Approved VCS Module VMD0011
Version 1.0
REDD Methodological Module:
Estimation of emissions from market effects (LK-ME)
Sectoral Scope 14

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module allows for estimating GHG emissions caused by the market-effects leakage related to extraction of wood for timber, fuelwood or charcoal in the baseline for carbon projects. As per the VCS AFOLU requirements international market leakage is not considered.

Applicability

This module is applicable for calculating market-effects leakage from REDD projects that are anticipated to reduce levels of wood harvest substantially and permanently. When REDD project activities result in reductions in wood harvest, it is likely that production could shift to other areas of the country to compensate for the reduction.

As referenced in the Framework (REDD-MF) the module is mandatory where:

- The process of deforestation involves timber harvesting for commercial markets[1]
- The baseline is calculated using BL-DFW AND fuel wood or charcoal is harvested for commercial markets

In all other circumstances the module shall not be used.

Parameters

This module provides procedures to determine the following parameter:

Parameter	SI Unit	Description

[1] Commercial markets here defined as sale of products to end users and public and private companies with sales conducted distant (>50km) from the project area

$\Delta C_{LK\text{-}ME}$	$t\text{-}CO_2\text{-}e$	Net greenhouse gas emissions due to market-effects leakage

II. PROCEDURE

Total leakage due to market effects is equal to the sum of market effects leakage through decreased timber harvest and decreased harvest for fuelwood / charcoal production.

$$\Delta C_{LK-ME} = LK_{MarketEffects,timber} + LK_{MarketEffects,FW/C} \tag{1}$$

Where:

$\Delta C_{LK\text{-}ME}$ Net greenhouse gas emissions due to market- effects leakage; t CO_2-e

$LK_{MarketEffects,timber}$ Total GHG emissions due to market- effects leakage through decreased timber harvest; t CO_2-e

$LK_{MarketEffects,FW/C}$ Total GHG emissions due to market leakage through decreased harvest of fuelwood and charcoal sold into regional and/or national markets; t CO_2-e

Section II.1 details calculations necessary for estimating market-effects leakage caused by decreased timber harvest and Section II.2 details calculations necessary for estimating market-effects leakage caused by decreased harvest of fuelwood or charcoal for sale to regional or national markets.

1. Market-Effects Leakage Through Decreased Timber Harvest

Leakage due to market effects is equal to the baseline emissions from logging multiplied by a leakage factor:

$$LK_{MarketEffects,timber} = \sum_{i=1}^{M} \left(LF_{ME} * AL_{T,i} \right) \tag{2}$$

Where:

$LK_{MarketEffects,timber}$ Total GHG emissions due to market- effects leakage through decreased timber harvest; t CO_2-e

LF_{ME} Leakage factor for market-effects calculations; dimensionless

$AL_{T,i}$ Summed emissions from timber harvest in stratum *i* in the baseline case potentially displaced through implementation of carbon project; t CO_2-e

i *1,2,3,…M strata*

The amount of leakage is determined by where harvesting would likely be displaced to. If in the forests to which displacement would occur a lower proportion of forest biomass in commercial species is in merchantable material than in project area, then in order to extract a given volume higher emissions should be expected as more trees will need to be cut to supply the same volume. In contrast if a higher proportion of the total biomass of commercial species is merchantable in the displacement forest than in the project forests, then a smaller area would have to be harvested and lower emissions would result.

Each project thus shall calculate within each stratum the proportion of total biomass in commercial species that is merchantable (PMP_i). This shall then be compared to mean proportion of total biomass that is merchantable for each forest type (PML_{FT}).

Merchantable biomass is defined as: Total gross biomass (including bark) of a tree 40 cm DBH or larger from a 30 cm stump to a minimum 10 cm top of the central stem.

The following deduction factors (LF_{ME}) shall be used:

Where:

PML_{FT} *is equal (± 15%) to* PMP_i:	$LF_{ME} = 0.4$
PML_{FT} *is > 15% less than* PMP_i	$LF_{ME} = 0.7$
PML_{FT} *is > 15% greater than* PMP_i	$LF_{ME} = 0.2$

Where:

PML_{FT}	Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type; %
PMP_i	Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* within the project boundaries; %
LF_{ME}	Leakage factor for market-effects calculations; dimensionless

The next step is to estimate the emissions associated with the displaced logging activity. This is based on the total volume that would have been logged in the baseline in the project area across strata and time periods:

$$AL_{T,i} = \sum_{t=1}^{t} \left(C_{BSL,XBT,i,t} \right) \quad (3)$$

Where:

$AL_{T,i}$	Summed emissions from timber harvest in stratum *i* in the baseline case potentially displaced through implementation of carbon project; t CO_2-e
$C_{BSL,XBT,i,t}$	Carbon emission due to displaced timber harvests in the baseline scenario in stratum *i* in time *t*; t CO_2-e
i	1, 2, 3, …*M* strata

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

The carbon emission due to the displaced logging has two components: the biomass carbon of the extracted timber (see also module CP-W which uses the same equation) and the biomass carbon in the forest damaged in the process of timber extraction:

$$C_{BSL,XBT,i,t} = \left(\left[V_{BSL,XE,i,t} * D_{mn} * CF\right] + \left[V_{BSL,XE,i,t} * LDF\right] + \left[V_{BSL,XE,i,t} * LIF\right]\right) * \frac{44}{12} \qquad (4)$$

Where:

$C_{BSL,XBT,i,t}$	Carbon emission due to timber harvests in the baseline scenario in stratum *i* at time *t*; t CO_2-e
$V_{BSL,EX,i,t}$	Volume of timber projected to be extracted from within the project boundary during the baseline in stratum *i* at time *t*; m^3
D_{mn}	Mean wood density of commercially harvested species; t d.m.m^{-3}. The value must be the same as that used in the module CP-W if this pool is included in the baseline.
CF	Carbon fraction of biomass for commercially harvested species *j*; t C t d.m.$^{-1}$. The value must be the same as that used in the module CP-W if this pool is included in the baseline.
LDF	Logging damage factor; t C m^{-3} (default 0.53 t C m^{-3} for broadleaf and mixed forests; 0.25 t C m^{-3} for coniferous forests)
LIF	Logging infrastructure factor; t C m^{-3} (default 0.29 t C m^{-3})
i	1, 2, 3, … *M* strata
t	1, 2, 3, … *t** years elapsed since the projected start of the REDD project activity

The logging damage factor (LDF) is a representation of the quantity of emissions that will ultimately arise per unit of extracted timber (m^3). These emissions arise from the non-commercial portion of the felled tree (the branches and stump) and trees incidentally killed during tree felling. The default values given here comes from the slope of the regression equation between carbon damaged and volume extracted based on 774 logging gaps measured by Winrock International in Bolivia, Belize, the Republic of Congo, Brazil and Indonesia (Annex 1), and 134 logging gaps in Mexico.

The logging infrastructure factor (LIF) is a representation of the quantity of emissions that will ultimately arise per unit of timber (m^3) from roads, skid trails and logging decks. The conservative default value is the upper confidence interval of the average emission from analyses conducted across 1,473 hectares in the Republic of Congo and 366 hectares in Brazil (Annex 1).

2. Market Effects Leakage Through Decreased Harvest of Fuelwood and Charcoal Sold into Regional and/or National Markets

Leakage due to market effects is equal to the emissions from fuelwood or charcoal harvests that are displaced outside the project area multiplied by a leakage factor:

$$LK_{MarketEffects,FW/C} = \sum_{i=1}^{M}\left(LF_{ME} * AL_{FW/C,i}\right) \tag{5}$$

Where:

$LK_{MarketEffects,FW/C}$	Total GHG emissions due to market leakage through decreased harvest of fuelwood and charcoal sold into regional and/or national markets; t CO_2-e
LF_{ME}	Leakage factor for market effects calculations; dimensionless
$AL_{FW/C,i}$	Summed emissions from fuelwood/charcoal harvests in stratum *i* in the baseline case potentially displaced through implementation of carbon; t CO_2-e

The leakage factor is determined by considering where in the country harvest of fuelwood/charcoal might be increased as a result of the decreased supply of the products caused by the project. As very few species would be considered unsuitable for fuelwood and charcoal and the infrastructure associated with fuelwood or charcoal is greatly less significant than for timber extraction it is not considered that the proportion of biomass in commercial species will have relevance. Thus LF_{ME} is set at the level where mean merchantable biomass as a proportion of total aboveground tree biomass is considered equal in the project area to areas where harvesting will be displaced (i.e. LF_{ME} = 0.4 for fuel wood/charcoal in all circumstances).

The next step is to estimate the emissions associated with the displaced harvesting activity. This is based on the total volume that would have been logged in the baseline in the project area across strata and time periods:

$$AL_{FW/C,i} = \sum_{t=1}^{t} C_{BSL,XBFWC,i,t} \tag{6}$$

Where:

$AL_{FW/C,i}$	Summed emissions from fuelwood/charcoal harvests in stratum *i* in the baseline case potentially displaced through implementation of carbon; t CO_2-e
$C_{BSL,XBFWC,t}$	Carbon emission due to displaced fuelwood/charcoal harvests in stratum *i* in the baseline scenario at time *t*; t CO_2-e

A_i	The area of stratum i in which harvesting of fuelwood and/or production of charcoal is anticipated in the baseline scenario; ha
i	1, 2, 3, … M strata
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity

The carbon emission due to displaced harvests is calculated from the volume that would likely be extracted in the baseline scenario minus any fuel wood supplied in the with-project scenario:

$$C_{BSL,XBFWC,i} = \left[\left(FG_{BSL,i,t} * D_{mn} * CF\right) - \left(FG_{P,i,t} * D_{mn} * CF\right)\right] * \frac{44}{12} \quad (7)$$

Where:

$C_{BSL,XBFWC,i,t}$	Likely carbon emission due to displaced fuelwood/charcoal harvests in the baseline scenario in stratum i at time t; t CO_2-e
$FG_{BSL,t}$	Average projected annual volume of fuelwood to be gathered in the project area in the baseline scenario in stratum i at time t; m^3 yr^{-1}
$FG_{LP,t}$	Volume of fuelwood gathered in the project area and in areas designated by the project for leakage prevention (i.e. fuelwood plantations) according to monitoring results in stratum i at time t; m^3 yr^{-1}
D_{mn}	Mean wood density of commercially harvested species; t d.m.m^{-3}
CF	Carbon fraction of biomass for commercially harvested species j; t C t^{-1} d.m.
i	1, 2, 3, …M_B strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the projected start of the REDD project activity

If $C_{BSL,XBFWC,i,t}$ as calculated in equation 7 is <0 then $C_{BSL,XBFWC,i,t}$ shall be set equal to 0 (this prevents positive leakage).

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

Data / parameter:	*CF*
Data unit:	t C t d.m.$^{-1}$
Used in equations:	4,7
Description:	Carbon fraction of dry matter
Source of data:	Species specific values from the literature (e.g. IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.3) or default value 0.47 t C t^{-1} d.m. Default shall be used if no species specific values are available
Measurement procedures (if any):	
Any comment:	

Data / parameter:	D_{mn}
Data unit:	t d.m.m^{-3}
Used in equations:	4,7
Description:	Mean wood density of commercially harvested species
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: (a) Averaged national and commercial species-specific (e.g. from National GHG inventory); (b) Averaged commercial species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a). (c) Averaged regional commercial species-specific (e.g. Table 4.13 IPCC National Guidance for Greenhouse Gas Inventories AFOLU Section). (d) Regional average (0.58 t d.m.m-3- tropical Africa; 0.60 t d.m.m-3- tropical America; 0.57 d.m.m-3- tropical Asia) from Brown, S. 1997. Estimating Biomass and Biomass Change of Tropical Forests: a Primer. For the Food and Agriculture Organization of the United Nations. Rome, 1997. FAO Forestry Paper - 134. ISBN 92-5-103955-0. Must use the same value in the CP-W module if this module is used.
Measurement procedures (if any):	
Any comment:	

Data / parameter:	*LDF*
Data unit:	t C m^{-3}
Used in equations:	4
Description:	Factor for calculating the biomass of dead wood created during logging operations per cubic meter extracted
Source of data:	Default value for broadleaf and mixed forests of 0.53 t C m^{-3} from 774 logging gaps measured by Winrock International in Bolivia, Belize, the Republic of Congo, Brazil and Indonesia may be used for tropical broadleaf forests (cf. Annex 1). Default value for coniferous forests of 0.25 t C m^{-3} from 134 logging gaps measured by Winrock International in Mexico (cf. Annex 1).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	*LIF*
Data unit:	t C m^{-3}
Used in equations:	4
Description:	Factor for calculating the emissions arising from the creation of logging infrastructure (roads, skid trails and decks) during logging operations per cubic meter extracted
Source of data:	Conservative default value of 0.29 t CO_2-e m^{-3} calculated from 1,839 hectares of logging concessions analysed by Winrock International in the Republic of Congo and Brazil, may be used for tropical broadleaf forests (cf. Annex 1).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	PML_{FT}
Data unit:	%
Used in equations:	
Description:	Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type

Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: 1. Peer-reviewed published sources (including carbon/biomass maps or growing stock volume[2] maps with a scale of at least 1km) 2. Official Government data and statistics 3. Original field measurements The forest types considered shall be only those relevant for the specific market effects leakage; i.e. only forest types with active timber production. An appropriate source of data will be Government records on annual allowable cuts for the areas of commercial forests. Where volumes are used the source of data wood density is required to convert to merchantable biomass. The source of data on wood densities shall be chosen with priority from higher to lower preference as follows: 1. Knowledge on commercial species and thus an appropriately weighted wood density derived from the density of these species 2. A region-specific mean wood density as given e.g. in Brown 1997[3]
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$V_{BSL,EX,i,t}$
Data unit:	m^3
Used in equations:	4
Description:	Volume of timber projected to be extracted from within the project boundary during the baseline in stratum *i* at time *t*
Source of data:	The source of data shall be chosen with priority from higher to lower preference as follows: 1. Timber harvest records and/or 2. Estimates derived from field measurements and/or 3. Assessments with aerial photography or satellite imagery.

[2] Volumes shall be converted to merchantable biomass using wood densities/specific gravities. A weighted wood density shall be used to convert multi-species data on growing stock volume to merchantable biomass

[3] Brown, S. 1997. Estimating biomass and biomass change of tropical forests: a Primer. FAO Forestry Paper 134. http://www.fao.org/docrep/W4095E/W4095E00.htm

Measurement procedures (if any):	
Any comment:	Note that this volume does not include logging slash left onsite (tracked as part of the dead wood pool). 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)

IV. DATA AND PARAMETERS MONITORED

Data / parameter:	PMP_i
Data unit:	%
Used in equations:	
Description:	Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* within the project boundaries
Source of data:	Within each stratum divide the summed merchantable biomass (defined as "Total gross biomass (including bark) of a tree 30 cm DBH or larger from a 30 cm stump to a minimum 10 cm top DOB of the central stem") by the summed total aboveground tree biomass Merchantable biomass is equal to merchantable volume multiplied by wood density (D_{mn})
Measurement procedures (if any):	
Monitoring frequency:	Must be monitored at least every 5 years or if verification occurs on a frequency of less than every 5 years examination must occur prior to any verification event
QA/QC procedures:	
Any comment:	*Ex-ante* a time zero measurement shall be made of this factor

V. PARAMETERS ORIGINATING IN OTHER MODULES

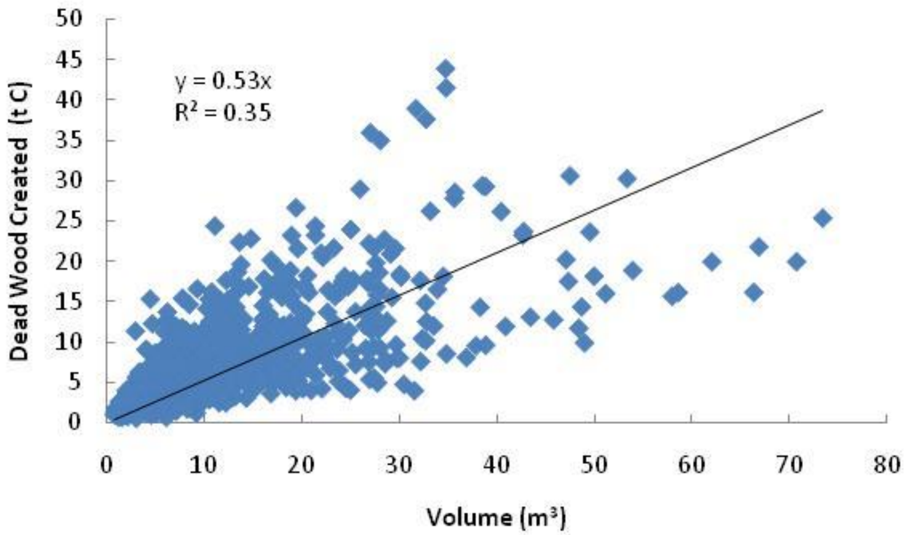
Data / parameter:	$FG_{BSL,i,t}$
Data unit:	$m^3\ yr^{-1}$
Used in equations:	7
Description:	Average projected annual volume of fuelwood to be gathered in the project area in the baseline scenario in stratum *i* at time *t*
Module parameter originates in:	BL-DFW
Any comment:	

Data / parameter:	$FG_{P,i,t}$
Data unit:	$m^3\ yr^{-1}$
Used in equations:	7
Description:	Average projected annual volume of fuelwood to be gathered in the project area in the baseline scenario in stratum *i* at time *t*
Module parameter originates in:	LK-DFW (used in equations 1 and 2)
Any comment:	

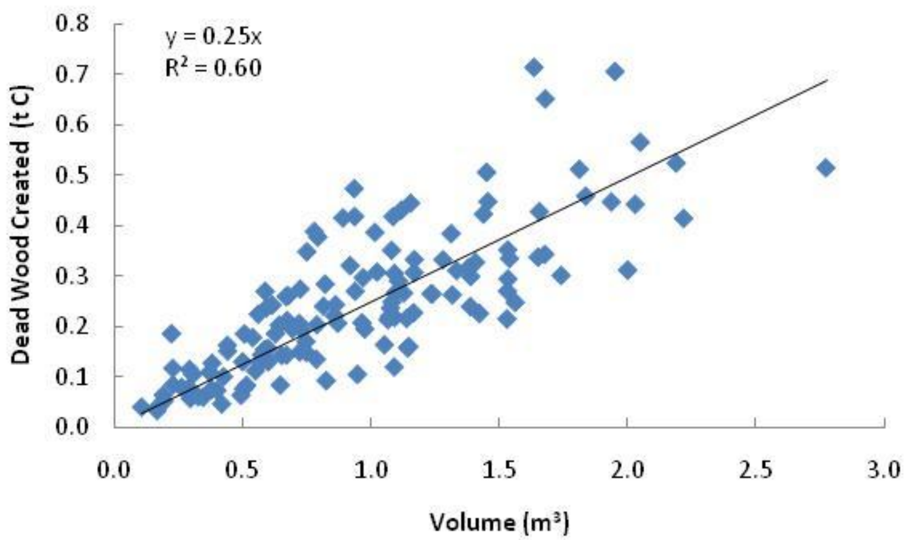
VI. ANNEX 1

LDF – Logging Damage Factor

For Broadleaf and Mixed Broadleaf/Conifer Forests:



For Conifer Forests:



Methods used by Winrock are described in the following reports to USAID:

Deliverable 9: Use of Aerial Digital Imagery to measure the impact of selective logging on carbon stocks of tropical forests in Republic of Congo

Deliverable 10: Quantification of carbon benefits in conservation project activities through spatial modeling: Republic of Congo as a case study

<u>Deliverable 13a</u>: Impact of logging on carbon stocks of forests: Chihuahua, Mexico as a case study

<u>Deliverable 17</u>: Impact of logging on carbon stocks of forests: The Brazilian Amazon as a case study

<u>Deliverable 21</u>: Use of aerial digital imagery to measure the impact of selective logging on carbon stocks of tropical forest in Brazilian Amazon

<u>Deliverable 24</u>: Impact of selective logging on carbon stocks of tropical forests in East Kalimantan, Indonesia

Under Carbon and Co-Benefits from Sustainable Land-Use Management project: Cooperative Agreement No. EEM-A-00-03-00006-00

And the following report to the Nature Conservancy:

Casarim, F.M., S.K. Grimland, and S. Brown. 2010. Carbon Impacts from Selective Logging of Forests in Berau, East Kalimantan, Indonesia

And in the following manuscript being prepared for peer-reviewed publication:

Pearson, TRH and Brown, S. 2009. Impact of selective logging on the carbon stocks of tropical forests: case studies from Belize, Bolivia, Brazil, Indonesia, Mexico and the Republic of Congo.

Results are from uneven forest management practices. Application to even-aged forest management practices is conservative as under even-aged practices the emissions are solely from the non-extracted proportion of the timber trees while in uneven-aged practices emissions also come from trees incidentally damaged and killed during the felling of timber trees.

LIF – Logging Infrastructure Factor

	Congo		Brazil	
Area examined (ha)	1,473		366	
Area of logging gaps (ha)	31.9		3.7	
Length of skid trails (km)	18.4		3.2	
Length of roads (km)	4.6		0.8	
Calculated extraction (m^3 +/- 95% C.I.)	14,150	*±870*	1,617	*±327*

Mean biomass of trees killed during logging operations:

Roads: 0.15 t C m^{-3} (± 0.08; 95 % confidence interval)

Skid Trails: 0.01 t C m^{-3} (± 0.05; 95 % confidence interval)

Logging Decks: 0.03 t C m^{-3} (± 0.04; 95 % confidence interval)

Therefore LIF = 0.1865 t C m^{-3} (± 0.11; 95 % confidence interval)

Therefore the conservative value for LIF = 0.29 t C m^{-3} (mean plus 95% confidence interval)

Methods used by Winrock are described in the following reports to USAID:

Deliverable 9: Use of Aerial Digital Imagery to measure the impact of selective logging on carbon stocks of tropical forests in Republic of Congo

Deliverable 10: Quantification of carbon benefits in conservation project activities through spatial modeling: Republic of Congo as a case study

Deliverable 17: Impact of logging on carbon stocks of forests: The Brazilian Amazon as a case study

Deliverable 21: Use of aerial digital imagery to measure the impact of selective logging on carbon stocks of tropical forest in Brazilian Amazon

Under Carbon and Co-Benefits from Sustainable Land-Use Management project: Cooperative Agreement No. EEM-A-00-03-00006-00

And in the following manuscript being prepared for peer-reviewed publication:

Pearson, TRH and Brown, S. 2009. Impact of selective logging on the carbon stocks of tropical forests: case studies from Belize, Bolivia, Brazil, Indonesia, Mexico and the Republic of Congo.