VCS Module

VMD0017

Estimation of Uncertainty for REDD+ Project Activities (X-UNC)

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Sectoral Scope 14

Module developed by:

Revision to include tidal wetland restoration and conservation activities (version 2.2 of this module) prepared by Silvestrum Climate Associates and Restore America's Estuaries

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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 versions of the following modules and tools:

Carbon pool modules:

- *VMD0001 Estimation of carbon stocks in the above- and belowground biomass in live tree and non-tree pools (CP-AB)*
- *VMD0002 Estimation of carbon stocks in the dead-wood pool (CP-D)*
- *VMD0003 Estimation of carbon stocks in the litter pool (CP-L)*
- *VMD0004 Estimation of carbon stocks in the soil organic carbon pool (mineral soils) (CP-S)*
- *VMD0005 Estimation of carbon stocks in the long-term wood products pool (CP-W)*

Baseline modules:

- *VMD0006 Estimation of baseline carbon stock changes and greenhouse gas emissions from planned deforestation and planned degradation (BL-PL)*
- *VMD0007 Estimation of baseline carbon stock changes and greenhouse gas emissions from unplanned deforestation (BL-UP)*
- *VMD0042 Estimation of baseline soil carbon stock changes and greenhouse gas emissions in peatland rewetting and conservation project activities (BL-PEAT)*
- *VMD00XX Estimation of baseline carbon stock changes and greenhouse gas emissions in tidal wetland restoration and conservation project activities (BL-TW)*

Emissions modules:

- *VMD0013 Estimation of greenhouse gas emissions from biomass and peat burning (E–BPB)*
- *VMD0014 Estimation of emissions from fossil fuel combustion (E-FFC)*
- CDM tool *Estimation of direct N_2O emissions from nitrogen application (E-NA)*

Monitoring modules:

- *VMD0046 Methods for monitoring of soil carbon stock changes and greenhouse gas emissions and removals in peatland rewetting and conservation project activities (M-PEAT)*
- *VMD00XX Methods for monitoring of carbon stock changes and greenhouse gas emissions in tidal wetland restoration and conservation project activities (M-TW)*

Tools:

- CDM tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*

2 SUMMARY DESCRIPTION OF THE MODULE

This module allows for estimating uncertainty in the estimation of emissions and removals in REDD and WRC project activities. Uncertainty in the estimation of emissions and removals from ARR project activities is treated in the CDM tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*. The module may also be used for project planning purposes. Use of the module while planning the project can assure the monitoring is of sufficient intensity to minimize uncertainty deductions. The purpose of the methodology is for calculating *ex ante* and *ex post* a precision level and any deduction in credits for lack of precision following project implementation and monitoring. The module assesses uncertainty in baseline estimations and in estimations of project sequestration, emissions and leakage.

3 DEFINITIONS AND ACRONYMS

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

DP Forest area that is cleared per additional person(s) entering the population

RRD Reference region for projecting rate of deforestation

4 APPLICABILITY CONDITIONS

This module is mandatory when using methodology *REDD+ ~~-~~MF*. It is applicable for estimating the uncertainty of estimates of emissions and removals of CO_2-e generated from REDD and WRC project activities. The module focuses on the following sources of uncertainty:

- Determination of rates of deforestation and degradation
- Uncertainty associated with estimation of stocks in carbon pools and changes in carbon stocks
- Uncertainty associated with estimation of peat emissions
- Uncertainty in assessment of project emissions

Where an uncertainty value is not known or cannot be simply calculated, a project must justify that it is using an indisputably conservative number and an uncertainty of 0% may be used for this component.

Guidance on uncertainty – a precision target of a 95% confidence interval half-width equal to or less than 15% of the recorded value must be targeted. This is especially important in terms of project planning for measurement of carbon stocks; sufficient measurement plots should be included to achieve this precision level across the measured stocks.

5 PROCEDURES

This module provides procedures to determine the following parameters:

NER_{REDD+_ERROR}	Cumulative uncertainty for the REDD+ (WRC and REDD) project activities up to year t^* (percent)
$Adjusted\text{-}NER_{REDD+}$	Total net GHG emission reductions of the REDD+ project activities up to year t^* adjusted to account for uncertainty (t CO_2e)

Estimated carbon emissions and removals arising from AFOLU activities have uncertainties associated with the measures/estimates of: area or other activity data, carbon stocks, biomass growth rates, expansion factors, and other coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default factors given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), expert judgment,[1] or estimates based on sound statistical sampling.

Alternatively, (indisputably) conservative estimates can also be used instead of uncertainties, provided that they are based on verifiable literature sources or expert judgment. In this case the uncertainty is assumed to be zero. However, this module provides a procedure to combine uncertainty information and conservative estimates resulting in an overall *ex-post* project uncertainty.

Planning to Diminish Uncertainty

It is important that the process of project planning consider uncertainty. Procedures including stratification (see Module *X-STR*), and the allocation of sufficient measurement plots can help ensure that low uncertainty in carbon stocks results and ultimately full crediting can result.

It is good practice to apply this module at an early stage to identify the data sources with the highest uncertainty to allow the opportunity to conduct further work to diminish uncertainty.

5.1 Part 1: Uncertainty in REDD Baseline Estimates

5.1.1 Step 1: Assess Uncertainty in Projection of Baseline Rate of Deforestation or Degradation

Table 1 below provides the parameters and corresponding modules relevant to this step.

Table 1: Step 1 Parameters and Modules

$A_{BSL,RR,unplanned}$	*BL-UP*
$D\%_{planned,i,t}$	*BL-PL*

It is here assumed that there is zero uncertainty in baseline rate of deforestation or degradation where numbers are equal to a long-term average (*BL-UP*), are based on actual deforestation plans (*BL-PL*) or are derived from *PRA* (*BL-DFW*). In these specific cases, assume:

[1] Justification should be supplied for all values derived from expert judgment

$Uncertainty_{BSL,RATE}$ = 0

In all other scenarios the uncertainty in rate shall be a component of net project uncertainty.

A. Planned Deforestation: where rate of deforestation is derived from measurements of proxy areas (see Module *BL-PL*):

The uncertainty shall be equal to the 95% confidence interval as a percentage of the mean of the area deforested in each proxy ($D\%_{pn}$) divided by the number of years over which deforestation occurred in each proxy (Yrs_{pn}).

B. Unplanned deforestation: where deforestation rate is derived using regression equations of past deforestation rate versus time, or deforested area versus population (population driver approach), the uncertainty introduced by this analysis must be incorporated (see Module *BL-UP*). Uncertainty in the baseline rate of deforestation ($Uncertainty_{BSL,RATE}$) is calculated referencing the 95% confidence limits of the regression model, calculated using standard regression analysis techniques.[2] For the value of the referenced independent variable (time or population) in year *t*, the half-width of the 95% confidence interval for the dependent variable (predicted deforestation) is calculated as a percent of the dependent variable (modeled) value. Uncertainty cannot be less than zero.

Uncertainty in the baseline rate is calculated as follows:

$Uncertainty_{BSL,RATE,t}$ = Half-width of the 95% confidence interval for $A_{BSL,RRD,unplanned,t}$ / $A_{BSL,RRD,unplanned,t}$ (1)

Where:

$Uncertainty_{BSL,RATE,t}$	Uncertainty in the baseline rate of deforestation in year *t* (%)
$A_{BSL,RRD,unplanned,t}$	Projected area of unplanned baseline deforestation in the RRD in year *t* (ha)

Note that for time year *t*, the value of the independent variable referenced is the value for the entire RRD (or RRD subset). For the population driver approach, the relevant value is total population (static approach) in year *t* or total change in population (dynamic approach) in year *t* – *t*-1, summed across all component population census units. If multiple subsets of the RRD are used, as in the population driver approach where each RRD_j may have its own regression, total uncertainty in the baseline rate is calculated as follows:

$$Uncertainty_{BSL,RATE,t} = \frac{\sqrt{\sum_{j=1}^{N}\left(Uncertainty_{BSL,RATE,t,j} \times \sum_{i}^{M} A_{BSLi,j,unplanned,t}\right)^2}}{\sum_{j=1}^{N}\sum_{i}^{M} A_{BSL,i,j,unplanned,t}} \quad (2)$$

Where:

$Uncertainty_{BSL,RATE,t}$	Uncertainty in the baseline rate of deforestation in year *t* (%)
$Uncertainty_{BSL,RATE,t,j}$	Uncertainty in the baseline rate of deforestation in year *t* for RRD subset *j* (%)

[2] Eg, Hamilton, L.C. 1992. Regression with Graphics. Duxbury Press. Belmont, California. 363 pp.

$A_{BSL,i,j,unplanned,t}$	Projected area of unplanned baseline deforestation in census unit *i* member of RRD subset *j* in year *t* (ha)
t	1, 2, 3, …*t* time elapsed since the start of the project activity (years)
j	1, 2, 3, …*N* subsets of RRD (sets of census units with separate *DP* parameters)
i	1, 2, 3, …*M* population census units

Uncertainty is then propagated across years to produce an estimate of cumulative uncertainty up to year *t**:

$$Uncertainty_{BSL,RATE,t*} = \frac{\sqrt{\sum_{t=1}^{t*}(Uncertainty_{BSL,RATE,t} \times \sum_{j=1}^{N}\sum_{i}^{M} A_{BSL,i,j,unplanned,t})^2}}{\sum_{t=1}^{t*}\sum_{j=1}^{N}\sum_{i}^{M} A_{BSL,i,j,unplanned,t}} \qquad (3)$$

Where:

$Uncertainty_{BSL,RATE,t*}$	Cumulative uncertainty in the baseline rate of deforestation up to time year *t** (%)
$Uncertainty_{BSL,RATE,t}$	Uncertainty in the baseline rate of deforestation in year *t* (%)
$A_{BSL,i,j,unplanned,t}$	Projected area of unplanned baseline deforestation in census unit *i* member of RRD subset *j* in year *t* (ha)
t	1, 2, 3, …*t** time elapsed since the start of the project activity (years)
i	1, 2, 3, …*M* population census units

5.1.2 Step 2: Assess Uncertainty of Emissions and Removals in Project Area in Baseline Scenario

Table 2 below provides the parameters and corresponding modules relevant to this step.

Table 2: Step 1 Parameters and Modules for REDD

$C_{AB\text{-}tree}$	*CP-AB*
$C_{BB\text{-}tree}$	*CP-AB*
C_{DW}	*CP-D*
C_{LI}	*CP-L*
C_{SOC}	*CP-S*
$C_{WP\ frp,}$	*CP-W*
$E_{biomassburn}$	*E-BPB*
E_{FC}	*E-FFC*
$N_2O_{direct\text{-}N}$	*E-NA*

Uncertainty should be expressed as the 95% confidence interval half width as a percentage of the mean. Uncertainty is first propagated across pools within strata. Note that where the REDD activity is conducted in combination with WRC, the belowground biomass and soil organic carbon pools are omitted here (treated as an emission source from peat in Part 2 below). The uncertainty is calculated as follows:

$$U_{REDD-BSL,SS,i} = \frac{\sqrt{\sum_1^n (U_{REDD-BSL,SS,i,pool\#} \times E_{REDD-BSL,SS,i,pool\#})^2}}{\sum_1^n E_{REDD-BSL,SS,i,pool\#}} \quad (4)$$

Where:

$U_{REDD\_BSL,SS,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the REDD baseline case scenario in stratum *i* (%)
$U_{REDD\_BSL,SS,i,pool\#}$	Percentage uncertainty for carbon stocks and greenhouse gas sources in the REDD baseline casescenario in stratum *i* (%)
$E_{REDD\_BSL,SS,i,pool\#}$	Carbon stock or GHG sources in the REDD baseline casescenario (t CO_2e)
i	1, 2, 3 …*M* strata (unitless)

Uncertainty across combined strata must be assessed as follows:

$$Uncertainty_{REDD-BSL,SS} = \frac{\sqrt{\sum_{i=1}^{M} (U_{REDD-BSL,SS,i} \times E_{REDD-BSL,SS,i})^2}}{\sum_{i=1}^{M} E_{REDD-BSL,SS,i}} \quad (5)$$

Where:

$Uncertainty_{REDD\_BSL,SS}$	Total uncertainty in the combined carbon stocks and greenhouse gas sources in the REDD baseline casescenario (%)
$U_{REDD\_BSL,SS,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in stratum *i* in the REDD baseline casescenario (%)
$E_{REDD\_BSL,SS,t,i}$	Sum of combined carbon stocks and GHG sources in the REDD baseline casescenario (t CO_2-e)
i	1, 2, 3, …*M* strata (unitless)

5.1.3 Step 3: Estimate Total Uncertainty in REDD Baseline Scenario

Rate uncertainty is incorporated as follows:

$$Uncertainty_{REDD-BSL,t*} = \sqrt{Uncertainty_{BSL,RATE,t*}^{2} + Uncertainty_{REDD-BSL,SS}^{2}} \quad (6)$$

Where:

$Uncertainty_{REDD-BSL,t*}$	Cumulative uncertainty in REDD baseline scenario up to time year t^* (%)
$Uncertainty_{REDD-BSL,RATE,t*}$	Cumulative uncertainty in the baseline rate of deforestation up to time year t (%)
$Uncertainty_{REDD-BSL,SS}$	Total uncertainty in the combined carbon stocks and greenhouse gas sources in the REDD baseline casescenario (%)
t	1, 2, 3, …t^* time elapsed since the start of the project activity (years)

5.2 Part 2: Uncertainty in WRC Baseline Estimates

5.2.1 :Uncertainty in Baseline Estimates for Peatland

Table 3 below provides the parameters and corresponding modules relevant to this section.

Table 3: Part 2 Parameters and Modules for Peatland

$E_{proxy-CO2,i,t}$	*BL-PEAT*
$E_{proxy-CH4,i,t}$	*BL-PEAT*
$E_{peatditch-CO2,i,t}$	*BL-PEAT*
$E_{peatditch-CH4,i,t}$	*BL-PEAT*
$E_{peatburn-BSL,i,t}$	*BL-PEAT* and *E-BPB*

Sources of uncertainty in the baseline scenario accounted for WRC activities on peatland include uncertainty around regression models, or discrete default factors, relating CO_2 and CH_4 emissions from peat and ditches to chosen proxies, and uncertainty around estimates of emissions from burning of peat. It is assumed that area and strata bounds, A_i and $A_{ditch-BSL,i,t,}$ are known exactly when complying with requirements in Modules *X-STR* and *BL-PEAT* and that uncertainty around estimates of proxy parameters is zero when complying with requirements of Module *BL-PEAT*.

Where regression models are used to estimate emissions from oxidation of peat from proxy parameters, uncertainty is calculated by referencing the 95% confidence limits of the regression model, calculated using standard regression analysis techniques. For the value of the referenced proxy in year t, the half-width of the 95% confidence interval for the dependent variable (emissions) is calculated to produce parameters U_{*t}.

Where emissions are estimated applying a discrete default factor, uncertainty, $U_{*t,}$ is simply calculated by referencing the 95% confidence limit of the default factor estimate, or assigned as zero if an indisputably conservative value is used.

Note that each parameter U_{*t} is in units of t CO_2e yr^{-1} (not percent) and represents error in year *t* propagated across strata as follows:

$$U_{*,t} = \sqrt{\sum_{i=1}^{M}(A_i \times U_{*,i,t})^2} \quad (7)$$

Where:

$U_{*,t}$	Uncertainty in parameter * in year *t* (t CO_2e yr^{-1})
$U_{*,i,t}$	Uncertainty in parameter * in stratum *i* in year *t*, equal to the half width of the 95% confidence interval (t CO_2e $ha^{-1}yr^{-1}$)
A_i	Total area of stratum *i* (ha)
i	1, 2, 3, …*M* strata (unitless)
t	1, 2, 3, …*t* time elapsed since the project start (years)

* = parameters $E_{proxy-CO2,t}$, $E_{proxy-CH4,t}$, $E_{peatditch-CO2,t}$, $E_{peatditch-CH4,t}$ and $E_{peatburn-BSL,t}$.

Total uncertainty in the WRC baseline for peatland in year *t* is then calculated as follows:

$$Uncertainty_{PEAT-BSL,t} = \sqrt{U_{Eproxy-CO2,t}^{\;2} + U_{Eproxy-CH4,t}^{\;2} + U_{Epeatditch-CO2,t}^{\;2} + U_{Epeatditch-CH4,t}^{\;2} + U_{Epeatburn-BSL,t}^{\;2}} \quad (8)$$

Where:

$Uncertainty_{PEAT-BSL,t}$	Uncertainty in the WRC baseline ~~case~~scenario for peatland in year *t* (t CO_2e)
$U_{Eproxy-CO2,t}$	Uncertainty in parameter $E_{proxy-CO2,t}$ (emission of CO_2 in relation to the chosen proxy in year *t*) (t CO_2e yr^{-1})
$U_{Eproxy-CH4,t}$	Uncertainty in parameter $E_{proxy-CH4,t}$ (emission of CH_4 in relation to the chosen proxy in year *t*) (t CO_2e yr^{-1})
$U_{Epeatditch-CO2,t}$	Uncertainty in parameter $E_{peatditch-CO2,t}$ (emission of CO_2 from ditch and open water in year *t*) (t CO_2e yr^{-1})
$U_{Epeatditch-CH4,t}$	Uncertainty in parameter $E_{peatditch-CH4,t}$ (emission of CH_4 from ditch and open water in year *t*) (t CO_2e yr^{-1})
$U_{Epeatburn-BSL,t}$	Uncertainty in parameter $E_{peatburn-BSL,t}$ (GHG emissions from burning of peat in the base line scenario in year *t*) (t CO_2e yr^{-1})
t	1, 2, 3, …*t* time elapsed since the project start (years)

Uncertainty is then propagated across years to produce an estimate of cumulative uncertainty up to year *t** as follows:

$$Uncertainty_{PEAT-BSLWRC_{BSL},t*} = \frac{\sqrt{\sum_{t=1}^{t*} Uncertainty_{PEAT-WRC_{BSL}BSL,t}^{2}}}{\sum_{t=1}^{t*} GHG_{PEAT-BSL_{WRC}BSL,t}} \quad (9)$$

Where:

$Uncertainty_{WRC\_BSL PEAT-BSL,t*}$	Cumulative uncertainty in the WRC baseline ~~case~~scenario for peatland up to year t* (%)
$Uncertainty_{WRC\_BSL PEAT-BSL,t}$	Uncertainty in the WRC baseline ~~case~~scenario for peatland in year t (t CO_2e)
$GHG_{BSL-PEAT-BSL WRC,t}$	Net GHG emissions in the WRC baseline scenario for peatland in year t (t CO_2e)
t	1, 2, 3, …t* time elapsed since the project start (years)

5.2.2 Uncertainty in Baseline Estimates for Tidal Wetland (excluding peatland)

For peatland areas within tidal wetlands, use the procedures set out in Section 5.2.1 above.

Table 4 below provides the parameters and corresponding modules relevant to this section.

Table 4: Parameters and Modules for Tidal Wetland

$GHG_{BSL-soil-CO2,i,t}$	*BL-TW*
$Deduction_{alloch}$	*BL-TW*
$GHG_{BSL-soil-CH4,i,t}$	*BL-TW*
$GHG_{BSL-soil-N2O,i,t}$	*BL-TW*

Follow the general guidance provided in Section 5.2.1, while substituting *BL-TW* for *BL-PEAT* and noting that parameters U_{*t} involve $GHG_{BSL-soil-CO2,i,t}$, $Deduction_{alloch}$, $GHG_{BSL-soil-CH4,i,t}$ and $GHG_{BSL-soil-N2O,i,t}$.

Total uncertainty in the WRC baseline for tidal wetland in year t is then calculated as follows:

$$Uncertainty_{TW-BSL,t} = \sqrt{UGHG_{BSL-soil-CO2,t}^{2} + UDeduction_{alloch}^{2} + UGHG_{BSL-soil-CH4,t}^{2} + UGHG_{BSL-soil-N2O,t}^{2}} \quad (10)$$

Where:

$Uncertainty_{TW-BSL,t}$	Uncertainty in the WRC baseline scenario for tidal wetland in year t (t CO_2e)
$UGHG_{BSL-soil-CO2,t}$	Uncertainty in parameter $GHG_{BSL-soil-CO2,t}$ (CO_2 emissions from the SOC pool in the baseline scenario in year t) (t CO_2e yr^{-1})
$UDeduction_{alloch}$	Uncertainty in parameter $Deduction_{alloch}$ (Deduction from CO_2 emissions from the SOC pool to account for the percentage of the carbon stock that is derived from allochthonous soil organic carbon) (t CO_2e yr^{-1})
$UGHG_{BSL-soil-CH4,t}$	CH_4 emissions from the SOC pool in the baseline scenario in year t) (t CO_2e yr^{-1})
$UGHG_{BSL-soil-N2O,t}$	Uncertainty in parameter $GHG_{BSL-soil-N2O,t}$ (N_2O emissions from the SOC pool in the baseline scenario in year t) (t CO_2e yr^{-1})
t	1, 2, 3, …t* time elapsed since the project start (years)

Uncertainty is then propagated across years to produce an estimate of cumulative uncertainty up to year *t** as follows:

$$Uncertainty_{TW-BSL,t*} = \frac{\sqrt{\sum_{t=1}^{t*} Uncertainty_{BSL-TW,t}^{2}}}{\sum_{t=1}^{t*} GHG_{BSL-TW,t}} \quad (11)$$

Where:

$Uncertainty_{TW-BSL,t*}$	Cumulative uncertainty in the WRC baseline scenario for tidal wetland up to year *t* (%)
$Uncertainty_{TW-BSL,t}$	Uncertainty in the WRC baseline scenario for tidal wetland in year *t* (t CO_2e)
$GHG_{TW-BSL,t}$	Net GHG emissions in the WRC baseline scenario for tidal wetland in year *t* (t CO_2e)
t	1, 2, 3, …*t** time elapsed since the project start (years)

5.2.3 Total Uncertainty in WRC Baseline Estimates

Uncertainties in baseline estimates for peatland and tidal wetlands are combined as follows:

$$Uncertainty_{WRC-BSL,t*} = \sqrt{Uncertainty_{PEAT-BSL,t*}^{2} + Uncertainty_{TW-BSL,t*}^{2}} \quad (12)$$

Where:

$Uncertainty_{WRC-BSL,t*}$	Cumulative uncertainty in WRC baseline scenario up to year *t** (%)
$Uncertainty_{PEAT-BSL,t*}$	Cumulative uncertainty in the WRC baseline scenario for peatland up to year *t** (%)
$Uncertainty_{TW-BSL,t*}$	Cumulative uncertainty in the WRC baseline scenario for tidal wetland up to year *t** (%)
t	1, 2, 3, …*t** time elapsed since the start of the project activity (years)

5.3 Part 3: Uncertainty *Ex Post* in the REDD Project Scenario

Table 4 below provides the parameters and corresponding modules relevant to this section.

Table 4: ~~Part 3~~ Parameters and Modules for REDD

$C_{AB-tree}$	*CP-AB*
$C_{BB-tree}$	*CP-AB*
C_{DW}	*CP-D*
C_{LI}	*CP-L*
C_{SOC}	*CP-S*
C_{WP}	*CP-W*

$E_{biomassburn}$	E-BPB
E_{FC}	E-FFC
$N_2O_{direct-N}$	E-NA

Area of deforestation or degradation in the project scenario should be tracked directly using the same accuracy assessment criterion as used in the baseline (accuracy of 90% or more – see Module *BL-UP*).

Uncertainty is first propagated across pools within strata. Note that where the REDD activity is conducted in combination with WRC, the belowground biomass and soil organic carbon pools are omitted here (treated as an emission source from peat in Part 4 below):

$$U_{REDD-WPS,SS,i} = \frac{\sqrt{\sum_1^n (U_{REDD-WPS,SS,i,pool\#} \times E_{REDD-WPS,SS,i,pool\#})^2}}{\sum_1^n E_{REDD-WPS,SS,i,pool\#}} \quad (13)$$

Where:

$U_{REDD-WPS,SS,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the REDD project scenario in stratum *I* (%)
$U_{REDD-WPS,SS,i,pool\#}$	Percentage uncertainty for carbon stocks and greenhouse gas sources in the REDD project scenario in stratum *i* (%)
$E_{REDD-WPS,SS,i,pool\#}$	Carbon stock or GHG sources in stratum *i* in the REDD project scenario (t CO_2)
i	1, 2, 3, …*M* strata (unitless)

Uncertainty across combined strata is assessed as follows:

$$Uncertainty_{REDD-WPS} = \frac{\sqrt{\sum_{i=1}^M (U_{REDD-WPS,SS,i} \times E_{REDD-WPS,SS,i})^2}}{\sum_{i=1}^M E_{REDD-WPS,SS,i}} \quad (14)$$

Where:

$Uncertainty_{REDD-WPS}$	Total uncertainty in the REDD project scenario (%)
$U_{REDD-WPS,SS,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in stratum *i* in the REDD project scenario (%)
$E_{REDD-WPS,SS,t,i}$	Sum of combined carbon stocks and GHG sources multiplied by the area of stratum *i* (A_i) in the REDD project scenario (t CO_2e)
i	1, 2, 3, …*M* strata (unitless)

Where no *ex post* (re-)measurements of carbon pools or GHG sources have been made, ie, uncertainty from these sources is already included in $Uncertainty_{REDD-BSL,t*}$, $Uncertainty_{REDD-WPS}$ is set equal to zero.

5.4 Part 4: Uncertainty in WRC Project Scenario Estimates

5.4.1 :Uncertainty in Project Scenario Estimates for Peatland

Table 5 provides the parameters and corresponding modules relevant to this section.

Table 5: Part 3 Parameters and Modules for Peatland

$E_{proxy\text{-}CO2,i,t}$	*M-PEAT*
$E_{proxy\text{-}CH4,i,t}$	*M-PEAT*
$E_{peatditch\text{-}CO2,i,t}$	*M-PEAT*
$E_{peatditch\text{-}CH4,i,t}$	*M-PEAT*
$E_{peatburn\text{-}WPS,i,t}$	*E-BPB*

Sources of uncertainty in the project scenario accounted for in WRC activities on peatland include uncertainty around regression models, or discrete default factors, relating CO_2 and CH_4 emissions from peat and ditches to chosen proxies, and uncertainty around estimates of emissions from burning of peat.

Fire reduction premiums assigned using Module *M-PEAT* are demonstrably conservative and no uncertainty from this parameter is accounted.

It is assumed that area and strata bounds, A_i and $A_{ditch\text{-}WPS,i,t,}$ are known exactly when complying with requirements in Modules *X-STR* and *M-PEAT* and that uncertainty around estimates of proxy parameters is zero when complying with monitoring procedures requirements of Module *M-PEAT*.

Where regression models are used to estimate emissions from oxidation of peat from proxy parameters, uncertainty is calculated by referencing the 95% confidence limits of the regression model, calculated using standard regression analysis techniques. For the value of the referenced proxy in year *t*, the half-width of the 95% confidence interval for the dependent variable (emissions) is calculated to produce parameters $U_{*t.}$

Where emissions are estimated applying a discrete default factor, uncertainty, $U_{*t,}$ is simply calculated by referencing the 95% confidence limit of the default factor estimate, or assigned as zero if an indisputably conservative value is used.

Note that each parameter U_{*t} is in units of t CO_2e yr^{-1} (not percent) and represents error in year *t* propagated across strata as follows:

$$U_{*,t} = \sqrt{\sum_{i=1}^{M}(A_i \times U_{*,i,t})^2} \qquad (15)$$

Where:

$U_{*,t}$	Uncertainty in parameter * in year *t* (t CO_2e yr^{-1})
$U_{*,i,t}$	Uncertainty in parameter * in stratum *i* in year *t*, equal to the half width of the 95% confidence interval (t CO_2e $ha^{-1}yr^{-1}$)
A_i	Total area of stratum *i* (ha)
i	1, 2, 3, …*M* strata (unitless)
t	1, 2, 3, …*t** time elapsed since the project start (years)

* = parameters $E_{proxy\text{-}CO2,t}$, $E_{proxy\text{-}CH4,t}$, $E_{peatditch\text{-}CO2,t}$, $E_{peatditch\text{-}CH4,t}$ and $E_{peatburn\text{-}WPS,t}$.

Total uncertainty in the WRC project scenario for peatland in year *t* is then calculated as follows:

$$Uncertainty_{WRC_{WPS}PEAT-WPS,t} = \sqrt{U_{Eproxy-CO2,t}^{\,2} + U_{Eproxy-CH4,t}^{\,2} + U_{Epeatditch-CO2,t}^{\,2} + U_{Epeatditch-CH4,t}^{\,2} + U_{Epeatburn-WPS,t}^{\,2}}$$

(16)

Where:

~~$Uncertainty_{WRC}$~~ $Uncertainty_{PEAT\_WPS,t}$	Uncertainty in the WRC project scenario for peatland in year *t* (t CO_2e)
$GHG_{PEAT~~WPS~~\text{-}WRC,t}$	Net GHG emissions in the WRC project scenario for peatland in year *t* (t CO_2e)
$U_{Eproxy\text{-}CO2,t}$	Uncertainty in parameter $E_{proxy\text{-}CO2,t}$ (emission of CO_2 in relation to the chosen proxy in year *t*) (t CO_2e yr^{-1})
$U_{Eproxy\text{-}CH4,t}$	Uncertainty in parameter $E_{proxy\text{-}CH4,t}$ (emission of CH_4 in relation to the chosen proxy in year *t*) (t CO_2e yr^{-1})
$U_{Epeatditch\text{-}CO2,t}$	Uncertainty in parameter $E_{peatditch\text{-}CO2,t}$ (emission of CO_2 from ditch and open water in year *t*) (t CO_2e yr^{-1}
$U_{Epeatditch\text{-}CH4,t}$	Uncertainty in parameter $E_{peatditch\text{-}CH4,t}$ (emission of CH_4 from ditch and open water in year *t*) (t CO_2e yr^{-1})
$U_{Epeatburn\text{-}WPS,t}$	Uncertainty in parameter $E_{peatburn\text{-}BSL,t}$ (GHG emissions from burning of peat in the project scenario 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 (year)

Uncertainty is then propagated across years to produce an estimate of cumulative uncertainty up to year *t** as follows:

$$Uncertainty_{WRC_{WPS}PEAT-WPS,t*} = \frac{\sqrt{\sum_{t=1}^{t*} Uncertainty_{WRC_{WPS}PEAT-WPS,t}^{\,2}}}{\sum_{t=1}^{t*} GHG_{WPS-PEAT-WRC,t}}$$

(17)

Where:

$Uncertainty_{PEAT~~WRC~~\_WPS,t*}$	Cumulative uncertainty in the WRC project scenario for peatland up to year *t* (%)
$Uncertainty_{PEAT~~WRC~~\_WPS,t}$	Uncertainty in the WRC project scenario for peatland in year *t* (t CO_2e)
$GHG_{WPS\text{-}PEAT~~WRC~~,t}$	Net GHG emissions in the WRC project scenario for peatland in year *t* (t CO_2e)
t	1, 2, 3, …*t** time elapsed since the project start (year)

5.4.2 Uncertainty in Project Scenario Estimates for Tidal Wetland (excluding peatland)

For peatland areas within tidal wetlands, use the procedures set out in Section 5.4.1 above.

Table 6 provides the parameters and corresponding modules relevant to this section.

Table 6: Parameters and Modules for Tidal Wetland

$GHG_{WPS\text{-}soil\text{-}CO2,i,t}$	*M-TW*
$Deduction_{alloch}$	*M-TW*
$GHG_{WPS\text{-}soil\text{-}CH4,i,t}$	*M-TW*
$GHG_{WPS\text{-}soil\text{-}N2O,i,t}$	*M-TW*

Follow the general guidance provided in Section 5.4.1, while substituting *M-TW* for *M-PEAT* and noting that parameters U_{*t} involve $GHG_{WPS\text{-}soil\text{-}CO2,i,t}$, $Deduction_{alloch}$, $GHG_{WPS\text{-}soil\text{-}CH4,i,t}$ and $GHG_{WPS\text{-}soil\text{-}N2O,i,t}$.

Total uncertainty in the WRC baseline for tidal wetland in year *t* is then calculated as follows:

$$Uncertainty_{TW-WPS,t} = \sqrt{UGHG_{WPS-soil-CO2,t}{}^{2} + UDeduction_{alloch,t}{}^{2} + UGHG_{WPS-soil-CH4,t}{}^{2} + UGHG_{WPS-soil-N2O,t}{}^{2}} \qquad (18)$$

Where:

$Uncertainty_{TW\text{-}WPS,t}$	Uncertainty in the WRC baseline scenario for tidal wetland in year *t* (tCO_2e)
$UGHG_{WPS\text{-}soil\text{-}CO2,i,t}$	Uncertainty in parameter $GHG_{BSL\text{-}soil\text{-}CO2,t}$ (CO_2 emissions from the SOC pool in the project scenario in year *t*) (t CO_2e yr^{-1})
$UDeduction_{alloch}$	Uncertainty in parameter $Deduction_{alloch}$ (Deduction from CO_2 emissions from the SOC pool to account for the percentage of the carbon stock that is derived from allochthonous soil organic carbon) (t CO_2e yr^{-1})
$UGHG_{WPS\text{-}soil\text{-}CH4,t}$	Uncertainty in parameter $GHG_{WPS\text{-}soil\text{-}CH4,t}$ (CH_4 emissions from the SOC pool in the project scenario in year *t*) (t CO_2e yr^{-1})
$UGHG_{WPS\text{-}soil\text{-}N2O,i,t}$	Uncertainty in parameter $GHG_{WPS\text{-}soil\text{-}N2O,t}$ (N_2O emissions from the SOC pool in the project scenario in year *t*) (t CO_2e yr^{-1})
t	1, 2, 3, …*t** time elapsed since the project start (years)

Uncertainty is then propagated across years to produce an estimate of cumulative uncertainty up to year *t** as follows:

$$Uncertainty_{TW-WPS,t*} = \frac{\sqrt{\sum_{t=1}^{t*} Uncertainty_{WPS-TW,t}{}^{2}}}{\sum_{t=1}^{t*} GHG_{WPS-TW,t}} \qquad (19)$$

Where:

$Uncertainty_{TW\text{-}WPS,t*}$	Cumulative uncertainty in the WRC project scenario for tidal wetland up to year *t* (%)

$Uncertainty_{TW\text{-}WPS,t}$ Uncertainty in the WRC project scenario for tidal wetland in year *t* (t CO_2e)

$GHG_{TW\text{-}WPS,t}$ Net GHG emissions in the WRC baseline scenario for tidal wetland in year *t* (t CO_2e)

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

5.5

5.4.3 Total Uncertainty in WRC Project Scenario Estimates

Uncertainties in project scenario estimates for peatland and tidal wetlands are combined as follows.:

$$Uncertainty_{WRC-WPS,t} = \sqrt{Uncertainty_{PEAT-WPS,t}^{\ 2} + Uncertainty_{TW-WPS,t}^{\ 2}} \quad (20)$$

Where:

$Uncertainty_{WRC\text{-}WPS,t*}$ Cumulative uncertainty in WRC project scenario up to year *t* (%)

$Uncertainty_{PEAT\text{-}WPS,t*}$ Cumulative uncertainty in the WRC project scenario for peatland up to year *t* (%)

$Uncertainty_{TW\text{-}WPS,t*}$ Cumulative uncertainty in the WRC project scenario for tidal wetland up to year *t* (%)

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

~~5.6~~5.5 Part 5: Total Error in the REDD+ Project Activity

Calculation of leakage is conservative in all instances and therefore uncertainty in leakage is not considered here. Total project uncertainty is therefore equal to the combined uncertainty in baseline and project estimates for the REDD and WRC activities:

$$NER_{REDD+ERROR} = \sqrt{(Uncertainty_{REDD_{BSL},t*} \times \Delta C_{BSL-REDD,t*})^2 + (Uncertainty_{REDD_{WPS}} \times \Delta C_{WPS-REDD,t*})^2 + (Uncertainty_{WRC_{BSL},t*} \times GHG_{BSL-WRC,t*})^2 + (Uncertainty_{WRC\_WPS,t*} \times GHG_{WPS-WRC,t*})^2} \times \left(\frac{1}{\Delta C_{BSL-REDD,t*} + \Delta C_{WPS-REDD,t*} + GHG_{BSL-WRC,t*} + GHG_{WPS-WRC,t*}}\right) \quad (21)$$

Where:

NER_{REDD+_ERROR}	Cumulative uncertainty for the REDD+ (REDD and WRC) project activities up to year *t** (%)
$Uncertainty_{REDD\_BSL,t*}$	Cumulative uncertainty in REDD baseline scenario up to year *t* (%)
$Uncertainty_{WRC\_BSL,t*}$	Cumulative uncertainty in the WRC baseline ~~case~~scenario up to year *t* (%)
$Uncertainty_{REDD\_WPS}$	Total uncertainty in the REDD project scenario (%)
$Uncertainty_{WRC\_WPS,t*}$	Cumulative uncertainty in the WRC project scenario up to year *t* (%)
$GHG_{BSL-WRC,t*}$	Net GHG emissions in the WRC baseline scenario up to year *t* (t CO_2e)
$GHG_{WPS-WRC,t*}$	Net GHG emissions in the WRC project scenario up to year *t* (t CO_2e)
$\Delta C_{BSL-REDD,t*}$	Net GHG emissions in the REDD baseline scenario up to year *t** (t CO_2e
$\Delta C_{WPS-REDD,t*}$	Net GHG emissions in the REDD project scenario up to year *t** (t CO_2e)
t	1, 2, 3, …*t** time elapsed since the project start (year)

Part 6 – Implications for Project Accounting

The allowable uncertainty in this methodology *REDD+-MF* is +/- 15% of NER_{REDD+} at the 95% confidence level. Where this precision level is met then no deduction should result for uncertainty. Where uncertainty exceeds 15% of NER_{REDD+} at the 95% confidence level then the deduction shall be equal to the amount that the uncertainty exceeds the allowable level.

The adjusted value for NER_{REDD+} to account for uncertainty shall be calculated as:

$$Adjusted\_NER_{REDD+} = NGR_{ARR} + (NER_{REDD} + NER_{WRC}) \times (100\% - NER_{REDD+ERROR} + 15\%) \quad (22)$$

Where:

$Adjusted\_NER_{REDD+}$	Total net GHG emission reductions of the REDD+ project activities up to year *t** adjusted to account for uncertainty (t CO_2e)
NER_{REDD}	Total net GHG emission reductions of the REDD project activity up to year *t** (t CO_2e)
NER_{WRC}	Total net GHG emission reductions of the WRC project activity up to year *t** (t CO_2e)
NER_{REDD+_ERROR}	Cumulative uncertainty for the REDD+ (REDD and WRC) project activities up to year *t** (%)
NGR_{ARR}	Total net GHG removals of the ARR project activity up to year *t** (t CO_2e)

6 DATA AND PARAMETERS

Data / Parameter	$A_{BSL,RRD,unplanned,t}$
Data unit	ha
Description	Projected area of unplanned baseline deforestation in the RRD in year *t*
Equations	1
Source of data	Module *BL-UP*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Module *BL-UP*
Purpose of Data	Calculation of uncertainty
Comments	N/A

Data / Parameter	$A_{BSL,i,j,unplanned,t}$
Data unit	ha
Description	Projected area of unplanned baseline deforestation in census unit *i* member of RRD subset *j* in year *t*
Equations	2, 3
Source of data	Module *BL-UP*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Module *BL-UP*
Purpose of Data	Calculation of uncertainty
Comments	N/A

Data / Parameter	$E_{REDD\_BSL\ SS,i,\ pool\#}$
Data unit	t CO_2e
Description	Carbon stock or GHG sources (eg, trees, dead wood, soil organic carbon, emission from fertilizer addition, emission from biomass burning etc.) in the REDD baseline ~~case~~scenario
Equations	4
Source of data	The terms denoting significant carbon stocks, GHG sources or leakage emissions from baseline modules (*BL-DFW*, *BL-PL*, *BL-UP*) used to calculate net emission reductions.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See relevant modules
Purpose of Data	Calculation of uncertainty
Comments	Baseline stocks and sources are estimated *ex ante* for each baseline period

Data / Parameter	$U_{REDD\_BSL,SS,i,pool\#}$
Data unit	%
Description	4

Equations	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the REDD baseline ~~case~~scenario (1, 2…*n* represent different carbon pools and/or GHG sources)
Source of data	Calculations arising from field measurement data
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Uncertainty in pools derived from field measurement with 95% confidence interval calculated as the standard error of the averaged plot measurements in each stratum multiplied by the t value for the 95% confidence level. For wood products the uncertainty should be the confidence interval around the volume of timber extracted from the forest. For emission sources conservative parameters should be used sufficient to allow the uncertainty to be set as zero.
Purpose of Data	Calculation of uncertainty
Comments	Baseline stocks and sources are estimated *ex ante* for each baseline period

Data / Parameter	$U_{*,i,t}$
Data unit	t CO_2e $ha^{-1}yr^{-1}$
Description	Uncertainty in parameter * in stratum *i* in year *t* * = parameters $E_{proxy\text{-}CO2,t}$, $E_{proxy\text{-}CH4,t}$, $E_{peatditch\text{-}CO2,t}$, $E_{peatditch\text{-}CH4,t}$ and $E_{peatburn\text{-}BSL,t}$.
Equations	7, 8, 12, 13
Source of data	
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Where regression models are used to estimate emissions from oxidation of peat from proxy parameters, uncertainty is calculated by referencing the 95% confidence limits of the regression model, calculated using standard regression analysis techniques. For the value of the referenced proxy in year *t*, the half-width of the 95% confidence interval for the dependent variable (emissions) is calculated to produce parameters U_{*t}. Where emissions are estimated applying a discrete default factor, uncertainty, $U_{*t,}$ is simply calculated by referencing the 95% confidence limit of the default factor estimate, or assigned as zero if an indisputably conservative factor is used.

Purpose of Data	Calculation of uncertainty
Comments	N/A

Data / Parameter	$E_{REDD,WPS,SS,i,\ Pool\#}$
Data unit	t CO_2e
Description	Carbon stock or GHG sources (eg, trees, down dead wood, soil organic carbon, emission from fertilizer addition, emission from biomass burning etc.) in the project casescenario
Equations	10
Source of data	The terms denoting significant carbon stocks, GHG sources or leakage emissions used in calculating net emission reductions from the following relevant modules: *CP-AB*, *CP-D*, *CP-L*, *CP-S*, *CP-W*, E-BB, *E-FFC*, *E-NA*.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See relevant modules
Purpose of Data	Calculation of uncertainty
Comments	The *ex-ante* estimation shall be derived directly from the estimations originating in the relevant modules: *CP-AB*, *CP-D*, *CP-L*, *CP-S*, *CP-W*, E-BB, *E-FFC*, *E-NA*.

Data / Parameter	$U_{REDD,WPS,SS,i,pool\#}$
Data unit	%
Description	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the project casescenario (1, 2…*n* represent different carbon pools and/or GHG sources)
Equations	10
Source of data	Calculations arising from field measurement data
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Uncertainty in pools derived from field measurement with 95% confidence interval calculated as the standard error of the averaged plot measurements in each stratum multiplied by the t value for the 95% confidence level. For wood products the uncertainty should be the confidence

	interval around the volume of timber extracted from the forest. For emission sources conservative parameters should be used sufficient to allow the uncertainty to be set as zero.
Purpose of Data	Calculation of uncertainty
Comments	*Ex ante*, the uncertainty in the project carbon stocks and sources shall be equal to the calculated baseline uncertainty

Data / Parameter	$D\%_{pn}$
Data unit	%
Description	Percent of deforestation in land parcel[3] pn, etc., of a proxy area as a result of planned deforestation as defined in this module
Equations	N/AUncertainty in baseline rate
Source of data	Module *BL-PL*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Module *BL-PL*
Purpose of Data	Calculation of uncertainty
Comments	N/A

Data / Parameter	Yrs_{pn}
Data unit	years
Description	Number of years over which deforestation occurred in land parcel pn in proxy area
Equations	N/AUncertainty in baseline rate
Source of data	Module *BL-PL*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Module *BL-PL*
Purpose of Data	Calculation of uncertainty

[3] Parcels are a unit of land area. A stratum may contain many parcels.

Comments	N/A

7 REFERENCES

None.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	3 Dec 2010	Initial version
V2.0	31 July 2012	This module was updated to revise the procedure for calculating uncertainty for the BL-UP (VMD0007) module. Also, uncertainty is now calculated cumulatively in parallel with the procedure for calculating the associated parameters.
v2.1	9 Mar 2015	This module was updated to account for WRC activities.