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The AFOLU Carbon Calculator

AFOLU CARBON CALCULATOR

THE FOREST MANAGEMENT TOOL: UNDERLYING DATA AND METHODS

Winrock International

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TABLE OF CONTENTS

List of Figures 3
1. Scope 4
2. Applicability 4
3. approach to the FM tool 4
4. Data Sources 5
4.1. Uneven-Aged forest Management 6
Rotation AND PROJECT Length 6
Volume of Timber Extracted Before Project Activity 6
Wood Density 6
4.2. Even-Aged forest Management 6
5. Calculation Methods 7
5.1. Uneven-Aged Forest management 7
Stop Logging Activities 8
Reduced Impact Logging Activities 11
5.2. Uneven-Aged Forest management 13
5.3. Hypothetical Level A Example 13
6. Overriding Level A Data 15
7. References 16

LIST OF FIGURES

Figure 1. Emissions from selective logging operations in the Forest Management Calculator include: (A) emissions from timber extracted (minus a portion that ends up stored in long-term wood products), (B) emissions from incidental damage to surrounding trees, and (C) emissions from the creation of logging roads, skid trails and landing decks. Photos courtesy of Winrock International. 5

1. SCOPE

This document describes the underlying data sources and calculation methods employed in the Forest Management (FM) Tool of the AFOLU Carbon Calculator (http://afolucarbon.org/). The FM Tool is designed for project activities that aim at reducing carbon emissions by improving forest management and timber harvesting practices.

2. APPLICABILITY

The FM Tool is applicable to improved forest management activities that will reduce carbon emissions from logging practices. This Tool is designed to account for reduced carbon emissions from improved uneven-aged tropical forest management practices (i.e. selective logging); although capabilities for accounting reduced carbon emissions from improved even-aged forest management practices will also be added in a future iteration.

The improved uneven-aged forest management practices are comprised of: reduced impact logging (RIL); and stopping logging (SL).

3. APPROACH TO THE FM TOOL

The approach employed in the FM Tool is based on the methodology described by Pearson et al. (submitted for publication), and uses the IPCC's gain-loss approach to calculate the difference in CO_2 emissions between two scenarios: the pre-project intervention (i.e. conventional logging practices), and the post-project intervention (i.e. stopping or reducing the impact of logging practices). For each scenario, CO_2 emissions are calculated as shown in Box 1, and consist of the sum of emissions from timber extraction, the process of tree felling, and the creation of infrastructure, such as logging roads, skid trails and logging decks (Figure 1).

Box 1: Estimating emissions from conventional logging

Emissions (t CO_2e) = [(Timber Tree – Wood Products) + Incidental Damage + Logging Infrastructure]

Note: All terms are expressed in biomass carbon (t CO_2)

Figure 1. Emissions from selective logging operations in the Forest Management Calculator include: (A) emissions from timber extracted (minus a portion that ends up stored in long-term wood products), (B) emissions from incidental damage to surrounding trees, and (C) emissions from the creation of logging roads, skid trails and landing decks. Photos courtesy of Winrock International.

The approach describe by Pearson et al. (submitted for publication) and employed in the FM tool consist of a more complete carbon accounting than the guidance provided by the IPCC (2006) tier 1, as it includes losses in carbon stocks from incidental damage and logging infrastructure, and permanent storage of carbon in long-term wood products (Winjum et al., 1998).

The data required by the approach used in the FM Tool was collected directly in the field by Winrock International and/or consultants, compiled from literature and other global datasets (e.g. FAO FRA), and acquired through direct communications with partner government institutions, non-governmental organizations, or private sector forestry industries.

4. DATA SOURCES

Forest management practices can differ depending on the characteristics of the forest being managed, such as species composition and age. Forest management practices can be divided into two main groups: uneven-aged, and even-aged forest management. In highly diverse forest stands, such as many managed forests in the tropical zones, management practices often target select trees within the forest (i.e. selective logging), thus rendering the age of the remaining forest stands diverse. Other forests are managed for one or very few species creating homogeneous forest stands with low diversity, in this case management practices often entail clearcutting of a forest area, with subsequent planting or recruitment of a uniform new cohort of trees.

The FM Tool currently has capabilities for accounting carbon emissions and/or reductions from uneven-aged forest management practices. Even-aged forest management is in the process of development and will be included in the FM Tool soon.

4.1. UNEVEN-AGED FOREST MANAGEMENT

ROTATION AND PROJECT LENGTH

In many cases the area of managed forest is known but not the area harvested in any given year. Rotation length is used to here to estimate the annual area undergoing logging. Forests are assumed to be managed on a cycle of 30-year rotation in this component of the FM tool. The assumption is based on common practice for conducting selective logging in tropical forest. Users may change rotation length under Level B. An additional assumption made is that area logged on any given year must be greater than 200 ha and smaller than 10,000 ha. This assumption is based on personal communication with several concessionaries across the tropical world, and on expert knowledge on tropical silviculture. The tool calculates benefits over the length of 1 rotation. Therefore, if the project area would be fully logged before 30 years, the tool will only calculate benefits up to that point.

VOLUME OF TIMBER EXTRACTED BEFORE PROJECT ACTIVITY

Default annual timber extraction rates (m^3 ha^{-1} yr^{-1}) were compiled from the following data sources: FAO (1990), FAO FRA Country Reports (2010)[1], published literature (Holmes et al., 2002; Medjibe et al., 2011; Medjibe and Putz, 2012; Putz et al., 2012), countries' code of forestry practices whenever available (e.g. Guyana and Brazil), consultants (Tropical Forest Foundation [2]), and personal communications (for Bolivia, Brazil, Peru, Democratic Republic of Congo, Republic of Congo, Lao PDR, Vietnam, Cambodia, Thailand, Malaysia, Indonesia, and Papua New Guinea). Users can see what the default data is associated with the administrative region of their project by looking at the Level B part of the activity page. In some cases no default data was available, so a value of zero is given. Users will have to enter their own data for extraction rates to generate emissions benefits numbers.

WOOD DENSITY

Values for average volume-weighted wood density of a forest stand in the project area are taken from Reyes et al. (1992). These values are estimated for tropical tree species and vary by continent: 0.57 for Asia, 0.58 for Africa, and 0.60 for Latin America.

4.2. EVEN-AGED FOREST MANAGEMENT

Under development.

[1] Available at: http://www.fao.org/forestry/fra/fra2010/en/
[2] More information at: http://www.tropicalforestfoundation.org/

5. CALCULATION METHODS

Parameters in blue can be specified by the user under Level A. Parameters in red have default values under Level B, but can be changed by the user. Parameters in black are fixed within the calculations.

5.1. UNEVEN-AGED FOREST MANAGEMENT

The methods for estimating emissions from selective logging uses the IPCC (2003) gain-loss approach for carbon accounting, and is based on the methods described by Pearson et al. (submitted for publication). The overarching equation (equation 1) that allows calculations of emissions from logging prior to and after project intervention is a function of: (i) the area logged in a given year; (ii) the amount of timber extracted per unit area per year; (iii) the amount of dead wood produced in a given year from tops and stump of the harvested tree, mortality of the surrounding trees caused by the logging, and tree mortality from the skid trails, roads, and logging decks, and (iv) the biomass that went into long term storage as wood products.

$$\textit{Emissions (t } CO_2\textit{)} = AHA \times \{[(Vol \times WD \times CF) - WoodProducts] + (Vol \times DamageFactor) + (Vol \times LoggingInfrastructure)\} \times (44/12)$$

Where:

AHA	= annual harvest area (ha)
Vol	= volume timber over bark extracted ($m^3\ ha^{-1}$)
WD	= wood density (t d.m. m^{-3})
CF	= carbon fraction – the proportion of biomass that is carbon - 0.47 (IPCC, 2006)
WoodProducts	= amount of carbon of extracted wood in long-term products still in use after 100 yr (t C)
DamageFactor	= logging damage factor – dead biomass left behind in gap from felled tree and incidental damage (t C m^{-3})
LoggingInfrastructure	= logging infrastructure factor – dead biomass caused by construction of infrastructure: skid trails, logging roads and landing decks (t C m^{-3})
44/12	= conversion factor from carbon to carbon dioxide equivalent

Parameters in blue are required to be entered by the user. The volume of timber extracted, and the proportion of extracted wood destined to long-term wood products are optional to the user and can be modified from Tool's underlying data in Level B.

AHA (ha) = THA / RL

Where:

AHA	= annual harvest area (ha)
THA	= total harvestable area, total area under forest management during the lifetime of project (ha)
RL	= rotation length for returning to an already harvested area within the total forest management area (years)

Annual harvest area is a product of dividing the entire area harvestable area (*THA*) by the time it will take for harvesting to return to a previously harvested area (i.e. rotation length – *RL*). Default values are provided for rotation length, although users may alter it to represent project activities more accurately. Otherwise, users may choose to enter annual harvest area (*AHA*) directly under Level B, which will discard the use/need of *THA* or *RL*.

STOP LOGGING ACTIVITIES

For project activities that stop logging, there are no emissions associated with the project scenario because timber is no longer being extracted from the forest. Therefore, the CO_2 benefit of stopping logging activities is equal to the emissions associated with conventional logging activities that are no longer occurring. In other words, the volume of timber extracted per hectare after the project activity defaults to zero in the Stop Logging project scenario.

Benefits (t CO_2e) = Emissions from Convention Selective Logging

Carbon Emissions from Volume of Timber Extracted

TimberTree (t C) = {[VolExt_before x AHA x WD] x CF}

Where:

TimberTree	= carbon in extracted timber (t C)
VolExt_before	= volume timber over bark extracted before project intervention (m^3 ha^{-1})
AHA	= annual harvest area (ha)
RL	= rotation length for returning to an already harvested block (years)
WD	= wood density (t d.m. m^{-3})
CF	= carbon fraction, the proportion of biomass that is carbon - 0.47 (IPCC, 2006)

The equation to calculate timber emissions is based on the volume of timber extracted per hectare before the implementation of the project activity took place (*VolExt_before*) and the annual harvest area (AHA). Default values for both factors are provided, but can be changed under Level B if desired. Multiplying the volume of timber extracted per hectare by area harvested yields the total volume of

timber extracted from the forest, which is then converted to biomass using default values of wood density, which are also provided and can be changed under Level B if known. Biomass is converted to carbon by applying the carbon fraction of dry biomass.

Carbon Stored in Long Term Wood Products

$$WoodProducts\ (t\ C) = \sum_{class=1}^{4} C_timber_{class} - C_ww_{class} - C_slp_{class} - C_addlox_{class}$$

Where:

WoodProducts	= carbon permanently stored in long term wood products (tC)
C_timberclass	= carbon in timber extracted from project area that ends up in a given product class
C_wwclass	= carbon in a given product class that ends up as wood waste
C_slpclass	= carbon in a given product class that is oxidized in less than 5 years
C_addloxclass	= carbon in a given product class that is oxidized between 5-100 years

Much of the timber that is extracted from the forest as logs will be emitted to the atmosphere within 100 years of initial timber harvest as wood waste at the mill, or as a result of the oxidation of wood products. However, a small fraction will be effectively sequestered permanently, which is assumed to be any carbon remaining in wood products beyond 100 years. This fraction is calculated based on how much carbon is removed initially as extracted timber (*C_timber*), and varies based on the various wood products class harvested wood is destined to: sawnwood, wood based panels, roundwood, and pulp and paper. The methodology applied in the FM tool follows the approach outlined by Winjum et al (1998) and is described below.

Step 1. Proportion of total carbon extracted that resides in each wood product class. Wood products are classified into one of four categories commonly reported to the Food and Agriculture Organization (FAO): sawnwood, woodbase panels, other industrial roundwood, and paper and paperboard. Because these wood product classes have different lifecycles, it is necessary to divide the total timber extracted from the project area into these four product classes. For each country included in the FM tool, production volumes of sawnwood, wood-base panels, and other industrial roundwood were obtained from FAO databases for the year 2008 and converted to carbon using volume to biomass conversion factors from Table 1 of Winjum et al. (1998) and a carbon conversion factor of 0.47 (1 t biomass = 0.47 t C). (The paper and paperboard class is reported in units of biomass, therefore no conversion from volume was needed.) After all product classes were represented in a consistent unit (carbon), proportions of the total carbon in each product class could be derived for each country. The assumption was that the proportions of extracted timber in the project area going into each product class were equal to the proportions for the country in which the project is located.

Step 2: Carbon in wood waste. The proportion of carbon in each wood product class that is oxidized immediately at the mill as wood waste during the production of commodities (*C_ww*) is assumed to be equal to 24% for developing countries (Winjum et al., 1998).

Carbon emitted due to wood waste is therefore equal to:

*C_ww = C_timber * 0.24.*

Step 3: Carbon in short-lived products. Winjum et al. (1998) give the following proportions of each product class that are oxidized in the short-term (<5 yr):

Sawnwood	0.2
Woodbase panels	0.1
Other industrial roundwood	0.3
Paper and paperboard	0.4

Carbon emitted due to short-term oxidation of wood products in each class are:

*C_slp = (C_timber – C_ww) * proportion oxidized in <5yr*

Step 4: Carbon in additional oxidized fraction. Winjum et al. (1998) gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate, tropical). In the calculator, these fractions have been projected over 95 years to give the additional proportion that is oxidized between the 5th and 100th years after initial harvest. For this calculation, all administrative units in the tool were assumed to be in the tropical forest region.

Sawnwood	0.84
Woodbase panels	0.97
Other industrial roundwood	0.99
Paper and paperboard	0.99

Emissions associated with the additional oxidation in each class are:

*C_addlox = (C_timber – C_ww – C_slp) * proportion oxidized 5-100 yr*

Carbon Emissions from Incidental Damage

As part of past work funded in part by USAID and other partners such as TNC, and the Government of Guyana, Winrock International has conducted extensive field measurements to measure the impact of selective logging on carbon stocks in Belize, Bolivia, Brazil, Guyana, Indonesia, Malaysia, and Republic of Congo. These field measurements revealed a relationship between the volume of wood extracted out of the forest and resulting carbon emissions from surrounding forest (e.g. here referred to as "incidental damage"). The default calculation for carbon emissions from incidental damage is based on the total volume of timber extracted:

*IncidentalDamage (t C) = DamageFactor * TotalVolExtracted*

Total volume extracted (*TotalVolExtracted*) is calculated automatically using information about the total harvest area (THA) and the default value of *VolExt_before*. The damage factor (*DamageFactor*) estimated based on field sampling in 7 countries across the tropical world varies by continental region:

Latin America and the Caribbean:	1.047 *(t C m^{-3})*
Sub-Saharan Africa:	0.500 *(t C m^{-3})*
Asia and the Near East:	0.595 *(t C m^{-3})*

Carbon Emissions from Logging Infrastructure

During conventional logging operations in tropical humid forests, forests are cleared to build logging infrastructure, such as skid trails, logging roads and landing decks. During Winrock's field measurements to measure damage factors for tree felling, the mean biomass of trees killed for the creation of logging infrastructure was also measured and related to the volume of timber extracted:

LoggingInfrastructure (t C) = Skids + RoadsDecks

*Skids (t C) = SkidsFactor * TotalVolExtracted*

*Roads and Decks (t C) = RoadsDecksFactor * TotalVolExtracted*

During Winrock's field measurements the mean biomass of trees killed for the creation of logging infrastructure was also measured and related to the volume of timber extracted:

SkidsFactor:	*0.127 (t C m^{-3})*
RoadsDecksFactor:	*0.503 (t C m^{-3})*

Due to the open structure of tropical dry forests, trees do not need to be cleared to create logging infrastructure in these forests, and therefore, carbon emissions from logging infrastructure are assumed to be zero in administrative units dominated by dry forests.

REDUCED IMPACT LOGGING ACTIVITIES

For RIL projects, CO_2 emissions still occur in the project scenario because timber is still being extracted from the forest, but practices are in place to minimize the negative impact of logging operations on the surrounding forest and soil. Therefore, the benefit of RIL activities is equal to the difference between emissions associated with conventional logging activities and emissions associated with RIL activities:

Benefits (t CO_2e) = Emissions from Conventional Logging – Emissions from RIL

Emissions associated with reduced impact logging are also calculated using the same equations outlined above, but using adjustment factors to account for the minimized impact of RIL operations on forest carbon stocks.

Carbon Emissions from Volume of Timber Extracted

The equation to calculate timber emissions in the RIL scenario is based on the volume of timber extracted per hectare AFTER the project activity took place (*VolExt_after*). A default value is provided (default assumes that the quantity of timber extracted in RIL is the same as for conventional logging), but the user has the option to change this value.

C timber (t C) = {[*VolExt_before* x *AHA* x *WD*] x *CF*} - {[*VolExt_after* x *AHA* x *WD*] x *CF*}

Where:

C timber	=	carbon in extracted timber (t C)
VolExt_before	=	volume timber over bark extracted before project intervention (m^3 ha^{-1})
VolExt_after	=	volume timber over bark extracted after project intervention (m^3 ha^{-1})
AHA	=	annual harvest area (ha)
RL	=	rotation length for returning to an already harvested block (years)
WD	=	wood density (t m-3)
CF	=	carbon fraction, the proportion of biomass that is carbon - 0.47 (IPCC, 2006)

Carbon Stored in Long Term Wood Products

The same 3-step methodology proposed by Winjum et al. (1998) and described in Stop Logging Activities above is followed for calculating carbon storage in long-term wood products in the RIL scenario, but the calculations are based on the carbon removed in extracted timber (*C_timber*) before and after the project activity has started. In other words, carbon storage into wood products is estimated: (i) using volume of timber extracted before project activity (*VolExt_before*) for estimating emission prior to activity implementation (emissions from conventional logging); and (ii) using volume of timber extracted after project activity (based on *VolExt_after*) to estimate emissions reductions.

Carbon Emissions from Incidental Damage

The same methodology as cited above in Stop Logging section is followed, but in the project case the resulting estimates are multiplied by 0.723 to account for the reduced damage caused to the surrounding forest as a result of better logging practices. This value is taken from Pinard and Putz (1996), who measured carbon stock changes associated with forest harvesting for both conventional and reduced impact logging. Based on data reported in this paper, a factor of 0.723 was applied for the reduced impact of RIL on dead wood stocks produced by the process of tree felling.

Carbon Emissions from Logging Infrastructure

Carbon emissions from logging infrastructure are calculated in the RIL scenario in the same way cited above, except that the resulting estimates are multiplied by 0.47 and 0.65 to account for the reduced

damaged caused by skid trails and logging roads/decks respectively in a RIL scenario. Dry forests are also assumed to have no emissions associated with infrastructure, given their openness of understory.

The skid trail factor value of 0.47 was derived by analyzing the studies of Pereira et al. (2002), Holmes et al. (2002) and Pinard et al. (1995), who measured the area of skid trails under RIL and conventional logging and found RIL area to be 46, 62 and 34% of conventional logging. Averaging these studies gives a reduction of 47% under a RIL scenario.

The road and decks factor value of 0.65 was derived by analyzing the studies of Pereira et al. (2002) and Holmes et al. (2002), who measured the relative extent of infrastructure under RIL vs. conventional logging.

Users can, under Level B, input their own proportion reduction for skid trails and logging roads/decks which will override these default values.

5.2. UNEVEN-AGED FOREST MANAGEMENT

Under development.

5.3. HYPOTHETICAL LEVEL A EXAMPLE

A hypothetical FM project activity planting undertaking reduced impact logging in 10,000 hectares of native forests in Peru is given as an example here. First, users have to select the geographic location of the project, which in this hypothetical example will take place in the Amazon portion of Peru, in Loreto.

After entering the total harvestable area of the FM project activity, that is the total under forest management (10,000 ha), the annual harvest area of approximately 333 ha is calculated (automatically estimated in Level B using 30 years rotation length).

$AHA = THA / RL$

Where:
THA = 10,000 ha
RL = 30 years

Thus, equating to:
AHA = 10,000 / 30
AHA = 333.33 ha y^{-1}
The next step, is to select the type of management (only uneven-aged forest management is available at the time of writing this report), and the type of project activity, which in this case, is reduced impact logging (RIL). The user then goes to the Level B part of the tool to override the default data which

assumes that RIL volumes are equal to the project volumes and enters the extraction rate after the project activity intervention as 5m^3 ha^{-1} yr^{-1}.

Benefits (t CO_2e) = (Emissions from Conventional Logging) – (Emissions from RIL)

$$\text{Benefits (t } CO_2\text{e)} = (AHA \times \{[(Vol_{Conv} \times WD \times CF) - WoodProducts_{Conv}] + (Vol_{Conv} \times DamageFactor_{Conv\text{-}LA}) + LoggingInfrastructure_{Conv}\} \times (44/12)) - (AHA \times \{[(Vol_{RIL} \times WD \times CF) - WoodProducts_{RIL}] + (Vol_{RIL} \times DamageFactor_{RIL\text{-}LA}) + LoggingInfrastructure_{RIL}\} \times (44/12))$$

Where:

AHA	= 333.33 ha
Vol_{Conv}	= 8 m^3 ha^{-1}
Vol_{RIL}	= 5 m^3 ha^{-1}
WD	= 0.6 t m^{-3}
$WoodProducts_{Conv}$	= 0.13 t C
$WoodProducts_{RIL}$	= 0.08 t C
$DamageFactor_{Conv\text{-}LA}$	= 1.047 t C m^{-3} (for Latin America)
$DamageFactor_{RIL\text{-}LA}$	= 1.047*0.723 = 0.757 t C m^{-3} (for Latin America)
$LoggingInfrastructure_{Conv}$	= 5.04 t C
$LoggingInfrastructure_{RIL}$	= 1.93 t C
CF	= 0.47 (IPCC, 2006)
44/12	= conversion factor from carbon to carbon dioxide equivalent

Thus, benefits equate to:

$$\text{Benefits (t } CO_2\text{e)} = (333.33 \times \{[(8 \times 0.6 \times 0.47) - 0.13] + (8 \times 1.047) + 5.04\} \times (44/12)) - (333.33 \times \{[(5 \times 0.6 \times 0.47) - 0.08] + (5 \times 1.047 \times 0.723) + 1.93]\} \times (44/12))$$

Benefits (t CO_2e) = 19,001 – 8,615

Benefits (t CO_2e) = 10,386

In this hypothetical example, our FM project activity that harvests a little over 333 ha of native forests annually (10,000 ha managed over a 30 years) in Loreto, Peru, has resulted in a carbon benefit of approximately **10,386 t CO_2e** in the first year of the project's operation..

6. OVERRIDING LEVEL A DATA

The FM tool allows users to override various data sources used in the calculations, such as:

- Rotation length: RL (yr)
- Annual harvest area: AHA (ha yr^{-1})
- Extraction rate before intervention: VolExt_before (m^3 ha^{-1} yr^{-1})
- Extraction rate after intervention: VolExt_after (m^3 ha^{-1} yr^{-1}) (RIL Only since stop logging automatically locks after intervention rates as zero)
- Proportion of skid trails reduced
- Proportion of reduced roads and decks
- Average wood density: WD (g cm^{-3} or t m^{-3})
- Wood products fraction
    - Sawnwood
    - Roundwood
    - Woodbased panels
    - Pulp and paper

Given the investment demand of forest management activities prior to implementation of the activity itself, it is expected that users will have project-specific data on RL, AHA, and VolExt_after (intended harvest volume), but likely also on VolExt_before. The likely availability of one or more of these data would result in much more accurate estimates of carbon benefits from improved forest management practices, especially when considering that some of the data sources provided are at country, or even continent scale. Thus, users are encouraged to use project-specific data whenever possible.

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