VCS Module

VMD0046

Methods for monitoring of soil carbon stock changes and greenhouse gas emissions and removals in peatland rewetting and conservation project activities (M-PEAT)

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Sectoral Scope 14

Module developed by:

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1 SOURCES

This module is one of numerous modules that constitute VCS methodology *VM0007 REDD+ Methodology Framework (REDD-MF)*.

This module uses the latest version of the following tools and modules:

- CDM *Tool for testing significance of GHG emissions in A/R CDM project activities (T-SIG)*
- *VMD0006 Estimation of baseline carbon stock changes and greenhouse gas emissions from planned deforestation and planned degradation (BL-PL)*
- *VMD0013 Estimation of greenhouse gas emissions from biomass and peat burning (E–BPB)*
- *VMD0016 Methods for stratification of the project area (X-STR)*
- *VMD0044 Estimation of emissions from ecological leakage (LK-ECO)*

2 SUMMARY DESCRIPTION OF THE MODULE

This module provides approaches for monitoring of greenhouse gas (GHG) emissions from undisturbed, degraded and rewetted domed peatland. The module addresses GHG emissions from the soil organic (peat) carbon pool due to drainage, rewetting and fire.

In combination with modules *BL-PEAT* and *E-BPB* this module provides conservative procedures to estimate reductions of drainage-related GHG emissions (from microbial oxidation and fires) by Rewetting of Drained Peatland (RDP) project activities, and prevention of peat emissions due to microbial oxidation and from fire in Conservation of Undrained or Partially Drained Peatland (CUPP) projects. These project activities are both sub-categories of Restoration of Wetland Ecosystems (RWE) and Conservation of Intact Wetlands (CIW) of the Wetlands Restoration and Conservation (WRC) project category.

This module provides procedures for the following:

- Monitoring of project soil carbon stock changes and GHG emissions.
- Fire Reduction Premium: A rapid and conservative alternative approach to acknowledge peat fire emission reductions as a result of rewetting without having to develop complex baseline scenarios for peat fires.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions* and methodology *REDD-MF*, the following definitions and acronyms apply to this methodology:

3.1 Defined Terms

Domed peatland

Dome shaped peat landform usually located between interfluvial divides[1]

Proxy Area

In this module, the proxy area is defined as the area from which regional information on the occurrence and extent of fires or patterns in emission proxies is obtained

Water table depth[2]

Depth of the water table relative to the soil surface. Depth may be positive (above surface) or negative (below surface).

3.2 Acronyms

BD	Bulk Density
CC	Carbon Concentration of Peat
CIW	Conservation of Intact Wetlands
CUPP	Conservation of Undrained or Partially Undrained Peatland
GHG	Greenhouse Gas
RDP	Rewetting of Drained Peatlands
RWE	Restoration of Wetland Ecosystems
WPS	With Project Scenario
WRC	Wetland Restoration and Conservation

4 APPLICABILITY CONDITIONS

This module is applicable to RDP and CUPP activities as defined in VCS *AFOLU Requirements*.[3]

The project area must meet the VCS definition for peatland.[4] This module is limited to domed peatlands in the tropical climate zone.

Furthermore, the following applicability conditions apply:

- It must be demonstrated using tool *T-SIG* that N_2O emissions in the project scenario are

[1] See eg, Jaenicke *et al.* 2008; Dommain *et al.* 2010
[2] In some other methodologies this term may be referred to as 'drainage depth' where it is implied to have the same meaning.
[3] These project activities are both sub-categories of Restoration of Wetland Ecosystems (RWE) and Conservation of Intact Wetlands (CIW) of the Wetlands Restoration and Conservation (WRC) project category.
[4] These project activities are both sub-categories of Restoration of Wetland Ecosystems (RWE) and Conservation of Intact Wetlands (CIW) of the Wetlands Restoration and Conservation (WRC) project category.

not significant, or it must be demonstrated that N_2O emissions will not increase in the project scenario compared to the baseline scenario, and therefore N_2O emissions need not be accounted for.

- In the baseline scenario the peatland must be drained or partially drained.
- At project start the peatland may still be undrained.
- It must be demonstrated using module *LK-ECO* that ecological leakage must not occur.

5 PROCEDURES

5.1 Assessing Project Emissions

Determination of the net CO_2 equivalent emissions from the peat soil in the project scenario follows mainly the same procedure as for baseline emissions using module *BL-PEAT*.

Project emissions include the following as described in Equation 1:

1. GHG emissions from the peat soil due to microbial decomposition
2. GHG emissions from open water (eg, ditches)
3. GHG emissions from biomass and peat burning

$$GHG_{WPS-WRC} = \sum_{t=1}^{t^*}\sum_{i=1}^{M}(E_{peatsoil-WPS,i,t} + E_{peatditch-WPS,i,t} + E_{peatburn-WPS,i,t}) \qquad (1)$$

Where:

$GHG_{WPS-WRC}$ Net CO_2 equivalent peat GHG emissions in the project scenario up to year t^* (t CO_2e)

$E_{peatsoil-WPS,i,t}$ GHG emissions from microbial decomposition of the peat soil within the project boundary in the project scenario in stratum i in year t (t CO_2e yr^{-1})

$E_{peatditch-WPS,i,t}$ GHG emissions from water bodies within the project boundary in the project scenario in stratum i in year t (t CO_2e yr^{-1})

$E_{peatburn-WPS,i,t}$ GHG emissions from burning of peat within the project boundary in the project scenario in stratum i in year t (t CO_2e yr^{-1})

i 1, 2, 3 …M_{WPS} strata in the project scenario (unitless)

t 1, 2, 3, … t^* time elapsed since the project start (years)

5.2 Assessing Project GHG Emissions from the Peat Soil ($E_{peatsoil-WPS,i,t}$)

The estimation of GHG emissions in rewetted (for RPD projects) or undrained or partially drained (for CUPP projects) peat follows similar procedures as described in module *BL-PEAT*.

For each stratum the following is calculated:

$$E_{peatsoil\text{-}WPS,i,t} = E_{proxy\text{-}WPS,I,t} \quad (2)$$

Where:

$E_{peatsoil\text{-}WPS,i,t}$	Greenhouse gas emissions from the peat soil within the project boundary in the project scenario in stratum *i* in year *t* (t CO_2e yr^{-1})
$E_{proxy\text{-}WPS,i,t}$	GHG emissions as per the chosen proxy in the project scenario in stratum *i* in year *t* (t CO_2e yr^{-1})
i	1, 2, 3 …M_{WPS} strata in the project scenario (unitless)
t	1, 2, 3, … *t** time elapsed since the project start (years)

GHG emissions from the peat soil per stratum in the project scenario are estimated as follows:

$$E_{proxy\text{-}WPS,i,t} = A_i \times (E_{proxy\text{-}CO2,i,t} + E_{proxy\text{-}CH4,i,t}) \quad (3)$$

Where:

$E_{proxy\text{-}WPS,i,t}$	GHG emissions as per the chosen proxy in the project scenario in stratum *i* in year *t* (t CO_2e yr^{-1})
A_i	Total area of stratum *I* (ha)
$E_{proxy\text{-}CO2,i,t}$	Emission of CO_2 as per the chosen proxy in stratum *i* in year *t* (t CO_2e $ha^{-1}yr^{-1}$)
$E_{proxy\text{-}CH4,i,t}$	Emission of CH_4 as per the chosen proxy in stratum *i* in year *t* (t CO_2e $ha^{-1}yr^{-1}$)
i	1, 2, 3 …M_{WPS} strata[5] in the project scenario (unitless)
t	1, 2, 3, … *t** time elapsed since the project start (years)

During a transient period directly after rewetting, soil CH_4 emissions may be higher or lower before they stabilize to levels found in undrained sites. Unless it can be demonstrated that transient CH_4 emissions will not be higher, CH_4 emissions must be accounted for. Transient CH_4 emissions can be assessed by direct measurements (see Section 5.6.3) or by referring to literature values. Applicability of values must be justified and conservativeness demonstrated.

5.3 Assessing Project GHG from Ditches and Other Open Water Bodies ($E_{peatditch\text{-}WPS,i,t}$)

Reductions in GHG emissions from open water, such as drainage ditches, can be claimed. In RDP projects not all ditches must be closed and blocking of ditches may result in open water bodies with their specific GHG fluxes. Similarly, for CUPP projects ditches may continue to exist in case of conservation of partially drained peatland.

For each stratum

$$E_{peatditch\text{-}WPS,i,t} = A_{ditch\text{-}WPS,i,t} \times (E_{peatditch\text{-}CO2,i,t} + E_{peatditch\text{-}CH4,i,t}) \quad (4)$$

Where:

[5] Note that different water table classes result in different strata.

$E_{peatditch\text{-}WPS,i,t}$	GHG emissions from ditch and other open water stratum *i* in year *t* in the project scenario (t CO_2e yr^{-1})
$A_{ditch\text{-}WPS,,i,,t}$	Total area of ditch and other open water stratum *i* in year *t* in the project scenario (ha)
$E_{peatditch\text{-}CO2,i,t}$	Emission of CO_2 from ditch and open water stratum *i* in year *t* in the project scenario (t CO_2e $ha^{-1}yr^{-1}$)
$E_{peatditch\text{-}CH4,i,,t}$	Emission of CH_4 from ditch and open water stratum *i* in year *t* in the project scenario (t CO_2e $ha^{-1}yr^{-1}$)
i	1, 2, 3 …M_{WPS} strata[6] in the project scenario (unitless)
t	1, 2, 3, … *t** time elapsed since the project start (years)

The project may establish project-specific values for $E_{peatditch\text{-}CO2,i,t}$ and $E_{peatditch\text{-}CH4,i,t}$ or refer to appropriate literature sources or IPCC default factors. For literature values the accuracy must be defined or conservativeness must be justified. GHG emissions from drainage ditches and other open water bodies will not be higher in the project scenario compared to the baseline scenario (Couwenberg *et al.* 2011) and therefore, GHG emissions from channels and ditches may conservatively be omitted from GHG accounting.

5.4 Assessing GHG Emissions from Peat Burning ($E_{peatburn\text{-}WPS,i,t}$)

Procedures for assessing GHG emissions from burning of biomass and peat are provided in module *E-BPB*.

5.5 Assessing GHG Emission Reductions from Peat Combustion, Using the Fire Reduction Premium

The *Fire Reduction Premium* approach addresses human-induced peat fires occurring in drained peatland and establishes a conservative default factor, based on fire occurrence in the baseline scenario, so as to avoid the direct assessment of GHG emissions from fire in the baseline and the project scenarios.

The *Fire Reduction Premium* approach is only applicable if human-induced peat fires do not occur in the project scenario. The use of fire as a management tool (non-catastrophic fires or human-induced fires) in the project scenario is not allowed in the case that the *Fire Reduction Premium* approach is used to estimate emissions from peat fire.

Rationale: Fire Reduction Premium

The 20% Fire Reduction Premium is a rapid and conservative approach for acknowledging fire emissions reductions as a result of rewetting without having to develop complex baseline

[6] Note that different proxy classes result in different strata.

scenarios for peat fires. Emissions from peat fires are, like emissions from microbial peat oxidation, negatively correlated with water table depth (cf. Turetsky *et al.*, 2011, Ballhorn *et al.*, 2009). This allows a correlation of emissions from peat fires and microbial peat oxidation. C losses from peat fires are per hectare burned area on average ~10 times larger than the annual C emissions from microbial peat oxidation per ha drained peatland (ie, in temperate and boreal areas; in tropical SE Asia even ~20 times, cf. Ballhorn *et al.*, 2009, Couwenberg *et al.*, 2010, Van der Werf *et al.*, 2008). If in the baseline scenario at least 25% of the project area would burn at least once every 10 years and if rewetting and fire fighting in the project scenario would stop all C losses from microbial peat oxidation and all C losses from fire, the peat fire emission reduction would be 25% of the emission reduction from microbial peat oxidation. The 20% default premium is thus a conservative value.

In this procedure, the CO_2 emission reduction from microbial peat oxidation in the project scenario compared to the baseline scenario is estimated first by using the procedures in this module and in module *BL-PEAT*. The default factor for reduced emissions from peat fire has a maximum of 20% of the reduced CO_2 emissions from microbial peat oxidation ($E_{peatsoil\text{-}WPS} - E_{peatsoil\text{-}BSL}$) due to rewetting, if the cumulative area burnt in the fire reference period was equal to or exceeded 25% of the project area. This amount of emission reductions is denoted Fire Reduction Premium. The project will only be eligible to claim the premium if the following applies:

1) Over the period of minimum 10 to maximum 15 years ending 2 years before the project start date, the cumulative area of peat burnt exceeded 10% of the project area (in case of rewetting projects) or proxy area[7] (in case of conservation projects), where repeated burning of the same area adds to the percentage. Evidence must be provided using statistics and/or maps in official reports and/or remote sensing data; and,

2) In the baseline scenario the area is now, and in future will be, under risk of anthropogenic peat fires, as demonstrated by current and historic fire statistics and/or fire maps for the project area (in case of rewetting projects) or proxy area (in case of conservation projects), in combination with information on current and future land use; and,

3) The fire management plan proposed by the project proponent at validation reflects the best practices available with respect to fire prevention and control as determined by the relevant authorities[8] and takes into account specific project circumstances; and,

4) At each verification, documentation is provided demonstrating that fire management activities have been implemented according to the proposed plan.

[7] The same proxy area determined using the module *BL-PEAT* must be applied.
[8] Verifiable evidence must be provided in the PD.

The total area burnt ($A_{peatburn}$) is assessed as:

$$A_{PB} = \sum_{t=1}^{t*}\sum_{i=1}^{M}(A_{peatburn,i,t}) \qquad (5)$$

Where:

A_{PB}	Cumulative area of peat burnt in the baseline scenario (ha)
$A_{peatburn,i,t}$	Area of peat burnt in stratum i at time t in the baseline scenario (ha)
i	1, 2, 3 …M strata in the baseline scenario (unitless)
t	1, 2, 3, … t* time starting minimum 12 to a maximum of 17 years and ending 2 years prior to project start (years)

If peat fires in the baseline are more frequent than once per 10 years or more extensive than 25% of the project area (in case of rewetting projects) or proxy area (in case of conservation projects), the awarded premium is more conservative. If peat fires are less frequent or extensive, the premium is smaller accordingly. If peat fires in the baseline are less extensive than 10% of the project area (in case of rewetting projects) or proxy area (in case of conservation projects), the premium is not awarded.

If (A_{PB}/A_P) ≥ 0.25 then the emission reduction from peat combustion due to rewetting and fire management is estimated as:

$$\textit{Fire Reduction Premium} = 0.2 \times \sum_{t=1}^{t*}\sum_{i=1}^{M}(E_{peatsoil-WPS,i,t} - E_{peatsoil-BSL,i,t}) \qquad (6)$$

If (A_{PB}/A_P) < 0.1 then:

$$\textit{Fire Reduction Premium} = 0 \qquad (7)$$

If (A_{PB}/A_P) < 0.25 and $A_{peatburn}/A_P$ ≥ 0.1 then:

$$\textit{Fire Reduction Premium} = (A_{PB} / A_P) \times 0.8 \times \sum_{t=1}^{t*}\sum_{i=1}^{M}(E_{peatsoil-WPS,i,t} - E_{peatsoil-BSL,i,t}) \qquad (8)$$

Where:

Fire Reduction Premium	Greenhouse gas emission reduction from peat combustion due to rewetting and fire management up to year t^* (t CO_2e)
$E_{peatsoil\text{-}WPS,i,,t}$	GHG emissions from microbial decomposition of the peat soil within the project boundary in the project scenario in stratum *i* in year *t* (tCO_2e yr^{-1})
$E_{peatsoil\text{-}BSL,i,,t}$	GHG emissions from microbial decomposition of the peat soil within the project boundary in the baseline scenario in stratum *i* in year *t* (t CO_2e yr^{-1})
A_{PB}	Cumulative area of peat burnt in the reference period (ha)
A_P	Total area of peat in the project area (in case of rewetting projects) or proxy area (in case of conservation projects) (ha)
0.2	Default factor for reduced emissions from peat fire (unitless)
i	1, 2, 3 …*M* strata (unitless)
t	1, 2, 3, … t^* time elapsed since the project start (years)

Procedures for assessing $A_{peatburn}$ are provided under monitoring procedures below. The total area of peat (A_P) can be derived from the peat map established using module *X-STR*.

Fire Reduction Premium may be calculated on a total project basis, or alternatively, the assessment may be executed at the sub-project level, for example if the project is made up of a number of different peat areas that have different baseline fire histories, or in case of a grouped project.

If, a) peatland rewetting or conservation and, b) fire management best-practices have been implemented, peat fires occurring in the project scenario can be assumed to be catastrophic reversals[9] (ie, events that would have occurred in the baseline scenario but that would have been unaccounted for). Therefore, provided these two conditions are met, such fire events will not affect the claim to fire emission reduction by the project.

Although rewetting and fire management are aimed at stopping fire in the project scenario, rewetting and fire management may fail, causing peatland fires to occur. Peatland fires inside the project boundary must, therefore, be monitored and – if not catastrophic as defined above – accounted for by cancelling the premium for the entire project or the individual sub-project for the current monitoring period.

$$\textit{Fire Reduction Premium} = 0 \quad (9)$$

In case of non-catastrophic fires, adjustments must be made for the associated change in carbon store affecting the area eligible for carbon crediting (see Section 5 of module *X-STR* for procedures). Because underground fires may occur with surface fires, associated subsidence

[9] See *VCS Program Definitions* for definition of catastrophic reversal.

must be monitored for at least 3 years after the fire incident. If observed, emissions from subsidence must be estimated using module *E-BPB*.

5.6 Monitoring Procedures

Projects in which drainage continues or is maintained are not eligible. Accidents (eg, breaching of a dam) or unplanned drainage activities must be reversed and remediation must be monitored together with justifications that the effect has been temporal and insignificant. The project proponent must provide evidence that the applicability conditions of the methodology regarding the water table depth are met by monitoring the water table depth, for which procedures are provided below.

The estimation of carbon loss and GHG emissions from the oxidation of peat soil in a certain stratum can be based on the relation with proxies (see Section 1.2, Equations 2 and 3). Potential proxies are water table depth and soil subsidence.

The monitoring procedures for the following parameters are provided:

1. Water table depth (proxy for GHG emissions)
2. Water leakage
3. Direct measurements of GHG emissions
4. Soil subsidence (proxy for CO_2 emissions)
5. Volumetric carbon content of the peat
6. Peat thickness
7. Peat volume burnt (area burnt and fire scar depth)

5.6.1 Monitoring Water Table

If water table is used as a proxy for carbon loss and GHG emissions, monitoring of water tables in the project or proxy area must be based on measurements in appropriate strata (see module *X-STR*). Water table depth measurements can be continuous with data loggers and using min-max devices (eg, Bragg *et al*., 1994) or simple water level gauges (dipwells consisting of eg, perforated PVC tubes), Applied techniques must follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.

Water table depth measurements must be carried out at least every two months. At least 10 replicate dipwells must be evenly distributed per stratum, to ensure data consistency also when dipwells are lost. In peat swamp forest, dipwells must be placed in surface depressions between tree mounds. Visual inspection of the multiple records within a single stratum allows for identification of outlier values at single locations, indicating measurement errors that should be excluded from analysis. For remote and inaccessible areas, project proponents may rely on vegetation cover as an indicator for water table depth as supported by data or literature references in a conservative way.

5.6.2 Monitoring of Water Leakage

Procedures for the monitoring of water leakage to adjacent areas, that may cause changes in water table depths outside the project area (compared with the situation without the project intervention) and cause ecological leakage, are provided in module LK-ECO.

5.6.3 Direct Measurement of GHG Emissions

The project proponent may carry out direct measurements of GHG fluxes to assess emissions in relation to chosen proxies. Direct measurements of GHG fluxes may include closed chamber measurements, eddy covariance measurements and (for measuring C loss in drained sites only) subsidence measurements (see Section 5.6.4). Applied techniques must follow international standards of application as laid out in pertinent scientific literature (eg, Pattey *et al*. 2006, Alm *et al*. 2007, Evans *et al*. 2011).

5.6.4 Monitoring Soil Subsidence

If soil subsidence ($Rate_{subs,i,t}$) is used as a proxy for carbon loss and CO_2 emissions, applied techniques and calculations must follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks. The lowering of the peat surface over time (subsidence) must be measured relative to a fixed point (datum) (eg, using a pole fixed in the mineral subsoil). Dipwells used for water table depth monitoring can be used for subsidence monitoring with the advantage that water table depth and subsidence are monitored at the exact same location.

In areas where fire may occur, it is best (also) to place iron poles. If poles are lost due to fire, new poles must be installed. Height losses due to fire must be treated separately from those caused by microbial oxidation of the peat in assessing carbon losses (see module *E-BPB*, Section 5.2 for procedures to assess emissions from peat fires). Interpolation of the trend in peat height loss over a longer period surrounding the fire event allows for quantifying height loss due to the fire. At least 10 replicate subsidence poles must be evenly distributed per stratum (ie, the same as for dipwells, see Section 5.6.1). To prevent disturbance, poles may need to be fenced in. In order to avoid disturbance of the peat surface during readings it is advisable to place boardwalks.

For remote and inaccessible areas, project proponents may rely on vegetation cover as an indicator for water table depth and associated subsidence rates as supported by data or literature references in a conservative way. The minimum monitoring frequency for soil subsidence is once a year.

Consolidation of the saturated peat below the water table may contribute to subsidence over multiple years. Proponents must conservatively asses the contribution of consolidation to overall subsidence by reference to literature values or expert judgment or demonstrate that consolidation plays an insignificant role in overall subsidence (< 5%).

The calculation of carbon loss rates from subsidence data must follow pertinent scientific literature (eg, Couwenberg & Hooijer 2013) and usually requires data on the volumetric carbon content of the peat. When subsidence measurements are used to establish emission factors to be associated with other proxies, measurements must be carried out over a period of at least 24 months to cover intra- and inter-annual variability.

5.6.5 Determining Volumetric C Content of the Peat

Data on the amount of carbon contained in a volume of peat (C_{vol_upper} and C_{vol_lower}) is required to calculate carbon loss from subsidence rate. Volumetric carbon content is the product of the carbon concentration of the peat (*CC*, in %) and its dry bulk density (*BD*, in g cm^{-3}). The value for *BD* is more variable than *CC* (Warren *et al.* 2012), and must be estimated conservatively from literature or determined from field samples using standard laboratory techniques. When taken from literature, the project proponent must demonstrate that the applied values pertain to peat of the same type and degree of decomposition and are from areas that experience or have experienced the same or similar drainage intensity or that the chosen value is conservative.

In fibric/hemic peat of low ash content (< 5%), variation in *CC* contributes little to variation in derived carbon losses compared to variation in BD, and a default factor of 55% may be applied (Couwenberg & Hooijer 2013). Alternatively, project proponents may use the equation derived by Warren *et al.* (2012), which, based on a large dataset of bulk density and carbon content measurements, allows calculation of volumetric carbon content from BD measurements alone. Care should be taken that the equation of Warren *et al.* (2012) has been derived for undrained peat only.

If applied to drained peat soils, *BD* measurements of peat below the water table (BD_{lower}) must be used to calculate *CC*[10], which is then multiplied with the *BD* of the peat above the water table (BD_{upper}) to derive volumetric carbon content of the latter. For peat soils with high ash content *BD* and *CC* must be sampled using standard field and laboratory techniques.

Peat augers may compress peat samples or result in incomplete sampling of the peat when obstructed by coarse wood. Values derived using auger samples must be compared to literature values of undisturbed samples before they are applied.

[10] The variation in *BD* of undrained peat soils as presented by Warren *et al.* (2012) is predominantly determined by the admixture of clastic material (ash), which coincides with a lower C content. In a drained peat soil the high *BD* of the upper peat layer is, however, caused by compaction of the peat, which does not result in a change of its carbon content.

Undisturbed samples can be attained from open soil pits that are dug in the field (see eg, Hooijer *et al.* 2012) or by using a large diameter piston sampler. As such sampling is labour and resource intensive, it is allowed to sample selectively in those strata that deviate most in terms of drainage intensity and to derive *BD* of other strata conservatively by interpolation.

Samples must be taken near subsidence poles, to allow use of subsidence and soil information from the same locations. *CC* and *BD* must be determined *ex ante* and be re-assessed regularly and at least every 10 years.

5.6.6 Monitoring Peat Thickness

To create a peat thickness map peat thickness is measured using augers. It is best to use augers that are locally common, so experienced field staff and equipment is available. Two peat depth measurements must be made at each location, adding a third if there is more than one metre difference between the first two. Depth measurements must be carried out along transects perpendicular to the dome margin; see module *X-STR* for sampling design and distance and extrapolation of depth measurements. Additional peat depth measurements are provided when subsidence poles/dipwells are installed.

5.6.7 Area of Peat Burnt

To assess the area of peat burnt ($A_{peatburn}$), a map delineating all peat strata must be provided following criteria and procedures for differentiation of peatland from non peatland set out in module *X-STR*. The area of peat burnt ($A_{peatburn}$) can be assessed using field observations and/or remote sensing using best-practice methods (see eg, Congalton 1991; Congalton *et al*., 2008). Remote sensing-based data on burnt peat areas must be validated by field observations or other, higher resolution remote sensing data.

When using remote sensing, data must be georeferenced into a common geodetic system, for example using the UTM system using best-practice methods in remote sensing (see eg, Congalton 1991; Congalton *et al*., 2008). Semi automated image classification approaches may be applied. Strata must be validated by reference data collected in the field, other official documentation or from recent independent higher resolution remote sensing imagery.

5.6.8 Fire Scar Depth

The peat fire depth, or fire scar depth ($D_{peatburn,i,t}$) can be based on surface height measurements, using field measurements or remote sensing (eg, following methods described in Ballhorn *et al*. 2009) or be derived from expert judgment, literature (eg, Ballhorn *et al.* 2009; Couwenberg *et al.* 2010; Van der Werf *et al.* 2010; IPCC Wetlands Supplement) and/or datasets of historic burn depths involving the project or similar areas. Applicability of the derived burn depths must be justified and conservativeness must be demonstrated. A mean annualized burn depth may be calculated and applied to the entire project area in the baseline. As only part of the project area is likely to burn in the baseline, this constitutes a conservative approach.

6 DATA AND PARAMETERS

6.1 Data and Parameters Available at Validation

Data / Parameter	C_{vol_upper} and C_{vol_lower}
Data unit	g C cm^{-3}
Description	Average volumetric carbon content of the peat above and below the water table in stratum *i* at year *t*
Equations	N/A
Source of data	Own measurements
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Estimated conservatively from literature or determined from field sampling using standard laboratory techniques
Purpose of Data	Calculation of project emissions
Comments	Section 5.6.5

Data / Parameter	$D_{peatburn,i,t}$
Data unit	m yr^{-1}
Description	The peat fire depth, or fire scar depth per year
Equations	N/A
Source of data	Data sources or own measurements
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Field measurements or remote sensing, expert judgment, literature (eg, Ballhorn *et al.* 2009; Couwenberg et al. 2010; Van der Werf *et al.* 2010; IPCC) and/or datasets of historic burn depths involving the project or similar areas
Purpose of Data	Calculation of project emissions
Comments	Section 5.6.8

Data / Parameter	*CC*
Data unit	%
Description	Carbon concentration of the peat
Equations	N/A

Source of data	Default factor or own measurement
Value applied	Default factor (if employed): 0.55
Justification of choice of data or description of measurement methods and procedures applied	Sampling using standard field and laboratory techniques or (IPCC) default factors
Purpose of Data	Calculation of project emissions
Comments	Section 5.6.5

Data / Parameter	A_P
Data unit	ha
Description	Total area of peat in the project area (in case of rewetting projects) or proxy area (in case of conservation projects)
Equations	8
Source of data	Module *X-STR*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module *X-STR*
Purpose of Data	Calculation of project emissions
Comments	N/A

Data / Parameter	$A_{peatburn,i,t}$
Data unit	ha
Description	Area of peat burnt in stratum *i* at time *t* in the baseline scenario
Equations	5
Source of data	Module *X-STR*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module *X-STR*
Purpose of Data	Calculation of project emissions

Comments	N/A

Data / Parameter	$E_{peatsoil\text{-}BSL,i,t}$
Data unit	t CO_2e yr^{-1}
Description	GHG emissions from microbial decomposition of the peat soil within the project boundary in the baseline scenario in stratum *i* in year *t*
Equations	6, 8
Source of data	Module *BL-PEAT*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module *BL-PEAT*
Purpose of Data	Calculation of project emissions
Comments	N/A

6.2 Data and Parameters Monitored

Data / Parameter:	$E_{peatburn\text{-}WPS,i,t}$
Data unit:	t CO_2e yr^{-1}
Description:	GHG emissions from burning of peat within the project boundary in the project scenario in stratum *i* in year *t*
Equations	1
Source of data:	(IPCC) default factors, literature values or direct measurements
Description of measurement methods and procedures to be applied:	Procedures for assessing GHG emissions from burning of biomass and peat are provided in module *E-BPB*.
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of REDD-MF or other VCS methodology that uses this module.
Purpose of data:	Calculation of project emissions

Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$E_{proxy\text{-}CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Soil emission of CO_2 as per the chosen proxy in stratum *i* at year *t*
Equations	3
Source of data:	(IPCC) default factors, literature values or direct measurements
Description of measurement methods and procedures to be applied:	The estimation of GHG emissions in rewetted (for RPD projects) or undrained or partially drained (for CUPP projects) peat follows similar procedures as described in module *BL-PEAT*.
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Serction 9.3 of *REDD-MF* or other VCS methodology that uses this module.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Proxies must comply with VCS requirements on proxies.[11] It must be demonstrated that the proxy used is strongly correlated with CO_2 emissions by referring to IPCC, literature or own data. When referring to own data, comparison with literature values must be made.

Data / Parameter:	$E_{proxy\text{-}CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Soil emission of CH_4 as per the chosen proxy in stratum *i* at year *t*
Equations	3
Source of data:	(IPCC) default factors, literature values or direct measurements
Description of measurement methods and procedures to be applied:	The estimation of GHG emissions in rewetted (for RPD projects) or undrained or partially drained (for CUPP projects) peat follows similar procedures as described in module *BL-PEAT*.

[11] See Section 4.1.8 of the *VCS Standard* v3.4, or latest version

Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD-MF* or other VCS methodology that uses this module.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Proxies must comply with VCS requirements on proxies.[12] It must be demonstrated that the proxy used is strongly correlated with CO_2 emissions by referring to IPCC, literature or own data. When referring to own data, comparison with literature values must be made.

Data / Parameter:	A_i
Data unit:	ha
Description:	Total area of stratum *i*
Equations	3
Source of data:	Module *X-STR*
Description of measurement methods and procedures to be applied:	See module *X-STR*
Frequency of monitoring/recording:	See module *X-STR*
QA/QC procedures to be applied:	See Section 9.3 of REDD-MF or other VCS methodology that uses this module.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$E_{peatditch-CO2,i,t}$
Data unit:	t CO_2e ha^{-1} yr^{-1}
Description:	Emission of CO_2 from ditches and open water stratum *i* at year *t* in the project scenario

[12] See Section 4.1.8 of the *VCS Standard* v3.4, or latest version

Equations	4
Source of data:	(IPCC) default factors, literature values, direct measurements
Description of measurement methods and procedures to be applied:	The project may establish project-specific values for $E_{peatditch\text{-}CO2,i,t}$ or refer to appropriate literature sources or IPCC default factors. For literature values the accuracy must be defined or conservativeness must be justified.
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of REDD-MF or other VCS methodology that uses this module.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$E_{peatditch\text{-}CH4,i,t}$
Data unit:	t CO_2e ha^{-1} yr^{-1}
Description:	Emission of CH_4 from ditch and open water stratum *i* at year *t* in the project scenario
Equations	4
Source of data:	(IPCC) default factors, literature values, direct measurements
Description of measurement methods and procedures to be applied:	The project may establish project-specific values for $E_{peatditch\text{-}CH4,i,t}$ or refer to appropriate literature sources or IPCC default factors. For literature values the accuracy must be defined or conservativeness must be justified.
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD-MF* or other VCS methodology that uses this module.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$A_{ditch\text{-}WPS,,i,,t}$
Data unit:	ha
Description:	Total area of ditch and other open water stratum *i* in year *t* in the

	project scenario
Equations	4
Source of data:	Module *X-STR*
Description of measurement methods and procedures to be applied:	See module *X-STR*
Frequency of monitoring/recording:	See module *X-STR*
QA/QC procedures to be applied:	See Section 9.3 of *REDD-MF* or other VCS methodology that uses this module.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$Rate_{subs,i,t}$
Data unit:	m yr^{-1}
Description:	Soil subsidence rate
Equations	N/A
Source of data:	Direct measurements
Description of measurement methods and procedures to be applied:	Techniques and calculations must follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Frequency of monitoring/recording:	Once per year
QA/QC procedures to be applied:	See Section 9.3 of *REDD-MF* or other VCS methodology that uses this module.
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	See Section 5.6.4 for detailed instructions.

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DOCUMENT HISTORY

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v1.0	9 March 2015	Initial version