalents, per unit area for stratum *i*, at time *t*:

$$C_{SOCi,t} = \frac{\sum_{sp=1}^{P_i} C_{SOCsp,i,t0}}{P_i} * \frac{44}{12} \quad (28)$$

Where:

$C_{SOC,i,t}$	Mean carbon stock in soil organic carbon for stratum *i,* at time *t*; t CO_2-e ha^{-1}
$C_{SOCsp,i,t}$	Carbon stock in soil organic carbon for sample plot *sp*, stratum *i,* at time *t*; t C ha^{-1}
Sp	*1, 2, 3 … P_i* sample plots in stratum *i*
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}

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Part 2: *Ex ante* estimation of post-deforestation stocks of soil organic carbon

Post-deforestation soil carbon stocks are assumed to be the long-term average stocks on the land following deforestation. To estimate this long term average post-deforestation stock of soil organic carbon, the mean soil stock estimated in Part 1 at t=0 is multiplied by the stock change factors, equal to the carbon stock in the altered condition as a proportion of the reference carbon stock as defined in IPCC 2006GL6. This method assumes that changes will take place over 20 years and is assumed to equate to the long term average stocks.

$$C_{SOC,PD\text{-}BSL\ i,t} = C_{SOCi,t=0} * F_{LU} * F_{MG} * F_I \quad (29)$$

Where:

$C_{SOC,PD\text{-}BSLi,t}$	Mean post-deforestation stock in soil organic carbon in the post deforestation baseline stratum *i,* at time *t*; t CO_2-e ha^{-1}
$C_{SOC,i,t=0}$	Mean carbon stock in soil organic carbon for stratum *i,* at time *t=0*; t CO_2-e ha^{-1}
F_{LU}	Land use factor before or after conversion; dimensionless
F_{MG}	Management factor before or after conversion; dimensionless
F_I	Input factor before or after conversion; dimensionless
i	*1, 2, 3* … *M* strata
t	*1, 2, 3* … years elapsed in the baseline

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[6] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf

E. Long-Term Wood Products Pool

This procedure allows for *ex ante* estimation of carbon stocks in the long-term wood products pool.

Carbon stocks treated here are those stocks remaining in wood products after 100 years; the bulk of emissions associated with timber harvest, processing and waste, and eventual product retirement occur within this timeframe, and this procedure employs the simplifying assumption that the proportion remaining after 100 years is effectively "permanent"[7].

This procedure is applicable to all cases where wood is harvested for conversion to wood products *for commercial markets*, for all forest types and age classes. This procedure is applicable in the baseline if the wood products pool is included as part of the GHG assessment boundary, specifically:

- Timber harvest occurs prior to or in the process of deforestation, and where timber is destined for commercial markets
- The wood products pool is determined to be significant.

1. Output parameter(s)

Parameter	SI Unit	Description
$C_{WP\,i,t}$	t CO_2-e ha^{-1}	Mean carbon stock in wood products pool (stock remaining in wood products after 100 years) in strata *i* at time *t* post deforestation
$C_{XB,i,t}$	t CO_2-e ha^{-1}	Mean stock of extracted biomass carbon from strata *i* at time t

2. Procedure

The approach outlined in this procedure employs emission factors (OF, SLF, and WW) derived by Winjum *et al.* 1998. It is anticipated that new research findings may become available in the future (during the project lifetime) further refining these factors, and the use of this procedure requires that Project Proponents review research findings every ≤10 years to identify further refinements to the emission factors that are empirically-based and peer-reviewed. If new emission factors are discovered, they will replace the factors used here; otherwise the factors used here remain valid.

Part 1: *Ex ante* estimation of carbon stocks in the wood products pool in the baseline

This procedure estimates carbon stocks in wood products resulting from timber harvest occurring prior to or in the process of deforestation. Accounting for such wood products should only take place at the time of deforestation. This procedure follows the conceptual framework detailed in

[7] The proportion remaining after 100 years is effectively the amount sequestered in the wood products over 100 years.

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Winjum *et al.* 1998[8], applying the simplifying and conservative assumption that all extracted biomass not retained in long-term wood products after 100 years is emitted in the year harvested, instead of tracking annual emissions through retirement, burning and decomposition. All factors are derived from Winjum *et al*. 1998.

If approved timber harvest plans, specifying harvest intensity per strata in terms of volume extracted per ha, are available for the project area use Option 1. If approved harvest plans are not available use Option 2.

Part 1, Option 1: Direct Volume Extraction Estimation

Step 1: Calculate the biomass carbon of the volume extracted by wood product type *ty* at time *t* from within the project boundary:

$$C_{XB,ty,i,t} = \frac{1}{A_i} * \sum_{j=1}^{S_{PS}} (V_{ex,ty,j,i,t} * D_j * CF_j * \frac{44}{12}) \quad (30)$$

Where:

$C_{XB,ty,i,t}$	Mean stock of extracted biomass carbon by class of wood product *ty* from strata *i* at time *t*; t CO_2-e ha^{-1}
A_i	Total area of strata *i*; ha
$V_{ex,ty,j,t}$	Volume of timber extracted from within strata *i* (does not include slash left onsite) by species *j* and wood product class *ty* at time *t*; m^3
D_j	Mean wood density of species *j*; t d.m.m^{-3}
CFj	Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m.
t	*1, 2, 3 … t* years elapsed since the start of the project activity
j	*1, 2, 3 … S* tree species
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

Step 2: Calculate the proportion of biomass carbon extracted at time *t* that remains sequestered in long-term wood products after 100 years.

[8] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

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$$C_{WPi,t} = \sum_{s,w,oir,p,o}^{ty} C_{XBty,i,t} * (1 - WW_{ty}) * (1 - SLF_{ty}) * (1 - OF_{ty}) \quad (31)$$

Where:

$C_{WPi,t}$	Carbon stock in wood products pool (stock remaining in wood products after 100 years) in strata *i* at time *t*; t CO_2-e ha^{-1}
$C_{XB,ty,i,t}$	Mean stock of extracted biomass carbon by class of wood product *ty* from strata *i* at time *t*; t CO_2-e ha^{-1}
WW	Wood waste. The fraction immediately emitted through mill inefficiency; dimensionless
SLF	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest; dimensionless
OF	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest; dimensionless
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other
i	*1, 2, 3, …M* strata
t	*1, 2, 3 … t* years elapsed since the start of the project activity

Part 1, Option 2: Commercial inventory estimation

Step 1: Calculate the biomass carbon of the commercial volume extracted prior to or in the process of deforestation:

$$C_{XBi,t} = C_{AB_tree,i,t} * \frac{1}{BCEF} * Pcom_i \quad (32)$$

Where:

$C_{XB,i,t}$	Mean stock of extracted biomass carbon from strata *i* at time *t*; t CO_2-e ha^{-1}
$C_{AB_tree,i,t}$	Mean aboveground biomass carbon stock in stratum *i* at time *t*; t CO_2-e ha^{-1}
BCEF	Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass; dimensionless
$Pcom_i$	Commercial volume as a percent of total aboveground volume in stratum *i*;

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	dimensionless
t	*1, 2, 3* … *t* years elapsed since the start of the project activity
i	*1, 2, 3, …M* strata

Step 2: Identify the wood product class(es) (*ty*; defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other) that are the anticipated end use of the extracted carbon calculated in Step 1.

Step 3: Calculate the proportion of biomass carbon extracted at time *t* that remains sequestered in long-term wood products after 100 years. This procedure applies the simplifying and conservative assumption that all extracted biomass not retained in long-term wood products after 100 years is emitted in the year harvested, instead of tracking annual emissions through retirement, burning and decomposition. All factors are derived from Winjum *et al*. 1998.

$$C_{WPi,t} = \sum_{s,w,oir,p,o}^{ty} C_{XBty,i,t} * (1 - WW_{ty}) * (1 - SLF_{ty}) * (1 - OF_{ty}) \quad (33)$$

Where:

$C_{WPi,t}$	Carbon stock in long-term wood products pool (stock remaining in wood products after 100 years) in strata *i* at time *t* post deforestation; t CO_2-e ha^{-1}
$C_{XB,ty,i,t}$	Mean stock of extracted biomass carbon by class of wood product *ty* from strata *i* at time *t*; t CO_2-e ha^{-1}
WW	Wood waste. The fraction immediately emitted through mill inefficiency; dimensionless
SLF	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest; dimensionless
OF	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest; dimensionless
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other
i	*1, 2, 3, …M* strata
t	*1, 2, 3* … *t* years elapsed since the start of the project activity

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EMISSION SOURCES

F. Emissions from Biomass Burning

This section provides procedures for estimating GHG emissions from biomass burning.

If fire is used to clear the land or constitutes a cause of forest degradation, emissions of CO_2, N_2O and CH_4 result. Inclusion in the baseline is always optional. Where included in the baseline, accounting must occur under both the baseline and with-project scenarios, and both *ex ante* and *ex post*. Significance testing must be used to determine whether or not the emission source has to be included *ex post*. Significance testing shall be conducted for both the project area and the leakage belt.

The use of this procedure is mandatory if.

- Baseline:
  - In all cases, inclusion of GHG emissions from biomass burning is optional. If included in the baseline, emissions must be monitored *ex post*

- Where not included in the baseline, an *ex ante* assessment of the significance of GHG emissions from biomass burning shall be made:
  - If biomass burning emissions are projected to be higher within the project boundaries in the with-project scenario than in the baseline and significant, then the procedure shall be used *ex post* for all emissions within the project boundaries
  - If biomass burning emissions are projected to be higher within the leakage belt in the with-project scenario than in the baseline and significant, then the procedure shall be used *ex post* for all emissions within the leakage belt

- Where emissions from biomass burning are shown *ex ante* to not be significant, an *ex post* analysis is required to justify continued omission of the emission source:
  - The tool for significance testing must be applied *ex post* to any area of deforestation in the project area or the leakage belt. Where emissions are significant, the procedure in this section shall be used to account GHG emissions.
  - Where areas of fire are identified *ex post* in the project area and these areas coincide with areas deforested in the baseline case, the procedure in this section shall be used to account GHG emissions.

1. Output parameter(s)

Parameter	SI Unit	Description
$E_{BiomassBurn}$	tCO_2-e	Non-CO_2 emissions due to biomass burning as part of deforestation activities

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2. Procedure

GHG emissions from biomass burning can result from:

1. Conversion of forest land to non-forest land using fire
2. Periodical burning of grassland or agricultural land after deforestation
3. Burning in forest land remaining forest land

This procedure describes how GHG emissions from biomass burning shall be estimated. Carbon dioxide may be omitted from calculations if it can be shown that accounting of CO_2 emissions is accounted through stock change (e.g. where fire is used during deforestation).

Some GHG emissions can be measured, but because of the high spatial and temporal variability the following method shall be used. Based on the IPCC 2006 Inventory Guidelines, estimating GHG emissions from biomass burning shall be determined as:

$$E_{BiomassBurn} = \sum_{t=1}^{t}\sum_{i=1}^{M}\sum_{g=1}^{g} A_{burn,i,t} * B_{i,t} * COMF_i * G_{g,i} * 10^3 \quad (34)$$

Where:

$E_{BiomassBurn}$	GHG emissions due to biomass burning as part of deforestation activities, tCO_2-e of each GHG (CO_2, CH_4, N_2O)
$A_{burn,i,t}$	Area burnt for stratum *i* at time *t*, ha
$B_{i,t}$	Average above-ground biomass stock before burning stratum *i*, time *t*; tonnes d. m. ha^{-1}
$COMF_i$	Combustion factor for stratum *i*, dimensionless (see Table 1 for default values as derived from Table 2.6 of IPCC, 2006)
$G_{g,i}$	Emission factor for stratum *i* for gas *g*, kg t^{-1} dry matter burnt (see Table 2 for default values as derived from Table 2.5 of IPCC, 2006)
G	1, 2, 3 ... *G* greenhouse gases (to include carbon dioxide[9], methane and nitrous oxide)
i	1, 2, 3 …*M* strata
t	1, 2, 3, … *t* years elapsed since the start of the project activity

[9] Carbon dioxide may be omitted where carbon dioxide emissions are calculated in an alternate procedure through stock change

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$B_{i,t}$ The average above-ground biomass stock before burning for a particular stratum is estimated as follows:

$$B_{i,t} = (C_{AB_tree,i,t} + C_{DWi,t} + C_{LI,i,,t})*12/44 *(1/CF) \quad (35)$$

Where:

$B_{i,t}$	Average above-ground biomass stock before burning for stratum *i*, time *t*; tonnes d. m. ha^{-1}
$C_{AB_tree,i,t}$	Mean aboveground biomass carbon stock in stratum *i* at time *t*; t CO_2-e ha-1 (calculated per the procedure in Section A)
$C_{DWi,t}$	Carbon stock in dead wood for stratum *i,* at time *t*; t CO_2-e ha^{-1} (calculated per the procedure in Section B)
$C_{LI,i,,t}$	Mean carbon stock in litter for stratum *i,* at time *t*; t CO_2-e ha^{-1} (calculated per the procedure in Section C)
12/44	*Inverse* ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}
CF	Carbon fraction of biomass; t C t^{-1} d.m. (default carbon fraction of biomass is 0.47 tC t^{-1} d.m.
i	1, 2, 3 …*M* strata
t	1, 2, 3, … *t* years elapsed since the start of the project activity

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Table 1: Combustion factor values for parameter $COMF_i$ (from IPCC 2006)

TABLE 2.6
COMBUSTION FACTOR VALUES (PROPORTION OF PREFIRE FUEL BIOMASS CONSUMED) FOR FIRES IN A RANGE OF VEGETATION TYPES
(Values in column 'mean' are to be used for quantity C_f in Equation 2.27)

Vegetation type	Subcategory	Mean	SD	References
Primary tropical forest (slash and burn)	Primary tropical forest	0.32	0.12	7, 8, 15, 56, 66, 3, 16, 53, 17, 45,
	Primary open tropical forest	0.45	0.09	21
	Primary tropical moist forest	0.50	0.03	37, 73
	Primary tropical dry forest	-	-	66
All primary tropical forests		**0.36**	**0.13**	
Secondary tropical forest (slash and burn)	Young secondary tropical forest (3-5 yrs)	0.46	-	61
	Intermediate secondary tropical forest (6-10 yrs)	0.67	0.21	61, 35
	Advanced secondary tropical forest (14-17 yrs)	0.50	0.10	61, 73
All secondary tropical forests		**0.55**	**0.06**	56, 66, 34, 30
All tertiary tropical forest		**0.59**	-	66, 30
Boreal forest	Wildfire (general)	0.40	0.06	33
	Crown fire	0.43	0..21	66, 41, 64, 63
	surface fire	0.15	0.08	64, 63
	Post logging slash burn	0.33	0.13	49, 40, 18
	Land clearing fire	0.59	-	67
All boreal forest		**0.34**	**0.17**	45, 47
Eucalyptus forests	Wildfire	-	-	
	Prescribed fire – (surface)	0.61	0.11	72, 54, 60, 9
	Post logging slash burn	0.68	0.14	25, 58, 46
	Felled and burned (land-clearing fire)	0.49	-	62
All Eucalyptus forests		**0.63**	**0.13**	
Other temperate forests	Post logging slash burn	0.62	0.12	55, 19, 27, 14
	Felled and burned (land-clearing fire)	0.51	-	53, 24, 71
All "other" temperate forests		**0.45**	**0.16**	53, 56

TABLE 2.6 (CONTINUED)
COMBUSTION FACTOR VALUES (PROPORTION OF PREFIRE FUEL BIOMASS CONSUMED) FOR FIRES IN A RANGE OF VEGETATION TYPES

(Values in column 'mean' are to be used for quantity C_f in Equation 2.27.)

Vegetation type	Subcategory	Mean	SD	References
Shrublands	Shrubland (general)	0.95	-	44
	Calluna heath	0.71	0.30	26, 56, 39
	Fynbos	0.61	0.16	70, 44
All shrublands		**0.72**	**0.25**	
Savanna woodlands (early dry season burns)*	Savanna woodland	0.22	-	28
	Savanna parkland	0.73	-	57
	Other savanna woodlands	0.37	0.19	22, 29
All savanna woodlands (early dry season burns)		**0.40**	**0.22**	
Savanna woodlands (mid/late dry season burns)*	Savanna woodland	0.72	-	66, 57
	Savanna parkland	0.82	0.07	57, 6, 51
	Tropical savanna	0.73	0.04	52, 73, 66, 12
	Other savanna woodlands	0.68	0.19	22, 29, 44, 31, 57
All savanna woodlands (mid/late dry season burns)*		**0.74**	**0.14**	
Savanna Grasslands/ Pastures (early dry season burns)*	Tropical/sub-tropical grassland	0.74	-	28
	Grassland	-	-	48
All savanna grasslands (early dry season burns)*		**0.74**	-	
Savanna Grasslands/ Pastures (mid/late dry season burns)*	Tropical/sub-tropical grassland	0.92	0.11	44, 73, 66, 12, 57
	Tropical pasture~	0.35	0.21	4, 23, 38, 66
	Savanna	0.86	0.12	53, 5, 56, 42, 50, 6, 45, 13, 44, 65, 66
All savanna grasslands (mid/late dry season burns)*		**0.77**	**0.26**	
Other vegetation types	Peatland	0.50	-	20, 44
	Tropical Wetlands	0.70	-	44
Agricultural residues (Post harvest field burning)	Wheat residues	0.90	-	see Note b
	Maize residues	0.80	-	see Note b
	Rice residues	0.80	-	see Note b
	Sugarcane[a]	0.80	-	see Note b

* Surface layer combustion only
~ Derived from slashed tropical forest (includes unburned woody material)
[a] For sugarcane, data refer to burning before harvest of the crop.
[b] Expert assessment by authors.

Table 2: Emission factor values for parameter G_{gi} (from IPCC 2006)

TABLE 2.5
EMISSION FACTORS (g kg^{-1} DRY MATTER BURNT) FOR VARIOUS TYPES OF BURNING. VALUES ARE MEANS ± SD AND ARE BASED ON THE COMPREHENSIVE REVIEW BY ANDREAE AND MERLET (2001)
(To be used as quantity 'G_{ef}' in Equation 2.27)

Category	CO_2	CO	CH_4	N_2O	NO_X
Savanna and grassland	1613 ± 95	65 ± 20	2.3 ± 0.9	0.21 ± 0.10	3.9 ± 2.4
Agricultural residues	1515 ± 177	92 ± 84	2.7	0.07	2.5 ± 1.0
Tropical forest	1580 ± 90	104 ± 20	6.8 ± 2.0	0.20	1.6 ± 0.7
Extra tropical forest	1569 ± 131	107 ± 37	4.7 ± 1.9	0.26 ±0.07	3.0 ± 1.4
Biofuel burning	1550 ± 95	78 ± 31	6.1 ± 2.2	0.06	1.1 ± 0.6

Note: The "extra tropical forest" category includes all other forest types.

Note: For combustion of non-woody biomass in Grassland and Cropland, CO_2 emissions do not need to be estimated and reported, because it is assumed that annual CO_2 removals (through growth) and emissions (whether by decay or fire) by biomass are in balance (see earlier discussion on synchrony in Section 2.4.

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G. Emissions from Fossil Fuel Combustion

This section provides procedures for estimating emissions from fossil fuel combustion.

All fossil fuel combustion associated with a project may be accounted, including fossil fuel combustion of subcontractors that are conducting work to implement the project. Fossil fuel combustion in all situations is an optional emission source. Project Proponents may, however, elect to include fossil fuel combustion if emissions are higher in the baseline than in the project case thus generating emission reductions through project activities. Where emissions from fossil fuel combustion are estimated in the baseline, monitoring and estimation must also occur in the with-project scenario[10].

Where estimation of fossil fuel combustion is elected fuel consumption must be monitored.

1. Output parameter(s)

Parameter	SI Unit	Description
E_{FC}	tCO_2-e	Emission from fossil fuel combustion

2. Procedure

Emissions can be estimated from either the fuel consumed or the distance travelled by vehicles. Even though in general the first approach is appropriate for CO_2 and the second (distance travelled by vehicle type and road type) is appropriate for CH_4 and N_2O, the IPCC (2006) allows CH_4 and N_2O emissions from fossil fuel combustion to be estimated as:

$$E_{FC,t} = \sum_{a} (Fuel_{a,t} \times EF_a) \quad (36)$$

Where:

$E_{FC,t}$ Net CO_2-e emissions of Fuel Consumption in year *t*; tCO_2-e

$Fuel_{a,t}$ Amount of Fuel of type *a* consumed in year *t*; terrajoule (TJ)

EF_a Emission Factor of Fuel type *a*; tCO_2-e/TJ

A Fuel type *a* (e.g. diesel, gasoline, etc.)

The amount of fuel of a particular kind combusted in year *t* ($Fuel_{a,t}$) can be estimated as:

[10] Emissions due to fossil fuel combustion both inside and outside the project boundary will be considered project emissions.

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$$Fuel_{a,t} = Liters_{Fuel_{a,t}} \times Density_{Fuel_a} \times NCV_{Fuel} \div 10^6 \quad (37)$$

Where:

$Fuel_{a,t}$	Amount of Fuel type *a* consumed in year *t*; TJ
$Liters_{Fuel\ a,t}$	Quantity of Fuel of type *a* consumed in year *t*; ltr
$Density_{Fuel\ a}$	Density of Fuel type *a*; kg/ltr
$NCV_{Fuel\ a}$	Net Calorific Value of Fuel type *a*; TJ/Gg

Default values are provided in Annex 1 for all parameters not monitored. However, it is recommended and encouraged to use country-specific NCVs and EFs where available.

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H. Direct N_2O Emissions from Nitrogen Application

N_2O emissions from fertilizer application only need to be accounted for if they are higher in the project scenario than in the baseline scenario and if they are found to be significant. If a source is included in the estimation of baseline emissions, it shall also be included in the estimation of project and leakage emissions.

1. Output parameter(s)

Parameter	SI Unit	Description
$N_2O_{direct-N,t}$	tCO_2-e	Direct N_2O emission as a result of nitrogen application within the project boundary in year t

2. Procedure

For the calculation of direct N_2O emissions, the latest A/R CDM tool "Estimation of direct nitrous oxide emission from nitrogen fertilization"[11] shall be used.

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[11] http://cdm.unfccc.int/EB/033/eb33_repan16.pdf

ANNEX 1: PARAMETERS

A. Data and parameters not monitored (default or measured one time)

Data / parameter:	*BCEF*
Data unit:	Dimensionless
Used in equations:	32
Description:	Biomass conversion and expansion factor for conversion of commercial wood volume per unit area to total aboveground tree biomass per unit area; note that BCEF as defined here, and in most applications, is not applied on a per stem basis
Source of data:	Equations must have been derived using a wide range of measured variables (commercial wood volume per unit area and total aboveground biomass per unit area) based on datasets that comprise at least 30 trees. Equations must be based on statistically significant regressions and must have an r^2 that is ≥ 0.8. The source of data shall be chosen with priority from higher to lower preference as follows: (a) Existing local forest type-specific; (b) National forest type-specific or eco-region-specific (e.g. from national GHG inventory); (c) Forest type-specific or eco-region-specific from neighboring countries with similar conditions. Sometimes (c) might be preferable to (b); (d) Global forest type or eco-region-specific (e.g. IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.5) The project volume data to which the selected BCEF is applied must conform to the data the BCEF was originally derived from. In particular, it must match forest type, stand structure, minimum DBH, and cover the range of potential independent variable values (commercial volumes) likely to be encountered in the project area. *Care must be taken to ensure that the selected BCEF does not account for non-commercial species not represented in commercial volume estimates (i.e. is restricted to expanding merchantable volumes to account for only non-merchantable tree components).*
Measurement procedures (if any):	
Any comment:	Alternatively, BCEF, where not directly available, can be calculated as wood density (t dry mass m^{-3} green volume) * BEF (Biomass Expansion Factor = ratio of aboveground biomass to biomass of the commercial volume). If using BCEFs developed outside the project country (cases (c) and (d) above under Source of data), it is necessary to validate the applicability of BCEFs used.

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	Validation is performed by limited measurements: • Select at least 20 plots in the project area covering a wide range of commercial volumes. • Obtain tree measurements (e.g. DBH, height to a 10 cm diameter top) from which to calculate commercial volume and total biomass. • Calculate commercial volume per unit area (e.g. using Smalian's formula) and total biomass per unit area (using the biomass equation(s) selected for application in Section A of this chapter) for each plot • Calculate BCEF for each plot (biomass (t) / commercial volume (m^3) • Graph the plot-level estimates of BCEF versus commercial volume along with the BCEF equation (predicted) to be validated. If the estimated BCEFs of the measured plots are distributed both above and below the predicted value the BCEF equation may be used. The BCEF equation may also be used if the measured plots have a BCEF consistently lower than that predicted. If graphing the BCEF of the measured plots indicates a systematic bias to overestimation of BCEF (>75% of the plots above the predicted value) then another BCEF equation must be selected or developed anew.

Data / parameter:	*CF*
Data unit:	t C t^{-1} d.m.
Used in equations:	1, 4, 12, 13, 26, 30, 35
Description:	Carbon fraction of biomass for tree or species group *j*
Source of data:	Values from the literature (e.g. IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.3) shall be used if available, otherwise default value of 0.47 t C t^{-1} d.m. can be used
Measurement procedures (if any):	
Any comment:	Where new species are encountered in the course of monitoring, new carbon fraction values must be sourced from the literature or otherwise use the default value.

Data / parameter:	CF_{DW}
Data unit:	t C t^{-1} d.m.
Used in equations:	25

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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:	$COMF_i$
Data unit:	dimensionless
Used in equations:	34
Description:	Combustion factor for stratum *i* (vegetation type)
Source of data:	Default values in Table 2.6 of IPCC, 2006 (reproduced in Table 1 of Section F)
Measurement procedures (if any):	
Any comment:	The combustion factor is a measure of the proportion of the fuel that is actually combusted, which varies as a function of the size and architecture of the fuel load (i.e., a smaller proportion of large, coarse fuel such as tree stems will be burnt compared to fine fuels, such as grass leaves), the moisture content of the fuel and the type of fire (i.e., intensity and rate of spread). Default values shall be updated whenever new guidelines are produced by the IPCC.

Data / parameter:	*D*
Data unit:	t d.m. m^{-3}
Used in equations:	17, 18, 23, 24, 30
Description:	Basic wood density in 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) National species-specific or group of species-specific (e.g. from National GHG inventory);

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	(b) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a); (c) Global species-specific or group of species-specific (e.g. IPCC 2006 INV GLs AFOLU Chapter 4 Tables 4.13 and 4.14). Species-specific wood densities may not always be available, and may be difficult to apply with certainty in the typically species rich forests of the humid tropics, hence it is acceptable practice to use wood densities developed for forest types or plant families or species groups.
Measurement procedures (if any):	N/A
Any comment:	Where using wood densities developed outside of the project country (cases (b) and (c) above under Source of data), wood densities must be validated with either limited destructive sampling or direct measurement of wood hardness (e.g. with a Pilodyn wood tester) in the field and correlating with wood density. Samples or measurements should be from 20-30 trees. For validation of mean forest type or species group wood densities, representation of species in the sample should be proportional to their occurrence in terms of basal area or volume in the project area (not abundance or stem density). Samples should provide representation across the length of the tree. 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}). If the density of the samples/measurements (or mean density in the case of forest type or species group means) is within ±10% of the selected density values, then the selected density values may be used. Otherwise, a new density value must be developed with more extensive sampling, using the validation samples as a base. Where new species are encountered in the course of monitoring, new wood density values must be sourced from the literature and validated, if necessary, as per requirements and procedures above.

Data / parameter:	*D:RAD*
Data unit:	Dimensionless
Used in equations:	4, 21
Description:	Ratio of DBH to plot radius, specific to prism Basal Area Factor (BAF) employed in point sampling
Source of data:	BAF (m^{2}/ha) D:RAD 2 35.4

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	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:	17,18
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 (c) may be preferable to (b); (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

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	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), 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:	

Data / parameter:	$Density_{Fuel\ a}$
Data unit:	Kg/ltr
Used in equations:	37
Description:	Density of Fuel type
Source of data:	Table A3.8 Page 181 of the Energy Statistics Manual of OECD/IEA, 2004.
Measurement procedures (if any):	Densities for relevant petroleum products as presented in table A3.8 Typical Density Values for Selected Petroleum Products
Any comment:	Shall be assessed every 10 years to determine whether more accurate defaults are available

Fuel Type	Density (kg/ltr)	Liters per tonne
Motor gasoline	0.7407	1350
Gas/Diesel Oil	0.8439	1185
Naphtha	0.6906	1448
Aviation gasoline	0.7168	1350
Aviation Turbine fuel	0.8026	1246
Other kerosene	0.8026	1246

Data / parameter:	Dep_{sample}
Data unit:	cm
Used in equations:	27
Description:	Depth in cm to which soil sample is collected

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Source of data:	Core dimensions recorded in the field
Measurement procedures (if any):	Depth of sampling for soil organic carbon is centered on the upper soil horizons where root biomass and organic matter inputs are concentrated, depending on soil type and ecosystem, typically between 20 cm and 100 cm. Depth of soil sampling employed in inventories is held constant for the duration of the project.
QA/QC procedures:	
Any comment:	

Data / parameter:	EF_a
Data unit:	tCO_2-e/TJ
Used in equations:	36
Description:	Emission factor
Source of data:	Table 1.4 Chapter 1 Volume 2 of IPCC, 2006.
Measurement procedures (if any):	Default emission factors are presented in the table below. Table: Road transport default CO_2 emission factors.[a]

Fuel Type	Default effective CO_2 emission factor (tCO_2/TJ)
Motor gasoline	69,3
Gas/Diesel Oil	74,1
Liquefied Petroleum Gases	63,1
Kerosene	71,9
Lubricants	73,3
Compressed Natural Gas	56,1
Liquefied Natural Gas	56,1

[a] Values represent 100% oxidation of fuel carbon content.

The emission factors assume that 100% of the carbon content of the fuel is oxidized during or immediately following the combustion process (for all fuel types in all vehicles) irrespective of whether the CO_2 has been emitted as CO_2, CH_4, CO or NMVOC or as particulate matter.

Any comment:	Shall be assessed every 10 years to determine whether more accurate defaults are available

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Data / parameter:	$f_j(X,Y)$
Data unit:	t d.m. tree^{-1}
Used in equations:	1, 4
Description:	Allometric equation for species *j* linking measured tree variable(s) to aboveground biomass of living trees, expressed as t d.m. tree^{-1}
Source of data:	Equations must have been derived using a wide range of measured variables (e.g. DBH, height, etc.) based on datasets that comprise at least 30 trees. Equations must be based on statistically significant regressions and must have an r^2 that is ≥ 0.8. The source of equation(s) shall be chosen with priority from higher to lower preference, as available, as follows: (a) National species-, genus-, family-specific; (b) Species-, genus-, family-specific from neighboring countries with similar conditions (i.e. broad continental regions); (c) National forest-type specific; (d) Forest-type specific from neighboring countries with similar conditions (i.e. broad continental regions); (e) Pan-tropical forest type-specific such as those provided Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC 2003) or in Pearson, T., Walker, S. and Brown, S. 2005. *Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and the World Bank Biocarbon Fund*. 57pp. Available at: http://www.winrock.org/Ecosystems/files/Winrock-BioCarbon_Fund_Sourcebook-compressed.pdf or in Chave, J., C. Andalo, S. Brown, M. A. Cairns, J. Q. Chambers, D. Eamus, H. Folster, F. Fromard, N. Higuchi, T. Kira, J.-P. Lescure, B. W. Nelson, H. Ogawa, H. Puig, B. Riera, T. Yamakura. 2005. *Tree allometry and improved estimation of carbon stocks and balance in tropical forests*. Oecologia 145: 87-99. Species-, genus- and family-specific allometric equations may not always be available, and may be difficult to apply with certainty in the typically species-rich forests of the humid tropics. Hence it is acceptable practice to use equations developed for regional or pantropical forest types, provided that their accuracy has been validated with direct site-specific data (per guidance below). If a forest-type specific equation is used, it should not be used in combination with species-specific equation(s) (i.e. it must be used for all tree species[12]).
Measurement procedures (if any):	
Any comment:	It is necessary to validate the applicability of equations used. Source data from

[12] Note that forest type specific and pantropical equations will typically not include palm species or hollow-stem species (e.g. *Cecropia*) and so specific equations for these growth forms will be needed.

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which equation was derived should be reviewed and confirmed to be representative of the forest type/species and conditions in the project and covering the range of potential independent variable values.

Allometric equations can be validated either by:

1. Limited Measurements

- Select at least 30 trees (if validating forest type-specific equation, selection should be representative of the species composition in the project area, i.e. species representation in roughly in proportion to relative basal area). Minimum diameter of measured trees shall be 20cm and maximum diameter shall reflect the largest trees present or potentially present in the future in the project area (and/or leakage belt)
- Measure DBH and height to a 10 cm diameter top or to the first branch.
- Calculate stem volume from measurements and multiplying by species-specific density to gain biomass of bole.
- Apply a biomass expansion factor to estimate total aboveground biomass from stem biomass. For broadleaf tropical trees this factor shall be:
    - 1.38 for trees 20-40cm
    - 1.33 for trees 40-80cm
    - 1.25 for trees ≥ 80cm[13]
- Plot all the estimated biomass of all the measured trees along with the curve of biomass against diameter as predicted by the allometric equation. If the estimated biomass of the measured trees are distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a biomass consistently higher than predicted by the equation. If plotting the biomass of the measured trees indicates a systematic bias to overestimation of biomass (>75% of the trees above the predicted curve) then destructive sampling must be undertaken, or another equation selected.

or

2. Destructive Sampling

- Select at least 5 trees (if validating forest type-specific equation, selection should be representative of the species composition in the project area, i.e. species representation in roughly in proportion to relative basal area) at the upper end of the range of independent variable values existing in the project area.
- Measure DBH and commercial height and calculate volume using the same procedures/equations used to generate commercial volumes to which Biomass conversion and expansion factors (BCEFs) will be applied.
- Fell and weigh the aboveground biomass to determine the total (wet) mass of the stem, branch, twig, leaves, etc. Extract and immediately weigh subsamples from each of the wet stem and branch components, followed by oven drying at 70 degrees C to determine dry biomass.
- Determine the total dry weight of each tree from the wet weights and the

[13] Biomass expansion factors conservatively selected from destructively sampled trees in Bolivia and Belize, reference to IPCC GPG LULUCF BEF values, and expert opinion.

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	averaged ratios of wet and dry weights of the stem and branch components. • Plot the biomass of all the harvested trees along with the curve of biomass against diameter as predicted by the allometric equation. If the biomass of the harvested trees are distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the harvested individuals have a biomass consistently higher than predicted by the equation. If plotting the biomass of the harvested trees indicates a systematic bias to overestimation of biomass (>75% of the trees above the predicted curve) then additional destructive sampling must be undertaken, or another equation selected. Details of destructive sampling measurements are given in Brown, S. 1997. *Estimating biomass and biomass change of tropical forests: a primer*. FAO Forestry Paper 134, Rome, Italy. Available at http://www.fao.org/docrep/W4095E/W4095E00.htm If using species-specific equations, and new species are encountered in the course of monitoring, new allometric equations must be sourced from the literature and validated, if necessary, as per requirements and procedures above.

Data / parameter:	f_i*(vegetation parameters)*
Data unit:	t. d.m. individual^{-1}
Used in equations:	13
Description:	Allometric equation for non-tree species / linking parameters such as stem count, diameter of crown, height, or others to above-ground biomass of an individual
Source of data:	Whenever available, use allometric equations that are species-specific or group of species-specific, provided the equations have been derived using a wide range of diameters and heights, based on datasets that comprise at least 30 individuals. Proponent may create project location specific-equation where appropriate.
Measurement procedures (if any):	It is necessary to verify the applicability of existing equations used. Allometric equations can be verified either by: 1. Review of source data from which equation was derived and confirmation that the source data is representative of the species and conditions in the project and covers the range of potential sizes. 2. Destructive Sampling • Selecting at least 5 individuals covering the range of sizes existing, and felling and weighing the above-ground biomass to determine the total (wet) mass of the stem and branch components; • Extracting and immediately weighing subsamples from each of the wet stem

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	and branch components, followed by oven drying at 70°C to determine dry biomass; • Determining the total dry weight of each individual from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components. If the biomass of the harvested individual is within ±10% of the mean values predicted by the selected allometric equation, and is not biased, then mean values from the equation may be used. Otherwise, the equation must be re-parameterized to conform to the validation data before using, or another equation selected. To create a new allometric equation, follow guidance in Pearson, T., Walker, S. and Brown, S. 2005. *Sourcebook for Land Use, Land-Use Change and Forestry Projects*. Winrock International and the World Bank Biocarbon Fund. 57pp. Available at: http://www.winrock.org/Ecosystems/files/Winrock-BioCarbon_Fund_Sourcebook-compressed.pdf.
Any comment:	

Data / parameter:	F_{MG}
Data unit:	Dimensionless
Used in equations:	29
Description:	Management factor before or after conversion
Source of data:	Stock Change Factors are provided in Tables 5.5, 5.10, and 6.2 of the IPCC 2006GL Volume 4
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	Stock Change Factors must be selected to reflect the circumstances most closely matching those of the project area and baseline scenario, especially regarding climate and post-conversion land-use, taking into account management practices and carbon inputs (e.g. manure).
Any comment:	Stock Change Factors as defined in IPCC 2006GL are equal to the carbon stock in the altered condition as a proportion of the reference carbon stock.

Data / parameter:	F_I

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Data unit:	Dimensionless
Used in equations:	29
Description:	Input factor before or after conversion
Source of data:	Stock Change Factors are provided in Tables 5.5, 5.10, and 6.2 of the IPCC 2006GL Volume 4
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	Stock Change Factors must be selected to reflect the circumstances most closely matching those of the project area and baseline scenario, especially regarding climate and post-conversion land-use, taking into account management practices and carbon inputs (e.g. manure).
Any comment:	Stock Change Factors as defined in IPCC 2006GL are equal to the carbon stock in the altered condition as a proportion of the reference carbon stock.

Data / parameter:	G_{gi}
Data unit:	g kg^{-1} dry matter burnt
Used in equations:	34
Description:	Emission factor for stratum *i* for gas *g*
Source of data:	Defaults can be found in Volume 4, Chapter 2, of the IPCC 2006 Inventory Guidelines in table 2.5 (reproduced in Table 5 below).
Measurement procedures (if any):	
Any comment:	Default values shall be updated whenever new guidelines are produced by the IPCC

Data / parameter:	NCV_a
Data unit:	TJ/Gg

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Used in equations:	37
Description:	Net Caloric Value per Fuel Type
Source of data:	Table A3.8, page 181, IEA Statistics Manual, OECD/IEA, 2004; Table 1.2, Chapter 1, Volume 2, IPCC 2006 Inventory Guidelines
Measurement procedures (if any):	Default NCVs are presented in tables below.

Fuel Type	Density (kg / ltr)	NCV (GJ/t)[a]
Motor gasoline	0.7407	44.75
Gas/Diesel Oil	0.8439	43.38
Naphtha	0.6906	45.34
Aviation gasoline	0.7168	45.03
Aviation Turbine fuel	0.8026	43.92
Other kerosene	0.8026	43.92

[a] 1000 GJ = 1 TJ

Table: Default NCVs (excerpt from table 1.2, Chapter 1, Volume 2, IPCC, 2006 Inventory Guidelines)

Fuel type (English description)	Default Net Caloric Value (NCV) (TJ/Gg)[b]
Crude Oil	42.3
Orimulsion	27.5
Natural Gas Liquids	44.2
Motor Gasoline	44.3
Aviation Gasoline	44.3
Jet Gasoline	44.3
Jet Kerosene	44.1
Other Kerosene	43.8
Gas/Diesel Oil	43.0
bio-gasoline/bio-diesel	27.0
other liquid biofuels	27.4

[b] TJ/Gg = GJ/t

Any comment:	For more NCVs for other fuels, see the original data sources. Shall be assessed every 10 years to determine whether more adequate defaults are available

Data / parameter:	*R*

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Data unit:	t root d.m. t^{-1} shoot d.m.
Used in equations:	7, 9, 15
Description:	Root:shoot ratio appropriate to species or forest type/biome; note that as defined here, root:shoot ratio is applied as belowground biomass per unit area:aboveground biomass per unit area (not on a per stem basis)
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) Detailed data collected using common practices for root sampling in the area; (b) Globally forest type-specific or eco-region-specific (e.g. IPCC GPG-LULUCF). *Root to shoot ratios for tropical and subtropical forests modified from Table 4.4. in IPCC GL AFOLU*
Measurement procedures (if any):	
Any comment:	Guidelines for Conservative Choice of Default Values: 1. If in the sources of data mentioned above, default data are available for conditions that are similar to the project (similar forest or vegetation type; same climate zone), then mean values of default data may be used and considered conservative. 2. Global values may be selected from Table 4.4 (modified as given above) of the AFOLU Guidelines (IPCC 2006), by choosing a climatic zone and forest type that most closely matches the project circumstances.

Domain	Ecological Zone	Aboveground biomass	Root-to-shoot ratio	Range
Tropical	Tropical rainforest	*<125 t.ha^{-1}*	0.20	*0.09-0.25*
		>125 t.ha^{-1}	0.24	*0.22-0.33*
	Tropical dry forest	*<20 t.ha^{-1}*	0.56	*0.28-0.68*
		>20 t.ha^{-1}	0.28	*0.27-0.28*
Subtropical	Subtropical humid forest	*<125 t.ha^{-1}*	0.20	*0.09-0.25*
		>125 t.ha^{-1}	0.24	*0.22-0.33*
	Subtropical dry forest	*<20 t.ha^{-1}*	0.56	*0.28-0.68*
		>20 t.ha^{-1}	0.28	*0.27-0.28*

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B. Data and parameters monitored

Data / parameter:	A_r
Data unit:	ha
Used in equations:	14
Description:	Total area of all non-tree allometric method sample plots in stratum *i*
Source of data:	Recording and archiving size of non-tree allometric method sample plot
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{sampleframe}$
Data unit:	m^{-2}
Used in equations:	22
Description:	Area of one sampling frame
Source of data:	Recording and archiving size of sampling frame plot
Measurement procedures (if any):	
Any comment:	

Data / parameter:	A_{sp}
Data unit:	ha
Used in equations:	3, 8, 16, 20, 26
Description:	Area of sample plots in ha
Monitoring interval:	Not more than 5 years
Source of data:	Recording and archiving of number and size of sample plots

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Measurement procedures (if any):	
QA/QC procedures:	
Any comment:	

Data / parameter:	A_{sp}
Data unit:	m^{-2}
Used in equations:	26
Description:	Total area of all sample plots
Source of data:	Recording and archiving of number and size of sample plots
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	BD_{sample}
Data unit:	$g\ cm^{-3}$
Used in equations:	27
Description:	Bulk density of fine (< 2 mm) fraction of mineral soil per unit volume of sample in $g\ cm^{-3}$; bulk density equals the oven dry weight of the fine fraction (< 2 mm) of the soil core divided by the core volume
Monitoring interval:	Not more than 5 years
Source of data:	Field sampling and laboratory determination
Measurement procedures (if any):	For bulk density determination, samples (cores) of known volume are collected in the field and oven dried to a constant weight at 105°C (for a minimum of 48 hours). The total sample is then weighed, then any coarse rocky fragments (>2

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	mm) are sieved and weighed separately. The bulk density of the soil core is estimated as: $$BD_{sample} = \frac{ODW - RF}{CV}$$ Where: BD_{sample} Bulk density of the < 2mm fraction, in grams per cubic centimeter (g/cm^3) ODW Oven dry mass total sample in grams CV Core volume in cm^3 RF Mass of coarse fragments (> 2 mm) in grams Note that volume includes coarse (>2mm) fragments. Because coarse rocky fragments occupy space in the soil profile in which carbon is not stored, discounting this volume as in traditional bulk density calculations would overestimate soil carbon stocks when applied to a volume that does not distinguish between coarse and fine fractions. Further guidance is provided in the IPCC 2003 GPG-LULUCF and in Nelson, D.W., and L.E. Sommers. 1982. *Total carbon, organic carbon, and organic matter*. p. 539–580. In A.L. Page et al. (ed.) *Methods of soil Analysis. Part 2*. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI and Pearson, T., Walker, S. and Brown, S. 2005. *Sourcebook for Land Use, Land-Use Change and Forestry Projects*. Winrock International and the World Bank Biocarbon Fund. 57pp. Available at: http://www.winrock.org/Ecosystems/files/Winrock-BioCarbon_Fund_Sourcebook-compressed.pdf
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:	17,18
Description:	Basal diameter of standing dead tree in cm

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Monitoring interval:	Not more than 5 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:	$B_{LI,sp,i,t}$
Data unit:	kg d.m.
Used in equations:	26
Description:	Biomass of litter in sample plot *sp* in stratum *i* at time *t*
Source of data:	Field sampling and laboratory determination
Measurement procedures (if any):	Litter (dead organic surface material < 10 cm diameter) is collected from within fixed area sampling frames, harvested at ground level and dried at 70ºC to a constant weight to determine dry weight biomass. In cases where sample bulk is excessive, the green weight of the total sample and of a representative sub-sample are recorded in the field and the sub-sample taken for moisture content determination in the lab (i.e. oven dry weight:green weight ratio), from which the dry weight biomass of the total green weight recorded in the field can be estimated. Further guidance is provided in the IPCC 2003 GPG-LULUCF.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	$C_{SOCsample}$
Data unit:	g C/100 g soil (fine fraction <2 mm)

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Used in equations:	27
Description:	Soil organic carbon of the sample in g C/100 g soil
Monitoring interval:	Not more than 5 years
Source of data:	Field sampling and laboratory determination
Measurement procedures (if any):	For soil carbon determination, an aggregate sample (e.g. from 4 systematically-distributed cores) is collected from within a sample plot in the field, thoroughly mixed and sieved through a 2 mm sieve. The prepared sample is analyzed for percent organic carbon using either dry combustion using a controlled-temperature furnace (e.g. LECO CHN-2000, LECO RC-412 multi-carbon analyzer, or equivalent), dichromate oxidation with heating, or Walkley-Black method. Further guidance is provided in the IPCC 2003 GPG-LULUCF and in Nelson, D.W., and L.E. Sommers. 1982. *Total carbon, organic carbon, and organic matter*. p. 539–580. In A.L. Page et al. (ed.) *Methods of soil Analysis. Part 2*. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI and Pearson, T., Walker, S. and Brown, S. 2005. *Sourcebook for Land Use, Land-Use Change and Forestry Projects*. Winrock International and the World Bank Biocarbon Fund. 57pp. Available at: http://www.winrock.org/Ecosystems/files/Winrock-BioCarbon_Fund_Sourcebook-compressed.pdf
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:	4, 21
Description:	Diameter at breast height of a tree in cm
Monitoring interval:	Not more than 5 years
Source of data:	Field measurements in sample plots

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Measurement procedures (if any):	Typically measured 1.3m aboveground. Measure all trees above some minimum *DBH* in the sample plots. The minimum *DBH* varies depending on tree species and climate; for instance, the minimum *DBH* may be as small as 2.5 cm or as high as 20 cm, but for himud tropical forests 10 cm is commonly used. 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:	QA/QC procedures apply not only to DBH but to all tree or non-tree vegetation dimension variables measured, as may be identified by allometric equations employed but not specifically identified here.

Data / parameter:	$Dia_{n,i,t}$
Data unit:	cm
Used in equations:	23
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*, at time *t* in *cm*
Monitoring interval:	Not more than 5 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[14]). 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 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:	

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[14] 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.

Data / parameter:	$Fuel_{a,t}$
Data unit:	litres
Used in equations:	36
Description:	Fuel consumed
Source of data:	Records of fuel consumed or distance travelled by vehicles.
Measurement procedures (if any):	In the absence of direct fuel consumption data, each major fuel type used by each road vehicle type can be estimated from data on vehicle kilometers travelled (which requires a km registration system) or from the expenditure on fuel (on the basis of receipts/fuel acquired). Records / monitoring shall be continuous and consumption/mileage shall be divided by equipment type / road vehicle type. Where estimation of fossil fuel combustion is elected as an emission source, fossil fuel use by the project both inside and outside the project boundary shall be recorded and considered as project emissions.
Any comment:	

Data / parameter:	H_{SDW}
Data unit:	m
Used in equations:	17, 18
Description:	Height of standing dead tree in m
Monitoring interval:	Not more than 5 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 clinometer, 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:	

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Data / parameter:	*N*
Data unit:	Dimensionless
Used in equations:	6, 10, 22
Description:	Number of sample points
Monitoring interval:	Not more than 5 years
Source of data:	Recording and archiving of number of sample points
Measurement procedures (if any):	
QA/QC procedures:	
Any comment:	

Data / parameter:	*OF*
Data unit:	Dimensionless
Used in equations:	31, 33
Description:	OF = Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years after production. Winjum *et al*. 1998 gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate and tropical). This methodology projects these fractions over 95 years to give the additional proportion (*OF* value) that is oxidized between the 5th and 100th years after initial harvest:
Source of data:	The source of data is the published paper of Winjum *et al*. 1998[15]

Wood Product Class	*OF*		
	Boreal	Temperate	Tropical
Sawnwood	0.36	0.60	0.84
Woodbase panels	0.60	0.84	0.97
Other industrial roundwood	0.84	0.97	0.99
Paper and paperboard	0.36	0.60	0.99

[15] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

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Measurement procedures (if any):	
Any comment:	Parameter values to be updated if new empirically-based peer-reviewed findings become available. At least every 10 years, Project Proponents should review research findings every to identify further refinements to the emission factors that are empirically-based and peer-reviewed.

Data / parameter:	$Pcom_i$
Data unit:	Dimensionless
Used in equations:	32
Description:	Commercial volume as a percent of total aboveground volume in stratum *i*.
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) Direct forest inventory of the project area, distinguishing commercially viable stocks on the basis of species and tree size, referencing local expert knowledge or a participatory rural assessment (PRA) of harvest practices and markets; (b) Forest inventory from a proxy area in the same region, representing the same forest type and age class, distinguishing commercially viable stocks on the basis of species and tree size, referencing local expert knowledge of harvest practices and markets National and forest type-specific or eco-region-specific (e.g. from National GHG inventory).
Measurement procedures (if any):	This parameter is updated at baseline renewal when aboveground biomass is re-inventoried (every < 10 years).
Any comment:	Note that application of the commercial percentage of total volume introduces the simplifying assumption (and conservative, as it is only used in the *ex ante* baseline calculations) that all commercial stocks are extracted (i.e. perfect efficiency).

Data / parameter:	*SLF*
Data unit:	Dimensionless
Used in equations:	31, 33
Description:	SLF = Fraction of wood products that will be emitted to the atmosphere within 5 years of production

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	Winjum *et al.* 1998 give the following proportions for wood products with short-term (<5 yr) uses after which they are retired and oxidized (applicable internationally): Sawnwood 0.2 Woodbase panels 0.1 Other industrial roundwood 0.3 Paper and Paperboard 0.4 The methodology makes the assumption that all other classes of wood products, and where wood product class *ty* is unknown, are 100% oxidized within 5 years. Therefore SLF, by wood product class, is equal to:

Wood Product Class	*SLF*
Sawnwood	0.2
Woodbase panels	0.1
Other industrial roundwood	0.3
Paper and paperboard	0.4
Other classes of wood products	1.0

Source of data:	The source of data is the published paper of Winjum *et al*. 1998[16]
Measurement procedures (if any):	
Any comment:	Parameter values to be updated if new empirically-based peer-reviewed findings become available.

Data / parameter:	TD_{SDW}
Data unit:	cm
Used in equations:	18
Description:	Top diameter of standing dead tree in cm
Monitoring interval:	Not more than 5 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

[16] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

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	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:	$V_{ex,i}$
Data unit:	m^3
Used in equations:	30
Description:	The volume of timber in m^3 extracted from within the stratum (does not include slash left onsite), reported by wood product class and preferably species.
Source of data:	Timber harvest records and/or estimates derived from field measurements or remote assessments with aerial photography or satellite imagery.
Measurement procedures (if any):	
Any comment:	Note that this volume does not include logging slash left onsite. Data compilers should also make sure that extracted volumes reported are gross volumes removed (i.e. reported volume does not already discount for estimated wood waste, as is often the practice in harvest records). Assignment of volume extracted to wood product class(es) must be substantiated on the basis of participatory rural appraisal (PRA) findings or records of timber sales. Assignment of volume extracted to species, must be substantiated on the basis of either PRA findings, harvest records, or a commercial inventory.

Data / parameter:	*WW*
Data unit:	dimensionless
Used in equations:	31, 33
Description:	WW = Fraction of extracted biomass effectively emitted to the atmosphere during production Winjum *et al*. 1998 indicate that the proportion of extracted biomass that is oxidized (burning or decaying) from the production of commodities to be equal to

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	19% for developed countries, 24% for developing countries. *WW* is therefore equal to $C_{XB,ty}$ multiplied by 0.19 for developed countries and 0.24 for developing countries.
Source of data:	The source of data is the published paper of Winjum *et al*. 1998[17]
Measurement procedures (if any):	
Any comment:	Parameter values to be updated if new empirically-based peer-reviewed findings become available.

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[17] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284