Approved VCS Module VMD0013
Version 1.0
REDD Methodological Module:
Estimation of greenhouse gas emissions from biomass burning (E-BB)
Sectoral Scope 14

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module provides a step-wise approach for estimating greenhouse emissions from biomass burning.

Applicability

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 used in the baseline, accounting must occur under both the baseline and with-project scenarios in both the project area and in the leakage belt. Where fires occur *ex-post* the module shall be used to account greenhouse gas emissions.

As described in the Framework REDD-MF the use of this module is mandatory.

Parameters

Parameter	SI Unit	Description
$E_{BiomassBurn,i,t}$	tCO_2-e	Non-CO_2 emissions due to biomass burning in stratum *i* in year *t*

II. PROCEDURE

Greenhouse 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 module describes how greenhouse emissions from biomass burning shall be estimated. Carbon dioxide may be omitted from calculations under this module if it can be shown that accounting of carbon dioxide 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 greenhouse gas emissions from biomass burning shall be determined as:

$$E_{BiomassBurn,i,t} = \sum_{g=1}^{G} \left(\left(\left(A_{burn,i,t} * B_{i,t} * COMF_i * G_{g,i} \right) * 10^{-3} \right) * GWP_g \right) \quad (1)$$

Where:

$E_{BiomassBurn,t}$	Greenhouse emissions due to biomass burning as part of deforestation activities in stratum *i* in year *t*; 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 aboveground biomass stock before burning stratum *i*, time *t*; tonnes d. m. ha^{-1}
$COMF_i$	Combustion factor for stratum *i*; dimensionless (see annex 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 section III and annex 2 for default values as derived from Table 2.5 of IPCC, 2006)
GWP_g	Global warming potential for gas *g;* t CO_2/t gas *g* (default values from IPCC SAR: CO_2 = 1; CH_4 = 21; N_2O = 310)
g	1, 2, 3 ... *G* greenhouse gases (to include carbon dioxide[1], methane and nitrous oxide)
i	1, 2, 3 …*M* strata
t	1, 2, 3, … *t** years elapsed since the start of the REDD project activity

The average aboveground biomass stock before burning for a particular stratum is estimated as follows:

$$B_{i,t} = (C_{AB\_tree,i,t} + C_{DWi,t} + C_{LI,i,t})*12/44*(1/CF) \quad (2)$$

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

Where:

$B_{i,t}$	Average aboveground 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 CO2-e ha-1 (estimated using the CP-AB)
$C_{DWi,t}$	Carbon stock in dead wood for stratum *i,* at time *t*; t CO_2-e ha^{-1} (estimated using CP-D)
$C_{LI,i,t}$	Mean carbon stock in litter for stratum *i,* at time *t*; t CO_2-e ha^{-1} (estimated using CP-L)
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. (see also section III))
i	1, 2, 3 …*M* strata
t	1, 2, 3, … *t** years elapsed since the start of the REDD project activity

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

Data / parameter:	*CF*
Data unit:	t C t^{-1} d.m.
Used in equations:	2
Description:	Carbon fraction of dry matter
Source of data:	Default value 0.47 t C t^{-1} d.m. can be used, or species specific values from the literature (e.g. IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.3)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$COMF_i$
Data unit:	dimensionless
Used in equations:	1
Description:	combustion factor for stratum *i* (vegetation type)
Source of data:	default values in Table 2.6 of IPCC, 2006 (Annex 2)

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:	G_{gi}
Data unit:	g kg^{-1} dry matter burnt
Used in equations:	1
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 (see Annex 2: emission factors for various types of burning for CH_4 and N_2O).
Measurement procedures (if any):	
Any comment:	Default values shall be updated whenever new guidelines are produced by the IPCC

IV. PARAMETERS ORIGINATING IN OTHER MODULES

Data / parameter:	$A_{burn,i,t}$
Data unit:	ha
Used in equations:	1
Description:	Area burnt in stratum *i* at time *t*
Module parameter originates in:	M-MON
Any comment:	Corresponding information shall be included in the VCS PD

Data / parameter:	$C_{AB,tree,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	2
Description:	Carbon stock in aboveground biomass in trees in stratum *i*
Module parameter originates in:	CP-AB
Any comment:	Corresponding information shall be included in the VCS PD

Data / parameter:	$C_{DW,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	2
Description:	Carbon stock in dead wood in the baseline in stratum *i*
Module parameter originates in:	CP-W
Any comment:	Corresponding information shall be included in the VCS PD

Data / parameter:	$C_{LI,i}$
Data unit:	t CO_2-e ha^{-1}
Used in equations:	2
Description:	Carbon stock in litter in the baseline in stratum *i*
Module parameter originates in:	CP-L
Any comment:	Corresponding information shall be included in the VCS PD

Annex 1:

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.

Annex 2:

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.