VCS MODULE VMD0031

ESTIMATION OF EMISSIONS FROM BIOMASS BURNING

Version 1.0

16 November 2012

Sectoral Scope 14

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Table of Contents

1 SOURCES 2
2 SUMMARY DESCRIPTION OF THE MODULE 2
3 DEFINITIONS 2
4 APPLICABILITY CONDITIONS 2
5 PROCEDURES 2
6 PARAMETERS 15
7 REFERENCES AND OTHER INFORMATION 24

1 SOURCES

VCS methodology, *VM0015 Methodology for Avoided Unplanned Deforestation, v1.0*

2 SUMMARY DESCRIPTION OF THE MODULE

This module provides methods for estimating non-CO_2 emissions from burning biomass.

3 DEFINITIONS

Baseline Scenario: The most likely sequence of events and actions which would be expected to occur within the project area in the absence of the project.

Canopy Surface: Area covered with vegetation canopy.

Conservative: Tending to err on the side of reduced creditable carbon in cases where uncertainty exists as to the correct value of variables, or relationships among variables.

4 APPLICABILITY CONDITIONS

None

5 PROCEDURES

Introduction:

Burning, whether anthropogenic or natural, results in CO_2 and non-CO_2 emissions from both woody and non-woody vegetation, and litter. CO_2 emissions are accounted as changes in accounted carbon pools using modules *VMD0021 Estimation of Stocks in the Soil Carbon Pool*, *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*, *VMD0023 Estimation of Carbon Stocks in the Litter Pool*, and *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool*. This module accounts for non-CO_2 emissions from biomass burning. Note that in this module, emissions from burning under the baseline scenario are only accounted if:

- Burning would be a result of planned, controlled burns; and
- The conditions (temperature, humidity, fuel moisture content, windspeed, etc.) under which burning would take place are prescribed, and sufficient ecosystem-specific information exists to forecast the amount of fuel that would be consumed under these conditions.

Otherwise, emissions from burning under the baseline scenario must be conservatively accounted as 0.

Two basic approaches can be used to calculate the non-CO_2 emissions from fire:

Approach A: Generic calculations using IPCC default values; or

Approach B: Calculations based on inventories of biomass consumed.

Note that if Approach A is used, the project proponent must provide sufficient evidence to demonstrate that the calculations produce conservative results.

Approach A: IPCC Default Values

Approach A uses consumption factors and emission factors from the IPCC GPG LULUCF to estimate the emissions of non-CO_2 GHGs (CH_4 and N_2O). The emissions are calculated separately for CH_4 and for N_2O using the following equation for both calculations:

$$L_{Fire} = A_{burn} \bullet BC \bullet EF \bullet 10^{-3} \quad (15.1)$$

Where:

L_{Fire}	=	The quantity of GHGs emitted, tonnes.
A_{burn}	=	Area burnt, hectares.
BC	=	Amount of biomass consumed, from Table 15.1 below (IPCC GPG for LULUCF Table 3A.1.13), tonnes/hectare.
EF	=	Emission factor for the GHG being calculated, from Table 15.2 below (IPCC GPG for LULUCF Table 3A.1.16), g/kg, equivalent to kg/tonnes.

Table 15.1- Part 1
Biomass consumption (t/ha) values for fires in a range of vegetation types
IPCC GPG for LULUCF Table 3A.1.13 or the most recent versions published by IPCC

Vegetation type	Sub category	Mean	SE
Tropical Forest (slash and burn	Primary tropical forest	83.9	25.8
	Primary open tropical forest	163.6	52.1
	Primary tropical moist forest	160.4	11.8
	Primary tropical dry forest	-	-
All primary tropical forest		119.6	50.7
Secondary tropical forest (slash and burn)	Young secondary tropical forest (3-5 yrs)	8.1	-
	Intermediate secondary tropical forest (6-10 yrs)	41.1	27.4
	Advanced secondary tropical forest (14-17 yrs)	46.4	8.0
All secondary tropical forest		42.2	23.6
All tertiary tropical forest		54.1	-
Boreal Forest	Wildfire (general)	52.8	48.4
	Crown fire	25.1	7.9
	Surface fire	21.6	25.1
	Post logging slash burn	69.6	44.8
	Land clearing fire	87.5	35.0
All boreal Forest		41.0	36.5
Eucalypt forest	Wildfire	53.0	53.6
	Prescribed fire- (surface)	16.0	13.7
	Post logging slash burn	168.4	168.8
	Felled and burned (land clearing fire)	132.6	-
All eucalypt Forest		69.4	100.8
Other temperate forests	Wildfire	19.8	6.3
	Post logging slash burn	77.5	65.0
	Felled and burned (land clearing fire)	48.4	62.7
All “other” temperate forests		50.4	53.7
Shrublands	Shrubland (general)	26.7	4.2
	Calluna Heath	11.5	4.3
	Sagebrush	5.7	3.8
	Fynbos	12.9	0.1
All shrublands		14.3	9.0

Table 15.1- Part 2
Biomass consumption (t/ha) values for fires in a range of vegetation types
IPCC GPG for LULUCF Table 3A.1.13 or the most recent versions published by IPCC

Vegetation type	**Sub category**	**Mean**	**SE**
Savannah Woodlands (mid/late dry season burns	Savannah woodland	2.5	-
	Savannah parkland	2.7	-
All savannah woodlands (early dry season burns)		2.6	0.1
Savannah Woodlands (mid/late dry season burns)	Savannah woodlands	3.3	
	Savannah parkland	4.0	1.1
	Tropical Savannah	6	1.8
	Other savannah woodlands	5.3	1.7
All savannah woodlands (mid/late dry season burns)		4.6	1.5
Savannah Grasslands/Pastures (mid/late dry season burns)	Tropical /sub-tropical grassland	2.1	-
	Grassland	-	-
All savannah grasslands (early dry season burns)		2.1	
Savannah grasslands/pastures (mid/late dry season burns)	Tropical/subtropical grasslands	5.2	1.7
	Grasslands	4.1	3.1
	Tropical pasture	23.7	11.8
	Savannah	7.0	2.7
All savannah grasslands(mid/late dry season burns)		10.0	10.1
Other vegetation Types	Peatland	41	1.4
	Tundra	10	

Table 15.2
Emission Factors (g/kg dry matter combusted) applicable to fuel combusted in various types if vegetation fires.
IPCC GPG for LULUCF Table 3A.1.16 or the most recent versions published by IPCC

	CO_2	CO	CH_4	NO_x	N_2O^*	NMHC[2]
Moist/infertile broadleaved savannah	1523	92	3	6	0.11	
Arid fertile fine-leaved savannah	1524	73	2	5	0.11	
Moist infertile grassland	1498	59	2	4	0.1	
Arid-fertile grassland	1540	97	3	7	0.11	
Wetland	1554	58	2	4	0.11	
All vegetation types[1]	1404-1503	67-120	4-7	0.5-0.8	0.10	
Forest Fires	1531	112	7.1	0.6-0.8	0.11	8-12
Savannah Fires	1612	152	10.8		0.11	
Forest Fires	1580	130	9	0.7	0.11	10
Savannah Fires	1640	65	2.4	3.1	0.15	3.1

[1] Assuming 41-45% C content, 85-100% combustion completeness
[2] NMHC = non methane hydro carbons
* calculated from data of Crutzen and Andrea (1990) assuming an N/C ratio of 0.01, except for savannah fires.

Approach B: Estimation of Emissions Based on Biomass Inventories

This approach consists of two steps:

Step 1: Determine the amount of biomass consumed by the fire

Most of the biomass consumed in a fire consists of fine fuels (litter, non-woody vegetation, leaves and twigs on woody vegetation). However, some course woody materials, both living and dead may also be consumed. Where superficial organic soil horizons exist, some part of these may also be consumed. The equation for determining the total amount of biomass consumed is therefore:

$$B_{burn} = OS_{burn} + Bdw_{burn} + WB_{burn} + Bsm_{burn} + Bl_{burn} \quad (15.2)$$

Where:

B_{burn}	=	The amount of biomass burned, t
OS_{burn}	=	The amount of organic soil burnt, t
Bdw_{burn}	=	The amount of course woody debris burnt, t
WB_{burn}	=	The amount of living woody biomass burnt, t
Bsm_{burn}	=	The amount of small woody and non-woody vegetation burnt, t
Bl_{burn}	=	The amount of litter burnt, t

The steps for each of these pools are as follows:

Step 1a: Litter

Accounting for litter must be undertaken using the methods contained in the module *VMD0023 Estimation of Carbon Stocks in the Litter Pool*. After a fire event, the methods contained in that module must be used to estimate the residual litter biomass in the burned portion of each stratum impacted by the fire. Where the litter biomass of the stratum was estimated using the methods in the module *VMD0023 Estimation of Carbon Stocks in the Litter Pool* prior to the fire event, that number will be used for $Bl_{s,pre}$ in equation 15.3.

Where no litter plots existed in the area prior to burning, estimations of the litter pool prior to the fire must be generated based on information gathered from comparable sites outside of the burned area using the methods outlined in module *VMD0023 Estimation of carbon tocks in the Litter Pool*. Comparable sites must be determined based on:

- Evidence found in existing photos which give some evidence of the amount and size distribution of litter before the fire;
- Similarity of ecosystem, and disturbance and management history; and/or
- Local knowledge.

Where this approach is used, the methods given in the module *VMD0023 Estimation of Carbon Stocks in the Litter Pool* must be used to estimate the pre-fire litter content of the burned area within the stratum only, and therefore $A_{sburn} = A_s$ in equation 15.3.

The amount of litter consumed by the fire is therefore:

$$Bl_{burn} = \sum_{s}((A_{sburn} \bullet A_{s}^{-1} \bullet Bl_{s,pre}) - Bl_{s,post}) \quad (15.3)$$

Where:

Bl_{burn}	=	The total biomass of litter burnt, t
s	=	Strata
A_{sburn}	=	The area burnt in stratum s, ha
A_{s}	=	The total area of stratum s, ha
$Bl_{s,pre}$	=	Litter biomass in stratum s prior to the fire, t
$Bl_{s,post}$	=	Litter biomass in the burnt area of stratum s after the fire, t

Step 1b: Small woody and Non-woody vegetation

Estimation of amounts of small woody and non-woody vegetation prior to and after burning are determined using the methods outlined in module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*. The breakpoint between small and large woody vegetation must be determined prior to the fire event during initial sampling of biomass in the ecosystem. After a fire event, the methods contained in that module must be used to estimate the residual small woody and non-woody biomass in the burned portion of each stratum impacted by the fire. Where the small woody and non-woody biomass of the stratum was estimated using the methods in the module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass* prior to the fire event, that number will be used for $B_{sms,pre}$ in equation 15.4.

Where no small woody and non-woody plots existed in the area prior to burning, estimations of the small woody and non-woody pool prior to the fire must be generated based on information gathered from comparable sites outside of the burned area using the methods outlined in the module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*. Comparable sites must be determined based on:

- Evidence found in existing photos which give some evidence of the amount and size distribution of litter before the fire;
- Similarity of ecosystem, and disturbance and management history; and/or
- Local knowledge.

Where this approach is used, the methods given in the module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass* are used to estimate the pre-fire litter content of the burned area within the stratum only, and therefore $A_{sburn} = A_{s}$ in equation 15.4.

The amount of non-woody vegetation consumed by the fire is therefore:

$$Bsm_{burn} = \sum_{s}((A_{sburn} \bullet A_{s}^{-1} \bullet B_{sms,pre}) - B_{sms,post}) \quad (15.4)$$

Where:

Bsm_{burn}	=	The amount of small woody and non-woody vegetation burnt, t
A_{sburn}	=	The area of the portion of the stratum which burnt, hectares
A_{s}	=	The area of the stratum, hectares

$B_{sms,pre}$ = The dry weight of small woody and non-woody vegetation in stratum s before the fire, t

$B_{sms,pre}$ = The dry weight of small woody and non-woody vegetation in the burnt area of stratum s after the fire, t

Step 1c: Large woody vegetation

Determining the amount of large woody vegetation consumed by a fire can be complex, as amounts can vary considerably depending on the intensity of the fire. For a given fire intensity, the amount of available fuel of this type will depend on the number, size and type of large woody plants present on the site. As well, the percentage of combustion will vary depending on the fuel size and position. Note that while large woody vegetation will typically be defined as woody individuals with a stem size above some minimum diameter or height cut-off, these individuals will also have many branches and twigs smaller than the cut-off, which will also be accounted as part of the large woody vegetation. The project proponent may propose and justify their own technique for estimating this fuel fraction, or use the following approach:

Fine fuels (leaves and twigs) make up the majority of the living biomass combusted, even in fairly intense fires. However, the amount of this fuel, as well as the amount of stem wood and large branches consumed, will vary from fire to fire, based on fire conditions, the size and type of living tissues present, and other factors. The method outlined in the steps below allows specific estimation of the amounts of fuel combusted. Since non-CO_2 emissions are largely associated with the combustion of volatile gasses, fuels reduced entirely to char (for instance, charcoal remnants of branches) are accounted as having been fully combusted for the purposes of this module.

The project proponent must use the following steps:

Step 1c-1: Estimate the amount of biomass present before the fire.

Determine the total amount of large woody above ground biomass present within the burned area prior to the fire using the methods given in the module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*. Where inventories already exist, and where a fire has not burned the entire area of a stratum, the amount of biomass present within the burned area of a stratum is calculated using the following equation:

$$B_{AB_b} = \sum_s B_{AB_s} \bullet A_{burn,s} \bullet A_s^{-1} \qquad (15.5)$$

Where:

B_{AB_b} = Total aboveground large woody biomass in the burned area of the stratum before the fire, t

B_{AB_s} = Total aboveground large woody biomass in stratum s before the fire, t

s = Stratum

$A_{burn,s}$ = Area burned within stratum s by the fire, ha

A_s = Total area of stratum s, ha

Note that where the “Census from Remote Sensing” method is used to determine large woody biomass, B_{AB_s} may not be directly available. In this case, B_{AB_s} must be derived from B_{ws} using the following equation:

$$B_{AB_s} = B_{ws} \bullet (1+R)^{-1} \quad (15.6)$$

Where

B_{AB_s}	=	Total aboveground large woody biomass in the stratum before the fire, t
B_{WS}	=	Total large woody biomass in the stratum before the fire, t
R	=	Root to shoot ratio, dimensionless

Step 1c-2: Determine the large woody vegetation types present in the burned area.

Woody vegetation types are classes of species, sizes, or other variables on which the fire had similar impacts. For instance, one vegetation type might consist of all large shrubs and small trees less than 6 m tall, another group might consist of isolated fire resistant trees greater than 6 m tall, and another type might consist of densely stocked areas of trees greater than 6 m tall where crown fire occurred. Document the definition of each woody vegetation type, and undertake each of the following steps for each of the types.

Step 1c-3: Determine the fuels consumed.

After the fire, sample each different woody vegetation type (species, species group, size group, or other grouping) to determine the average size class of the fine biomass consumed in areas of the canopy which were burned. Biomass will be conservatively counted as consumed when more than 50% of the cross-sectional area of the twig or branch is missing or consists of char. Thus for example, for a given species group, it may be determined that on average branches less than 1 cm in diameter were consumed.

Step 1c-4: Determine the percentage of canopy surface consumed.

Depending on the nature of the fire (ground fire, canopy fire, etc.), the fire may have consumed biomass throughout the canopy, or only in the lower sections. Through observation and/or sampling, determine the average percentage of the canopy surface consumed by fire for each species or species group.

Step 1c-5: Determine the amount of fuel per unit of canopy surface.

Sampling from unburned areas, determine the amount of biomass per unit area which falls into the burnt size class for each species or species group. This should be done by clipping all the biomass at or below the burnt size class within a specified area (a 1 m square, for example), drying and weighing it. Samples must be taken across the range of canopy locations where fire consumption occurred, since the amount of fine biomass may vary by canopy position. The total of all samples taken must be averaged to determine the amount of biomass burnt per unit of canopy surface. Determine the relationship between canopy surface and a known woody vegetation inventory variable such as DBH.

Canopy surface for a given tree may be approximated using the following equation which describes a simplified shape of a cylinder (with a height of (*ch-r) and radius of r* and a radius and with half a sphere (with a radius of r):

$$CA = 2(\pi r^2 + \pi r(ch - r)) \quad (15.7)$$

Where:

CA	=	Canopy surface, m^2
r	=	Average radius of the canopy (distance from the point of germination to the drip line), m
ch	=	Height of the canopy from the lowest branch to the top of the living crown., m

For each woody vegetation type, the proponent must derive values for r and ch. These values must be averages across the type. However, they must be calculated using a derived relationship from known variable found in the woody vegetation inventory data, such as height, basal area, or other variables.

Step 1c-6: Using pre-fire inventory data, calculate the total canopy surface per hectare for each woody vegetation type.

If a derived relationship is calculated in Step 1c-4, above, divide the average woody vegetation population within the woody vegetation type into classes (*k*) based on the range of values of the determining variable used. Thus, for instance if a relationship has been derived between *r* and *ch* and the height of the tree, divide the inventory for the woody species type being calculated into classes of tree heights. Determine the average number of trees per hectare for each class from the inventory. Calculate total canopy surface (which describes a simplified shape of a cylinder (with a height of (*ch-r)* and radius of r and a radius and with half a sphere (with a radius of r)): for the woody vegetation type using the following equations:

$$TCA_j = \sum_{k}^{n} (2 p_{kj} \bullet (\pi r_{kj}^{\ 2} + \pi r_{kj} \bullet ch_{kj})) \qquad (15.8)$$

Where:

j	=	The woody vegetation type
k	=	The class of the determining variable (canopy size class, height, or some other variable)
x	=	The number of different classes of the determining variable
TCA_j	=	The total canopy surface for woody vegetation type j, m^2/ha
p_{kj}	=	The population of the woody plants falling into class k for type j, #/ha
r_{kj}	=	The average radius of the crown for woody plants falling into class k for type j, m
ch_{kj}	=	The average canopy height for woody plants falling into class k for type j, m

Step 1c-7: Calculate the total biomass consumed.

Use the following equation:

$$WB_{burn} = A_{burn} \bullet \sum_{j}^{y} (TCA_j \bullet C\%_j \bullet B_{burn,j} \bullet 10^{-3}) \qquad (15.9)$$

Where:

j	=	The woody vegetation type
y	=	The number of different types of woody vegetation

WB_{burn}	=	The total large woody plant biomass consumed
A_{burn}	=	Area burnt, hectares
TCA_j	=	The total canopy surface for woody vegetation type j, m^2/ha
C%j	=	The percentage of canopy surface which was burned, m^2/m^2
$B_{burn,j}$	=	The amount of biomass consumed per unit of canopy surface burned, kg/m^2

Step 1c-8: Check the total biomass consumed against the total pre-fire above ground biomass.

Where WB_{burn} is within the margin of error for B_{ws} at a 90% confidence interval, for the stratum within which the fire occurred, as determined in Part A Step 5 of the module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*, no further checking is required. Where the burned area crosses more than one stratum, with differing confidence intervals, average confidence interval must be derived weighted by the percentage of the total burn area represented by the burned area within each stratum.

Where more substantial portions of the aboveground biomass have been consumed, check to ensure that WB_{burn} as a percentage of B_{AB_b} is reasonable. Checking may be undertaken though calculation of non-stem wood above ground biomass before the fire from B_{AB_b} using a biomass expansion factor, and destructive sampling of residual non-stem wood above-ground biomass in the burned area, to confirm that:

$$WB_{burn} + B_{ABns,postfire} \approx B_{AB_b} \bullet (1+BEF)^{-1} \bullet BEF \qquad (15.10)$$

Where

WB_{burn}	=	The total large woody plant biomass consumed, t
$B_{ABns,postfire}$	=	Residual non-stem biomass in the burned area, t
B_{AB_b}	=	Total aboveground large woody biomass in the burned area of the stratum before the fire, t
BEF	=	Biomass Expansion Factor, dimensionless
$\approx$	=	The difference between the right and left sides of the equation falls within the margin of error of B_{ws} at a 90% confidence interval, for the burned portion of the stratum, as determined in Part A, step 5 of the module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*. Where the burned area crosses more than one stratum, with differing confidence intervals, total confidence interval must be derived weighted by the percentage of the total burned area represented by the burned area within each stratum.

Step 1d: Dead wood

Dead wood consumption must be calculated using module *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool*, and subtracting post-fire dead wood biomass from pre-fire dead wood biomass, with the following modification. The radius of each piece measured will be considered to be the outer radius less the distance to which the point of a sharp knife can by sunk into the piece of wood with moderate pressure, when oriented across the grain, which will be used as a measure of the char layer.

Where pre-fire inventories of dead wood exist for the burnt area, these may be used directly for the pre-fire inventory. Where no such inventories exist, two options may be used to estimate pre-fire inventories:

Option A: Where fire consumption mostly consists of superficial charring.

In many cases, broadcast burning of distributed fuels will only result in surface charring. In these cases, the average outside diameter of the each piece measured on the transect line must be considered to be the pre-fire diameter of the piece. Because all of the charred material is considered to be fully consumed, this approach is conservative despite the fact that it may miss some small amount of pre-fire cross sectional area.

Note that this method may not work in the case of repeated fires, where some of the charred area detected may have resulted from previous fires. However, in such cases inventories should exist from the period immediately after the previous fire, and these must be used for the pre-fire case.

Option B: Where significant consumption of fuels has occurred.

For windrowed and similar materials significant consumption of fuels may occur. In most cases such burning will be deliberate, and a pre-fire inventory must have been completed. However, if no such inventory exists, similar fuel accumulations in unburned areas (proxy areas) must be inventoried using the methods outlined in module *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool* to provide an estimate of the conditions before the fire in the burnt area. Proxy areas must be selected based on similarity to the conditions found in the burn area before the fire in terms of amount of dead wood and dead wood piece size distribution. Since using the proxy area implies that no good quantitative inventory of dead wood within the burn area existed prior to the fire, similarity must be judged based on qualitative factors, including:

- Evidence found in existing photos which give some evidence of the amount and size distribution of dead wood before the fire;
- Similarity of ecosystem, and disturbance and management history; and/or
- Local knowledge.

If the burn area does not completely cover a pre-existing ecosystem, disturbance and management history stratum, residual unburnt areas of the stratum may be the best candidate for use as a proxy area, providing that there is no reason to suspect that the boundary of the burn area was determined by differences in dead wood density, piece size, or distribution.

Where no pre-fire inventory exists for the stratum, and where Option A or B are used, the methods given in module *VMD0024 Estimation of Emissions of Biomass Burning* must be used to estimate the pre-fire litter content of the burned area within the stratum only, and therefore $A_{sburn} = A_s$ in equation 15.11.

The total amount of dead wood burnt in stratum *s* is calculated by the following equation:

$$Bdw_{burn} = \sum_s ((A_{sburn} \bullet A_s^{-1} \bullet Bdw_{s,pre}) - Bdw_{s,post}) \qquad (15.11)$$

Where:

Bdw_{burn} = The amount of dead wood burnt in the fire, t

s = Strata

A_{sburn} = The area burnt in stratum s, ha

A_s = The total area of stratum s, ha

$Bdw_{s,pre}$ = Total dead wood biomass in stratum s prior to the fire, t

$Bdw_{s,post}$ = Total dead wood biomass in the burnt area of stratum s after the fire, t

Step 1e: Organic Soil

Where organic soil layers are consumed by fire, the amount of soil biomass consumed is calculated by the following equation:

$$OS_{burn} = A_{burn} \bullet D_b \bullet OS_m \bullet 10^{-1} \quad (15.12)$$

Where:

OS_{burn} = The amount of organic soil burned, t

A_{burn} = Area burnt, hectares

D_b = The average depth of the soil burnt, cm

OS_m - = The mass of the organic soil, kg/m^3

Step 2: Estimating of GHG emissions resulted from the biomass consumption by fire based on revised IPCC 1996 Guideline for LULUCF and GPG LULUCF.

Non-CO_2 emissions resulting from biomass consumption by fire will be estimated using the following equations:

$$E_b = E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \quad (15.13)$$

Where:

E_b = Non-CO_2 emission as a result of biomass burning, tonnes CO_2-e

$E_{BiomassBurn, N2O}$ = N_2O emission from biomass burning in slash and burn, tonnes CO_2-e

$E_{BiomassBurn, CH4}$ = CH_4 emission from biomass burning in slash and burn, tonnes CO_2-e

$$E_{BiomassBurn,N_2O} = B_{Burn} \cdot EF_{N_2O} \cdot 310 \cdot 10^{-3} \quad (15.14)$$

$$E_{BiomassBurn,CH_4} = B_{Burn} \cdot EF_{CH^4} \cdot 21 \cdot 10^{-3} \quad (15.12)$$

Where[1]:

B_{Burn} = Amount of biomass consumed in the fire, t

EF_{N^2O} = Emission factor for N_2O from Table 17.2 (IPCC GPG LULUCF Table 3A.1.16)

[1] Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF (http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch5wb1.pdf page 20 (visited 18-05-2010)and Equation 3.2.19 in GPG LULUCF http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/Chp3_2_Forest_Land.pdf; page 27 (visited 18-05-2010)

EF_{CH^4} = Emission factor for CH_4 from Table 17.2 (IPCC GPG LULUCF Table 3A.1.16)

310 = Global Warming Potential for N_2O

21 = Global Warming Potential for CH_4

6 PARAMETERS

Data Unit / Parameter:	L_{Fire}
Data unit:	Tonnes
Description:	Emitted GHG due to Fire
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	The quantity of GHG emitted, in units of CO_2e, due to fire
Any comment:	

Data Unit / Parameter:	A_s
Data unit:	Ha
Description:	Area of the stratum
Source of data:	Field surveys or remote sensing
Justification of choice of data or description of measurement methods and procedures applied:	Area of the stratum
Any comment:	

Data Unit / Parameter:	A_{burn}
Data unit:	Ha
Description:	Area burnt
Source of data:	Field surveys or remote sensing
Justification of choice of data or description of measurement methods and procedures applied:	Area burnt
Any comment:	

Data Unit / Parameter:	*BC*
Data unit:	Tonnes/hectare
Description:	Amount of biomass consumed
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	Amount of biomass consumed by fire
Any comment:	

Data Unit / Parameter:	*EF*
Data unit:	g/kg, equivalent to kg/tonnes
Description:	Emission factor
Source of data:	IPCC GPG for LULUCF Table 3A.1.16
Justification of choice of data or description of measurement methods and procedures applied:	Emission factor for the GHG being calculated (CO_2, N_2O, CH_4)
Any comment:	

Data Unit / Parameter:	B_{burn}
Data unit:	Tonnes
Description:	Amount of biomass burned
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	The amount of biomass burned
Any comment:	

Data Unit / Parameter:	OS_{burn}
Data unit:	Tonnes
Description:	Amount of organic soil burnt
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	The amount of organic soil burnt
Any comment:	

Data Unit / Parameter:	Bdw_{burn}
Data unit:	Tonnes
Description:	Amount of dead wood burnt
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	the amount of dead wood burnt
Any comment:	

Data Unit / Parameter:	WB_{burn}
Data unit:	Tonnes
Description:	Amount of living woody biomass burnt
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	The amount of living woody biomass burnt
Any comment:	

Data Unit / Parameter:	Bsm_{burn}
Data unit:	Tonnes
Description:	Amount of small woody and non-woody vegetation burnt
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	The amount of small woody and non-woody vegetation burnt
Any comment:	

Data Unit / Parameter:	Bl_{burn}
Data unit:	Tonnes
Description:	Amount of litter burnt
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	The amount of litter burnt
Any comment:	

Data Unit / Parameter:	$Bl_{s,pre}$
Data unit:	t
Description:	Dry weight of litter in stratum s before the fire
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	Dry weight of litter in stratum s before the fire
Any comment:	

Data Unit / Parameter:	$BI_{s,post}$
Data unit:	t
Description:	Dry weight of litter in the burnt area in stratum s after the fire
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	Dry weight of litter in the burnt area in stratum s after the fire
Any comment:	

Data Unit / Parameter:	A_{sburn}
Data unit:	ha
Description:	Area burnt in stratum s
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	Area burnt in stratum s
Any comment:	

Data Unit / Parameter:	$B_{sms,pre}$
Data unit:	t
Description:	The dry weight of small woody and non-woody vegetation in stratum s before the fire
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	The dry weight of small woody and non-woody vegetation in stratum s before the fire
Any comment:	

Data Unit / Parameter:	$B_{sms,post}$
Data unit:	t
Description:	The dry weight of small woody and non-woody vegetation in the burnt area of stratum s after the fire
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	The dry weight of small woody and non-woody vegetation in the burnt area of stratum s after the fire
Any comment:	

Data Unit / Parameter:	*CA*
Data unit:	m^2
Description:	Canopy surface
Source of data:	Estimated from remote sensing
Justification of choice of data or description of measurement methods and procedures applied:	Canopy surface
Any comment:	

Data Unit / Parameter:	*r*
Data unit:	m
Description:	Average radius of the canopy
Source of data:	Calculated from remote sensing
Justification of choice of data or description of measurement methods and procedures applied:	Average radius of the canopy (distance from the point of germination to the drip line)
Any comment:	

Data Unit / Parameter:	*ch*
Data unit:	m
Description:	Height of the canopy
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	Height of the canopy from the lowest branch to the top of the living crown
Any comment:	

Data Unit / Parameter:	TCA_j
Data unit:	m^2/ha
Description:	Total canopy surface
Source of data:	Estimated from remote sensing
Justification of choice of data or description of measurement methods and procedures applied:	The total canopy surface for woody vegetation type j,
Any comment:	

Data Unit / Parameter:	p_{kj}
Data unit:	#/ha
Description:	Population of the woody plants
Source of data:	Estimated from remote sensing and confirmed by field surveys
Justification of choice of data or description of measurement methods and procedures applied:	the population of the woody plants falling into size class k for type j,
Any comment:	

Data Unit / Parameter:	r_{kj}
Data unit:	m
Description:	Average radius of the crown for woody plants
Source of data:	Remote sensing or field surveys
Justification of choice of data or description of measurement methods and procedures applied:	the average radius of the crown for woody plants falling into size class k for type j,
Any comment:	

Data Unit / Parameter:	ch_{kj}
Data unit:	m
Description:	Average canopy height for woody plants
Source of data:	Remote sensing or field surveys
Justification of choice of data or description of measurement methods and procedures applied:	The average canopy height for woody plants falling into size class k for type j
Any comment:	

Data Unit / Parameter:	j
Data unit:	Dimensionless
Description:	Woody vegetation type
Source of data:	Field surveys
Justification of choice of data or description of measurement methods and procedures applied:	The woody vegetation type class determined by stratification based on fire impact.
Any comment:	

Data Unit / Parameter:	k
Data unit:	Dimensionless
Description:	Class of the determining variable
Source of data:	Remote sensing or field sampling
Justification of choice of data or description of measurement methods and procedures applied:	The class of the determining variable (canopy size class, height, or some other variable)
Any comment:	

Data Unit / Parameter:	*x*
Data unit:	#
Description:	Number of different classes of the determining variable
Source of data:	Remote sensing or field sampling
Justification of choice of data or description of measurement methods and procedures applied:	The number of different classes of the determining variable (canopy size class, height, or some other variable)
Any comment:	

Data Unit / Parameter:	WB_{burn}
Data unit:	Tonnes
Description:	Total woody plant biomass consumed
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	The total woody plant biomass consumed
Any comment:	

Data Unit / Parameter:	$C\%_j$
Data unit:	%
Description:	Percentage of canopy surface which was burned
Source of data:	Estimated from remote sensing or field surveys
Justification of choice of data or description of measurement methods and procedures applied:	The percentage of canopy surface which was burned
Any comment:	

Data Unit / Parameter:	$B_{burn,j}$
Data unit:	kg/m^2
Description:	Amount of biomass consumed per unit of canopy surface burned
Source of data:	Calculated from field surveys
Justification of choice of data or description of measurement methods and procedures applied:	The amount of biomass consumed per unit of canopy surface burned
Any comment:	

Data Unit / Parameter:	$Bdw_{s,pre}$
Data unit:	t
Description:	Total dead wood biomass in stratum s prior to the fire
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	Total dead wood biomass in stratum s prior to the fire
Any comment:	

Data Unit / Parameter:	$Bdw_{s,post}$
Data unit:	t
Description:	Total dead wood biomass in the burnt area of stratum s after the fire
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	Total dead wood biomass in the burnt area of stratum s after the fire
Any comment:	

Data Unit / Parameter:	D_b
Data unit:	cm
Description:	Average depth of the soil burnt
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	The average depth of the soil burnt
Any comment:	

Data Unit / Parameter:	OS_m
Data unit:	kg/m^3
Description:	Mass of the organic soil
Source of data:	Field survey
Justification of choice of data or description of measurement methods and procedures applied:	The mass of the organic soil
Any comment:	

Data Unit / Parameter:	E_b
Data unit:	Tonnes CO_2-e
Description:	Non-CO2 emission as a result of biomass burning,
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	The Non-CO2 emission as a result of biomass burning, tonnes CO2-e
Any comment:	

Data Unit / Parameter:	$E_{BiomassBurn, N2O}$
Data unit:	Tonnes CO_2-e
Description:	N2O emission from biomass burning
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	N2O emission from biomass burning in slash and burn, tonnes CO2-e
Any comment:	

Data Unit / Parameter:	$E_{BiomassBurn, CH4}$
Data unit:	tonnes CO2-e
Description:	CH4 emission from biomass burning
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	CH4 emission from biomass burning in slash and burn
Any comment:	

Data Unit / Parameter:	B_{Burn}
Data unit:	t
Description:	Amount of biomass consumed in the fire
Source of data:	Calculated
Justification of choice of data or description of measurement methods and procedures applied:	Amount of biomass consumed in the fire
Any comment:	

Data Unit / Parameter:	EF_{N2O}
Data unit:	#
Description:	Emission factor for N_2O
Source of data:	Table 17.2: IPCC GPG LULUCF Table 3A.1.16
Justification of choice of data or description of measurement methods and procedures applied:	Emission factor for N_2O
Any comment:	

Data Unit / Parameter:	EF_{CH4}
Data unit:	#
Description:	Emission factor for CH_4
Source of data:	Table 17.2: IPCC GPG LULUCF - Table 3A.1.16
Justification of choice of data or description of measurement methods and procedures applied:	Emission factor for CH_4
Any comment:	

Data Unit / Parameter:	*310*
Data unit:	#
Description:	Global Warming Potential for N_2O
Source of data:	IPCC
Justification of choice of data or description of measurement methods and procedures applied:	Global Warming Potential for N2O
Any comment:	

Data Unit / Parameter:	*21*
Data unit:	#
Description:	Global Warming Potential for CH_4
Source of data:	IPCC
Justification of choice of data or description of measurement methods and procedures applied:	Global Warming Potential for CH_4
Any comment:	

7 REFERENCES AND OTHER INFORMATION

IPCC. 1996. Revised Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html (Last visited 14-09-2011).

VCS methodology, *Methodology for Avoided Unplanned Deforestation VM0015, v1.0*

DOCUMENT HISTORY

Version	Date	Comment
v1.0	16 Nov 2012	Initial version released