VCS Methodology

VM0036

Methodology for Rewetting Drained Temperate Peatlands

Version 1.0

17 July 2017

Sectoral Scope 14

The methodology was developed by:

Silvestrum Climate Associates

University of Greifswald

Partner in the Greifswald Mire Centre

Acknowledgements:

This methodology has been developed for (but is not limited to) use in the Belarus Peatland Rewetting Project ("BPR Project"). The development of this methodology was funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the University of Greifswald, Partner in the Greifswald Mire Centre, both Germany, and Silvestrum Climate Associates, The Netherlands. The methodology development was supported by BirdLife Belarus (APB), Centre for International Migration (CIM), Germany, and the Royal Society for the Protection of Birds (RSPB), United Kingdom.

Authors:

Dr. Igino Emmer, Silvestrum Climate Associates
John Couwenberg, Greifswald University, Partner in the Greifswald Mire Centre

Table of Contents

1 SOURCES

The methodology makes use of the following approved methodologies and methodological tools[1]:

- CDM methodology *AR-ACM0001 Afforestation or reforestation of degraded land*
- CDM methodological tool *Calculation of the number of sample plots for measurements within A/R CDM project activities*
- CDM methodological tool *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities*
- CDM methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities*

This methodology uses the latest versions of the following module[2]:

- VCS module *VMD0019 Methods to project future conditions*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This methodology outlines procedures to estimate the reduction of net greenhouse gas emissions resulting from project activities implemented to rewet drained peatlands in temperate climatic regions. It allows for the estimation of GHG emissions from drained and rewetted peatlands and also accounts for changes in carbon stocks in selected non-peat carbon pools.

The scope of this methodology is essentially limited to project activities that aim at the rewetting of peatlands that have been drained for forestry, peat extraction or agriculture, but where these activities are not or no longer profitable. Post-rewetting land use is limited to forestry, agriculture, nature conservation/recreation, or activities limited to those aiming at GHG emission reductions, or a combination of these activities.

This methodology uses ground vegetation composition and water table depth as proxies for peatland GHG emissions, known as the ‘GEST’ approach (GEST: Greenhouse gas Emission Site Type). Vegetation is well qualified for indicating greenhouse gas fluxes (Couwenberg *et al.* 2011) due to the following:

- It is a good indicator of water table depth, which in turn strongly correlates with GHG fluxes;

[1] CDM tools are available at https://cdm.unfccc.int/methodologies/ARmethodologies/tools
[2] VCS modules are available at the VCS website.

- It is controlled by various other site factors that determine GHG emissions from peatland, such as nutrient availability, soil reaction (acidity) and land use (history);
- It is itself directly and indirectly responsible for the predominant part of the GHG emissions by regulating CO_2 exchange, supplying organic matter (including root exudates) for CO_2 and CH_4 formation, reducing peat moisture, and by providing possible bypasses for increased methane emission via aerenchyma ('shunt species');
- It reflects long-time water table conditions and thus provides indication of average GHG fluxes on an annual time scale;
- It allows fine-scaled mapping (e.g., at scales 1:2,500 – 1:10,000).

Procedures are provided for the estimation of the Peat Depletion Time (PDT) and the assessment of the maximum eligible quantity of GHG emission reductions by rewetting, and is based either on the difference between the remaining peat carbon stock in the project and baseline scenarios after 100 years (total stock approach), or the difference in cumulative carbon loss in both scenarios since project start (stock loss approach).

Transient peaks of CH_4 emissions after rewetting may occur. For their quantification, conservative estimates from peer-reviewed literature sources must be used.

This methodology addresses anthropogenic peat fires occurring in drained peatland and establishes a conservative default value (*Fire Reduction Premium*), based on fire occurrence and extension in the project area in the baseline scenario, so as to avoid the direct assessment of GHG emissions from fire in the baseline and the project scenarios.

Under the applicability conditions of this methodology, market leakage, activity shifting and ecological leakage do not occur and the methodology provides criteria for justification of the absence of such leakage.

The methodology provides for the determination of the project's net GHG benefits and the resulting Verified Carbon Units (VCUs) that are generated. The methodology details the steps necessary to come to the final calculation of the project's net GHG benefits, represented by NER_{RDP}.

$$NER_{RDP} = GHG_{BSL} - GHG_{WPS} + Fire\ Reduction\ Premium - GHG_{LK}$$

Where:

NER_{RDP}	Total net CO_2 equivalent emission reductions from the rewetting of drained peatland (RDP) project activity
GHG_{BSL}	Net CO_2 equivalent emissions in the baseline scenario
GHG_{WPS}	Net CO_2 equivalent emissions in the project scenario
Fire Reduction Premium	Net CO_2 equivalent emission reductions from peat combustion due to

	rewetting and fire management
GHG_{LK}	Net CO_2 equivalent emissions due to leakage

3 DEFINITIONS

Greenhouse gas Emission Site Type (GEST)
A combination of plant species indicating long-term water table depths and other characteristics relevant to GHG fluxes (e.g., peat type, pH, nutrient status), associated with annual mean GHG fluxes of carbon dioxide and methane (expressed as CO_2e) based on literature or country-specific measurements. In absence of vegetation, water table depth is used as the main proxy (Couwenberg *et al.* 2011).

Net Ecosystem Exchange (NEE)
An instantaneous measurement of the inward and outward flows of carbon within an ecosystem. NEE is measured by eddy-flux towers to determine the amount of CO_2 entering an ecosystem and the amount of carbon being lost through respiration simultaneously.

Net Ecosystem Production (NEP)
A measurement of the net gain (or loss) of carbon in a system over a period of time. NEP is estimated based on long-term averages of NEE measurements.

Peatland
The definition is provided in the *VCS Program Definitions*. For the purpose of this methodology, organic soils that do not meet the depth requirement in the used definition but that are connected to the peatland area may be deemed part of the peatland area included in the GHG accounting. Isolated areas of organic soil that do not meet the depth requirements are not considered peatland.

Water table depth[3]
Depth of sub-soil or above-soil surface of water, relative to the soil surface.

4 APPLICABILITY CONDITIONS

This methodology is applicable under the following conditions:

1) The project activity is the rewetting of drained peatland.
2) The project area:
    a) Meets the definition of a peatland;
    b) Is located in a temperate[4] climatic region.
3) The project area was drained for the following land use scenarios or a combination of the

[3] In other methodologies, this term may be referred to as ‘drainage depth’, where it is implied to have the same meaning.
[4] The GEST approach has, so far, only been developed for temperate climates.

following land use scenarios:

a) Forestry that is not or no longer profitable (as determined on the basis of annual reports, annual accounts, market studies, government studies, or land use planning reports and documents);

b) Peat extraction that has been abandoned at least 2 years prior to the project start date; and/or,

c) Agriculture that has been abandoned at least 2 years prior to the project start date or will be continued in the project, or where drainage of additional peatland for new agricultural sites will not occur or is prohibited by law.

4) Post-rewetting land use is limited to the following or a combination of the following:

   a) Forestry (including biomass production but excluding IFM and REDD activities);

   b) Agriculture (excluding ALM activities); and/or,

   c) Nature conservation/recreation.

5) The following activities may occur in the baseline scenario:

   a) Biomass burning.

6) The following activities must not occur in the baseline scenario:

   a) Harvesting for commercial purposes; or,

   b) Collection of firewood for commercial purposes.

7) The following activities may not occur in the project scenario:

   a) Peat extraction;

   b) Burning of peat;

   c) Burning of biomass; and,

   d) N-fertilizer usage.

8) Project design and site selection must include the following:

   a) Project GHG benefits are not negatively affected by drainage activities that occur outside the project area[5].

   b) Leakage caused by activity shifting, market effects and hydrological connectivity is avoided[6].

9) Live tree vegetation may be present and subject to carbon stock changes (e.g., due to harvesting) in both the baseline and project scenarios.

10) Where GHG emission reductions from reducing peat fires are claimed by the project, the following must be met:

[5] This is further specified in Section 5.2
[6] This is further specified in Section 8.4.

a) A threat of frequent on-site fires must be been demonstrated[7].

b) Where the default procedure provided by this methodology for assessing GHG emissions due to peat fires in the baseline scenario cannot be used, such baseline emissions must conservatively not accounted for; and,

c) Peatland rewetting must be combined with fire management.

11) It must be demonstrated by referring to peer-reviewed literature and by sufficient rewetting that N_2O emissions will not increase in the project scenario compared to the baseline scenario.

12) In the baseline scenario, the peatland must be drained.

5 PROJECT BOUNDARY

5.1 Temporal Boundaries

Project Crediting Period

The temporal boundary for projects applying this methodology is equal to the project crediting period. The project must have a robust operating plan covering this period.

Where emissions increase during a transient period after rewetting, this is regarded as a negative emission reduction and falls within the project crediting period.

Project proponents must determine the project crediting period, the project crediting period start date and the project start date and provide verifiable evidence to support these claims.

Peat Depletion Time (PDT)

Peat depletion may be accelerated by peat fires and is attained if the peat has disappeared or if a stable water table inhibits further oxidation of the peat. The PDT for a stratum in the baseline scenario equals the period during which the project can claim emission reductions from rewetting and is, per stratum *i*, at the project start date and at each reassessment of the baseline scenario (as outlined in Section 6.2) estimated as:

$$t_{PDT\text{-}BSL,i} = Depth_{peat\text{-}BSL,i} / Rate_{peatloss\text{-}BSL,i} \quad \textbf{(1)}$$

Where:

$t_{PDT\text{-}BSL,i}$	PDT in the baseline scenario in stratum *i* in years elapsed since the project start; yr
$Depth_{peat\text{-}BSL,i}$	Average peat depth above the drainage limit in the baseline scenario in stratum *i* at project start; m

[7] RWE projects may generate GHG credits from the reduction of GHG emissions associated with avoiding peat fires on drained or partially drained peatlands.

$Rate_{peatloss\text{-}BSL,i}$ Rate of peat loss due to subsidence and fire in the baseline scenario in stratum *i*; a conservative (high) value must be applied; m yr^{-1}

i 1, 2, 3, … M_{BSL} strata in the baseline scenario

Peat depths, depths of burn scars and subsidence rates must be derived from data sources as described in Section 9.1.

5.2 Geographic Boundaries

Project proponents must define the project boundary at the beginning of a proposed project activity and must provide the geographical coordinates of lands to be included, so as to allow clear identification for the purpose of verification. Remotely sensed data, officially certified topographic maps, land administration and tenure records, and/or other official documentation that facilitates the clear delineation of the project boundary may be used.

The RDP project activity may contain more than one discrete area of land. Each discrete area of land must have a unique geographical identification.

When describing physical project boundaries, the following information must be provided per discrete area:

- Name of the project area (including compartment numbers, local name (if any))
- Unique identifier for each discrete parcel of land
- Map(s) of the area (preferably in digital format)
- The data must be geo-referenced, and provided in digital format in accordance with the VCS rules.
- Total area
- Details of land rights holder and user rights

Stratification

If the project area at the start of the project is not homogeneous, stratification may be carried out to improve the accuracy and the precision of peat depth, carbon stock and GHG flux estimates. Different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy of the estimates of net GHG emissions or removals.

Strata are defined on the basis of peat depth (including eligibility as assessed below), water table depth (e.g., at 0 cm defining a level of zero emission, a deep water table depth defining the high end of emissions, and arbitrary levels in between), tree cover and/or vegetation composition, or expected changes in these.

In case of the presence of a tree cover, the GEST approach (Section 8.1.3) must be supplemented by procedures to estimate tree carbon stock change and therefore separate strata must be established for forested land. Furthermore, different GESTs give rise to different strata.

Stratification on the basis of peat depth must be based on a peat depth map for the entire project area. Existing peat depth maps can be used in combination with interpolation techniques to derive conservative peat depth maps of the required accuracy (see below). Stratification of the project area by peat depth is required:

a) When in more than 5% of the project area peat is absent or the depth of the peat is below a threshold value (e.g., 10 cm); the peat depth map only needs to distinguish where peat depth exceeds this threshold. It is conservative to omit shallow peat strata in accounting.

b) When, using a conservative (high) value for subsidence rates, in the project scenario in more than 5% of the project area the peat is depleted within 100 years ($\leq t$=100); the peat depth map only needs to distinguish where peat will be depleted at t=100.

c) When, using a conservative (high) value for subsidence rates, in the baseline scenario in more than 5% of the project area the project crediting period exceeds the PDT ; the peat depth map must distinguish with a depth resolution of 10 cm strata where peat will be depleted within the project crediting period. Areas where peat will not be depleted need not be further stratified.

No stratification on the basis of peat depth is required if the peat depth in 95% or more of the project area exceeds the required minimum peat depth for any of the above conditions.

Areas with a peat layer at project start shallower than required by the adopted definition of peatland may be included if such areas are connected with areas that meet the definition. Isolated pockets that do not meet the definition must not be included.

When using existing peat depth maps or data, these must be corrected, in a conservative way, for peat excavation and subsidence. When, after correction, strata exceed the required minimum peat depth by less than 50 cm, these strata must be verified using field observations (e.g., using a peat auger following the procedures to create a peat depth map outlined below).

To create a peat depth map, depth measurements must be conducted along transects that cover the peatland in a systematic way. Distance between transects must be 200 m at maximum. Starting from the peatland margin, the initial distance between depth observations along transects must not be greater than 100 m with a depth accuracy of at least 10 cm. When two subsequent depth observations along a transect fulfill the required depth criteria by a margin of at least 50 cm, the distance between transects and observation points can be raised to 500 m. Transects must cross the entire peatland and must be initiated from opposed margins. If transects cross mineral soil areas present inside a contiguous peat area, transects departing from these mineral soil areas must also have an initial distance between depth observations of not greater than 100 m. Peat depth maps must be based on peat depth measurements in combination with interpolation techniques to derive conservative peat depth maps of the required accuracy.

In case shallow peat areas are conservatively neglected, it is sufficient to conduct depth measurements that cover the peatland in a systematic way, with at least 4 measurement points per km^2 or at a distance of 500 m.

Strata must be spatially discrete and stratum areas must be known. Areas of individual strata must sum to the total project area. Strata must be identified with spatial data (e.g., maps, GIS coverage, classified imagery, or sampling grids) from which the area can be determined accurately. Land use/land cover maps in particular must be ground-truthed and less than 10 years old. Strata must be discernible taking into account good practice in terms of the accuracy requirements for the definition of strata limits / boundaries. This must be indicated in the project documentation and the choice must be justified.

The project area may be stratified *ex ante*, and this stratification may be revised *ex post* for monitoring purposes. Established strata may be merged if reasons for their establishment have disappeared or have proven irrelevant to key variables for estimating net GHG emissions or removals.

Baseline stratification must remain fixed until a reassessment of the baseline scenario occurs.

Stratification in the project scenario will be updated at each monitoring event prior to verification.

The area of channels and ditches must be quantified and treated as separate strata. CH_4 emissions from these channels and ditches will not increase in the project scenario compared to the baseline scenario (Couwenberg *et al.* 2011) and therefore, CH_4 emissions from these channels and ditches can be excluded from GHG accounting.

Peatland areas eligible for carbon crediting

The maximum eligible quantity of GHG emission reductions by rewetting is limited to the difference between the remaining peat carbon stock in the project and baseline scenarios after 100 years (total stock approach), or the difference in cumulative carbon loss in both scenarios over a period of 100 years since project start (stock loss approach). If a significant difference (≥ 5%) at the 100-years mark cannot be demonstrated, the project area is not eligible for carbon crediting. This assessment must be executed *ex ante* using conservative parameters.

The procedure assumes a variable rate of peat loss in the baseline and project scenarios, or, alternatively, a conservative – as explained in footnote 7 – value that remains constant over time, based on expert judgment[8], datasets and/or literature (see Section 9.1).

[8] Requirements for expert judgment are provided in Section 9.3.2.

1. Total stock approach

The difference between peat carbon stock in the project scenario and baseline scenario at t=100 is estimated as:

$$C_{WPS-BSL,t100} = \sum_{i=1}^{M_{WPS}} \left(C_{WPS,i,t100} \times A_{WPS,i,t100}\right) - \sum_{i=1}^{M_{BSL}} \left(C_{BSL,i,t100} \times A_{BSL,i,t100}\right) \quad \textbf{(2)}$$

$$C_{WPS,i,t100} = Depth_{peat\text{-}WPS,i,\,t100} \times VC_{peat} \times 10 \quad \textbf{(3)}$$

$$C_{BSL,i,t100} = Depth_{peat\text{-}BSL,i,\,t100} \times VC_{peat} \times 10 \quad \textbf{(4)}$$

$$Depth_{peat-BSL,i,t100} = Depth_{peat-BSL,i,t0} - \sum_{t=1}^{t=100} Rate_{peatloss-BSL,i,t} \quad \textbf{(5)}$$

$$Depth_{peat-WPS,i,t100} = Depth_{peat-WPS,i,t0} - \sum_{t=1}^{t=100} Rate_{peatloss-WPS,i,t} \quad \textbf{(6)}$$

If a conservative constant subsidence rate is applied, a possible negative outcome is substituted by zero.

Where:

$C_{WPS\text{-}BSL,t100}$	Difference between peat carbon stock in the project scenario and baseline scenario at t=100 ; t C
$C_{WPS,i,t100}$	Peat carbon stock in the project scenario in peat depth stratum i at t=100;t C ha^{-1}
$C_{BSL,i,t100}$	Peat carbon stock in the baseline scenario in peat depth stratum i at t=100; t C ha^{-1}
$Depth_{peat\text{-}BSL,i,t100}$	Average peat depth above the drainage limit in the baseline scenario in stratum i at t=100; m
$Depth_{peat\text{-}WPS,i,t100}$	Average peat depth above the drainage limit in the project scenario in stratum i at t=100; m
$Depth_{peat\text{-}BSL,i,t0}$	Average peat depth above the drainage limit in the baseline scenario in stratum i at project start; m
$Depth_{peat\text{-}WPS,i,t0}$	Average peat depth above the drainage limit in the project scenario in stratum i at project start; m
$Rate_{peatloss\text{-}BSL,i,t}$	Rate of peat loss due to subsidence and fire in the baseline scenario in stratum i at time t; alternatively, a conservative (low[9]) value may be applied that remains constant over time; m yr^{-1}

[9] Note that the use of a relatively low value for a constant rate of peat loss may not be confused with a relatively high value when determining the need for stratification of peat depth (p7).

$Rate_{peatloss,WPS,i,t}$	Rate of peat loss due to subsidence in the project scenario in stratum *i* at time *t*; alternatively, a conservative (high) value may be applied that remains constant over time; m yr^{-1}
VC_{peat}	Volumetric carbon content of peat; kg C m^{-3}
$A_{WPS,i,t100}$	Area of project stratum *i* at *t*=100; ha
$A_{BSL,i,t100}$	Area of baseline stratum *i* at *t*=100; ha
i	1, 2, 3, … M_{BSL} or M_{WPS} peat depth strata in the baseline scenario or project scenario
t_{100}	100 years since project start

The volumetric carbon content in peat can be taken from measurements within the project area or from literature involving the project or similar areas.

$C_{WPS,i,t100}$ needs no adjustments since under the applicability conditions leakage emissions are absent.

The difference between peat carbon stock in the project scenario and baseline scenario at *t*=100 ($C_{WPS-BSL,t100}$) is significant if:

$$\sum_{i=1}^{M_{WPS}} \left(C_{WPS,i,t100} \times A_{WPS,i,t100} \right) \geq 1.05 \times \sum_{i=1}^{M_{BSL}} \left(C_{BSL,i,t100} \times A_{BSL,i,t100} \right) \quad (7)$$

2. Stock loss approach

As $Depth_{peat-BSL,i,t0} = Depth_{peat-WPS,i,t0}$ the assessment can also be based on cumulative subsidence up to *t*=100 as follows:

$$C_{WPS-BSL,t100} = \sum_{i=1}^{M_{BSL}} \left(C_{peatloss-BSL,i,t100} \times A_{BSL,i,t100} \right) - \sum_{i=1}^{M_{WPS}} \left(C_{peatloss-WPS,i,t100} \times A_{WPS,i,t100} \right) \quad (8)$$

$$C_{peatloss-BSL,i,t100} = 10 \times \sum_{t=1}^{100} \left(Rate_{peatloss-BSL,i,t} \times VC_{peat} \right) \quad (9)$$

$$C_{peatloss-WPS,i,t100} = 10 \times \sum_{t=1}^{100} \left(Rate_{peatloss-WPS,i,t} \times VC_{peat} \right) \quad (10)$$

Where:

$C_{WPS-BSL,t100}$	Difference between peat carbon stock in the project scenario and baseline scenario at *t*=100; t C
$C_{peatloss-BSL,i,t100}$	Cumulative peat carbon loss due to subsidence and fire in the baseline scenario in subsidence stratum *i* at *t*=100; t C ha^{-1}

$C_{peatloss\text{-}WPS,i,t100}$	Cumulative peat carbon loss due to subsidence in the project scenario in subsidence stratum *i* at *t*=100; t C ha^{-1}
$Rate_{peatloss\text{-}BSL,i,t}$	Rate of peat loss due to subsidence and fire in the baseline scenario in stratum *i* in year *t*; alternatively, a conservative (low) value may be applied that remains constant over time; m yr^{-1}
$Rate_{peatloss\text{-}WPS,i,t}$	Rate of peat loss due to subsidence in the project scenario in stratum *i* in year *t*; alternatively, a conservative (high) value may be applied that remains constant over time; m yr^{-1}
VC_{peat}	Volumetric carbon content of peat; kg C m^{-3}
$A_{WPS,i,t100}$	Area of project stratum *i* at *t*=100; ha
$A_{BSL,i,t100}$	Area of baseline stratum *i* at *t*=100; ha
i	1, 2, 3, … M_{BSL} or M_{WPS} subsidence strata in the baseline scenario or project scenario
t_{100}	100 years after project start

Using short-term or historic subsidence rates for the entire period of 100 years is conservative since subsidence rates are likely to decline over time (Stephens *et al.*, 1984).

The difference between peat carbon stock in the project scenario and baseline scenario at *t*=100 ($C_{WPS\text{-}BSL,t100}$) is significant if:

$$\sum_{i=1}^{M_{BSL}} \left(C_{peatloss-BSL,i,t100} \times A_{BSL,i,t100} \right) \geq 1.05 \times \sum_{i=1}^{M_{WPS}} \left(C_{peatloss-WPS,i,t100} \times A_{WPS,i,t100} \right) \quad \textbf{(11)}$$

Buffer zones

Under the applicability conditions of this methodology, the project boundary must be designed such that the project GHG benefits are not affected by drainage activities that occur outside the project area (e.g., enhanced drainage, groundwater extraction, and changing water supply). This can be achieved either by an appropriate design (e.g., by establishing an impermeable dam) or by a buffer zone within the project boundary for which conservatively no GHG benefits are accounted. This buffer zone, if employed, must be mapped and is not eligible for carbon crediting. The size and shape of the buffer zone must be determined on the basis of quantitative hydrological modeling, or expert judgment.

Procedures for buffer zones against ecological leakage are provided in Section 8.4.

5.3 Carbon Pools

The carbon pools that are included and excluded from the project boundary are shown in Table 5.1.

In addition, carbon pools may be deemed *de minimis* and do not have to be accounted for if together the omitted decrease in carbon stocks or increase in GHG emissions (Table 5.2) amounts to less than 5% of the total GHG benefit generated by the project. Peer reviewed literature or the CDM A/R methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities* may be used to determine whether decreases in carbon pools are *de minimis*.

Table 5.1: Carbon Pools Included In or Excluded From the Project Boundary

Carbon pools	Included?	Justification/Explanation of choice
Above-ground tree biomass	Yes	Major carbon pool may significantly increase in the baseline, or decrease in the project, or both, in case of establishment or presence of tree vegetation. Tree vegetation in the baseline scenario must be included. Tree vegetation in the project scenario may be conservatively set to zero.
Above-ground non-tree biomass	Optional	This pool is only included if GESTs are based on vegetation cover. In such cases, changes in lower vegetation are included in the estimates of NEE (or NEP) represented by GESTs.
Below-ground biomass	Yes	Major carbon pool may significantly increase in the baseline, or decrease in the project, or both, in case of presence of tree vegetation Tree vegetation in the baseline scenario: must be included. Tree vegetation in the project scenario: may be conservatively set to zero. Lower (herb) vegetation: included in the NEE (or NEP).
Tree litter	Optional	The litter layer must only be included if it forms part of a GEST.
Wood products	Optional	This pool is optional.
Dead wood	Optional	This pool is optional.
Soil organic carbon	Yes	Major carbon pool subject to the project activity. The soil organic carbon component is represented by the peat component.

5.4 Greenhouse Gases

The emission sources included in or excluded from the project boundary are shown in Table 5.2.

In addition, GHG sources may be deemed *de minimis* and do not have to be accounted for if together the omitted decrease in carbon stocks (Table 5.1) or increase in GHG emissions amounts to less than 5% of the total GHG benefit generated by the project. Peer reviewed literature or the CDM A/R methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities* may be used to determine whether increases in GHG emissions are *de minimis*.

Table 5.2: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Changes in stocks in carbon pools in biomass	CO_2	Yes	Potential major source of removals considered under carbon pools
	Oxidation of drained peat	CO_2	Optional	May be conservatively excluded in the baseline scenario
		CH_4	Optional	Potentially significant emission; may be conservatively excluded in the baseline scenario
		N_2O	No	Excluded as per applicability condition
	Burning of biomass	CO_2	No	Not accounting in baseline scenario is conservative
		CH_4	No	Not accounting in baseline scenario is conservative
		N_2O	No	Not accounting in baseline scenario is conservative
	Peat burning	CO_2	Yes	Fire may occur in the baseline scenario and is accounted for with a default approach
		CH_4	No	Conservatively excluded in the baseline scenario
		N_2O	No	Conservatively excluded in the baseline scenario
Project	The production of methane by bacteria	CH_4	Yes	Potential major source of emissions in the project in low salinity and freshwater areas

Source		Gas	Included?	Justification/Explanation
	Accumulation of peat in project scenario	CO_2	No	Conservatively excluded in the project scenario
	Burning of biomass	CO_2	No	CO_2 is addressed in carbon stock change procedures
		CH_4	No	Accounting in project scenario is excluded as per applicability condition
		N_2O	No	Accounting in project scenario is excluded as per applicability condition
	Fossil fuel combustion from transport and machinery use in project activities	CO_2	No	Deemed *de minimis*
		CH_4	No	Deemed *de minimis*
		N_2O	No	Deemed *de minimis*
	Peat burning	CO_2	Yes	Fire may occur in the project scenario and is accounted for with a *Fire Reduction Premium* approach
		CH_4	No	Not included in the *Fire Reduction Premium* approach
		N_2O	No	Not included in the *Fire Reduction Premium* approach

6 BASELINE SCENARIO

6.1 Determination of the Most Plausible Baseline Scenario

At the project start date, the baseline scenario must consist of drained peatland with a land use that can be forestry, peat extraction or agriculture, abandonment after such activities, or a combination of these, but where these activities are not or no longer profitable. Continuations of these land uses and possible subsequent changes in various alternative baseline scenarios are determined using the latest version of the CDM tool *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities*.

The tool has been designed for A/R CDM project activities, but must be used for the purpose of this methodology, noting the following:

Where the tool refers to	It must be understood as referring to
A/R, afforestation, reforestation, or forestation	WRC, or rewetting
Net greenhouse gas removals by sinks	Net greenhouse gas emission reductions
CDM	VCS
DOE	VVB
tCERs, lCERs	VCUs

Step 0 and Sub-step 2b – 15 (regarding forested areas since 31 December 1989) must be omitted. Footnote No 1-3 must be omitted[10].

In instances where there is a conflict between the CDM tool requirements and the VCS rules, the VCS rules must be followed.

6.2 Re-assessment of the Baseline Scenario

The project proponent must reassess the baseline scenario in accordance with the VCS rules.

For this assessment, the historic reference period is extended to include the original reference period and all subsequent monitoring periods up to the beginning of the current monitoring period. The fire reference period must not be extended, as this is a fixed 10-year period ending 5 years before the project start date.

The project proponent must, for the duration of the project, re-determine the PDT every 10 years. This reassessment must use the procedure provided in Section 5.1. Data sources for peat depths, depths of burn scars and subsidence rates must be updated if new information relevant to the project area has become available.

7 ADDITIONALITY

This methodology uses a project method for the demonstration of additionality.

Additionality must be determined using the latest version of the CDM tool *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities*, with additional guidance as provided in Section 6.1.

[10] Sub-step and footnotes as in version 01 of the tool, the prevailing version of the tool as of the writing of this methodology.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

8.1.1 General approach

The net CO_2 equivalent emissions in the baseline scenario may be determined by carbon stock changes in non-peat carbon pools, GHG emissions as a result of peat oxidation due to drainage, or a combination of these. In addition, emissions as a result of peat combustion due to peatland fires can be determined.

GHG emissions of non-forested areas are determined using GESTs (Section 8.1.3). For forested areas, emissions are determined using GESTs (covering peat, herb vegetation and litter) in combination with carbon stock changes of the above- and below-ground tree biomass (Section 8.1.2).

For areas for which the vegetation composition does not provide a clear indication of GHG emissions (bare peat, transient phases of vegetation development after rewetting) water table depth measurements must be used as additional input to assess GHG fluxes. However, project proponents may also opt to choose water table depth as a proxy for the entire project area.

Peat combustion due to anthropogenic peatland fires is addressed using a conservative default value (*Fire Reduction Premium*) that is expressed as a proportion of the CO_2 emissions avoided through rewetting (Section 8.3).

It must be demonstrated (e.g., by referring to peer-reviewed literature) that under the project scenario, N_2O emissions are insignificant or decrease in the project scenario compared to the baseline, and therefore N_2O emissions need not be accounted for. Project circumstances are defined by pre-project land use (e.g., forestry, peat mining, agriculture, abandonment after such activities) and its intensity (especially related to N-fertilization), climatic zone, water table depths, and peat type.

The net CO_2 equivalent emissions in the baseline are estimated as:

$$GHG_{BSL} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} \left(-\frac{44}{12} \times \Delta C_{BSL-NP,i,t} + GHG_{drained,i,t} \right) \quad (12)$$

Where:

GHG_{BSL}	Net CO_2 equivalent emissions in the baseline scenario up to year t^*; t CO_2e
$\Delta C_{BSL-NP,i,t}$	Net carbon stock changes in non-peat carbon pools in the baseline scenario in stratum i in year t; t C yr^{-1}
$GHG_{drained,i,t}$	Greenhouse gas emissions from soil, lower ground vegetation and litter in the baseline scenario in stratum i in year t; t CO_2e yr^{-1}

i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

The project proponent must, for the duration of the project, re-quantify the baseline every 10 years. Based on the reassessment as defined in Section 6, the new baseline scenario must be incorporated into revised estimates of baseline emissions. This baseline reassessment must include the evaluation of the validity of proxies for GHG emissions from peatlands (i.e., GESTs on the basis of vegetation composition and/or water table depth).

8.1.2 Net carbon stock change in non-peat carbon pools ($\Delta C_{BSL-NP,i,t}$)

8.1.2.1 General

The non-peat carbon pools (see Table 5.1) to be accounted for in the baseline scenario include aboveground tree biomass and belowground tree biomass. Net fluxes to and from lower ground vegetation and litter are accounted for by GESTs.

GHG emissions may arise from the burning of biomass. Biomass burning in the baseline scenario may occur but not accounting for it is conservative. This methodology does not provide procedures for estimating GHG emissions from the burning of biomass.

Net carbon stock changes in non-peat carbon pools in the baseline scenario will be determined as:

$$\Delta C_{BSL-NP,i,t} = \Delta C_{BSL-biomass,i,t} \quad \textbf{(13)}$$

Where:

$\Delta C_{BSL-NP,i,t}$	Net carbon stock change in non-peat carbon pools in the baseline scenario in stratum i in year t; t C yr^{-1}
$\Delta C_{BSL-biomass,i,t}$	Net carbon stock change in tree biomass in the baseline scenario in stratum i in year t; t C yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

Assessing GHG removals in the baseline scenario consists of 3 steps:

1) Assess the pre-project spatial distribution of tree biomass
2) For the given baseline scenario, derive a time series of tree biomass development for each stratum; as per Section 6.2, *ex-ante* baseline projections beyond a 10-year period are not required
3) Determine annual GHG removals per stratum; as per Section 6.2, *ex-ante* baseline projections beyond a 10-year period are not required

To project future tree biomass within the project crediting period under the baseline scenario, use the latest version of the VCS module *VMD0019 Methods to Project Future Conditions*.

8.1.2.2 Net carbon stock change in biomass ($\Delta C_{BSLbiomass,i,t}$)

The net carbon stock change in biomass in the baseline scenario is estimated as:

$$\Delta C_{BSL\text{-}biomass,i,t} = A_{BSL,i,t} \times \Delta C_{BSL\text{-}tree,i,t} \quad \textbf{(14)}$$

$$\Delta C_{BSL-tree,i,t} = \sum_{j=1}^{S_{BSL}} (\Delta C_{BSL-tree,j,i,t}) \quad \textbf{(15)}$$

$$\Delta C_{BSL-tree,j,i,t} = \Delta C_{BSL-tree-AB,j,i,t} + \Delta C_{BSL-tree-BB,j,i,t} \quad \textbf{(16)}$$

$$\Delta C_{BSL-tree-BB,j,i,t} = \Delta C_{BSL-tree-AB,j,i,t} \times R_j \quad \textbf{(17)}$$

Where:

$\Delta C_{BSL\text{-}biomass,i,t}$	Change in carbon stock in biomass in the baseline scenario in stratum *i* in year *t*; t C yr^{-1}
$A_{BSL,i,t}$	Area of baseline stratum *i* in year *t*; ha
$\Delta C_{BSL\text{-}tree,i,t}$	Change in carbon stock in tree[11] biomass in the baseline scenario in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{BSL\text{-}tree,j,i,t}$	Change in carbon stock in tree biomass in the baseline scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Change in carbon stock in above-ground tree biomass in the baseline scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{BSL\text{-}tree\text{-}BB,j,i,t}$	Change in carbon stock in below-ground tree biomass in the baseline scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
R_j	Root:shoot ratio for tree species *j*[12]; t root t^{-1} shoot d.m.
j	1, 2, 3, … S_{BSL} tree species in the baseline scenario
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

Above-ground tree biomass

The change in carbon stock in above-ground tree biomass is estimated using one of the following methods that can be selected on the basis of the availability of data.

[11] With DBH ≥ 5 cm.
[12] Care should be taken that the root-shoot ratio may change as a function of the above-ground biomass present at time *t* (see IPCC GPG 2003, Annex 3.A1, Table 3A1.8)

Method 1 (Gain-loss method)

$$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t} = \Delta C_{G,j,i,t} - \Delta C_{L,j,i,t} \quad \textbf{(18)}$$

$$\Delta C_{G,j,i,t} = G_{j,i,t} \times CF_j \quad \textbf{(19)}$$

$$G_{j,i,t} = I_{v,j,i,t} \times D_j \times BEF_{1,j} \quad \textbf{(20)}$$

Where:

$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Change in carbon stock in above-ground tree biomass in the baseline scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{G,j,i,t}$	Average annual increase in carbon stock due to above-ground biomass growth of living trees for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{L,j,i,t}$	Average annual decrease in carbon stock due to above-ground biomass loss of living trees for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$G_{j,i,t}$	Average annual increment of above-ground biomass of living trees for species *j* in stratum *i* in year *t*; t dm. $ha^{-1}yr^{-1}$
CF_j	Carbon fraction[13] of dry matter for species *j*; t C t $d.m.^{-1}$
$I_{v,j,i,t}$	Average annual increment in merchantable volume for species *j* in stratum *i* in year *t*; $m^{-3}ha^{-1}yr^{-1}$
D_j	Basic wood density for species *j*; t d.m. m^{-3}
$BEF_{1,j}$	Biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j*
j	1, 2, 3, … *S* tree species
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

This methodology allows for the conservative assumption that, for any time *t,* $\Delta C_{L,j,i,t} = 0$ for the baseline scenario.

If biomass increment tables are available and applicable to the species present, these can directly be used in Equation 20. Note that available data on average annual increment in the volume of species *j* in stratum *i* for year *t* ($I_{v,j,i,t}$) may be expressed as a <u>net</u> average annual increment (i.e., the term $\Delta C_{L,j,i,t}$ is already implicitly allowed for and must be set to zero in Equation 18 in order to avoid double counting).

Alternatively, if the average annual increment in volume of species *j* in stratum *i*, for year *t* ($I_{v,j,i,t}$) is expressed as the gross average annual increment, then $\Delta C_{L,j,i,t}$ may be conservatively assumed

[13] IPCC default value = 0.5

as zero. Otherwise $\Delta C_{L,j,i,t}$ must be estimated on the basis of transparent and verifiable information on the rate at which pre-project activities (or mortality) are reducing carbon stocks in existing live trees (e.g., due to harvesting for fuelwood, or for animal consumption).

Depending on the kind of information locally available, instead of R_j and BEF_j one can use other parameters converting stem volume to total biomass, for example K_{ph} (Alexeyev coefficient; Alexeyev *et al*. (1995)).

<u>Method 2 (Stock difference method)</u>

$$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t} = (C_{BSL\text{-}tree\text{-}AB,j,i,t} - C_{BSL\text{-}tree\text{-}AB,j,i,(t\text{-}T)}) / T \qquad \textbf{(21)}$$

Two methods are provided for this method: the biomass expansion factors (*BEF*) method and the allometric equations method.

<u>1. *BEF* method</u>

$$C_{BSL\text{-}tree\text{-}AB,j,i,t} = V_{j,i,t} \times D_j \times BEF_{2j} \times CF_j \qquad \textbf{(22)}$$

Where:

$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Change in carbon stock in above-ground tree biomass in the baseline for species *j* in stratum *i* in year *t*; t C ha^{-1}yr^{-1}
$C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Carbon stock in above-ground biomass of tree species *j* in stratum *i* in year *t*; t C ha^{-1}
$V_{j,i,t}$	Stem volume of tree species *j* in stratum *i* in year *t*; m^3 ha^{-1}
D_j	Basic wood density of species *j*; t d.m. m^{-3}
BEF_{2j}	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*
CF_j	Carbon fraction[14] of dry matter for species *j*; t C t d.m.$^{-1}$
i	1, 2, 3, … M_{WPS} strata in the project scenario
j	1, 2, 3 ,… S_{WPS} tree species in the project scenario
t	1, 2, 3 … t^* years elapsed since the start of the project activity
T	Number of years between times *t* and t_{-1}

[14] IPCC default = 0.5

2. Allometric Equations method

$$C_{BSL\text{-}tree\text{-}AB,j,i,t} = nTR_{j,i,t} \times f_j(X,Y,\ldots) \times CF_j \quad \textbf{(23)}$$

Where:

$C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Carbon stock in above-ground biomass of species *j* in stratum *i* in year *t*; t C ha^{-1}
$nTR_{j,i,t}$	Tree stand density of species *j* in stratum *i* in year *t*; trees ha^{-1}
$f_j(X, Y, \ldots)$	Allometric equation for species *j* linking measured tree dimension variables (e.g., diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees; t d.m. $tree^{-1}$
CF_j	Carbon fraction of dry matter for species *j*; t C t^{-1} d.m.
i	1, 2, 3, … M_P strata in the project scenario
j	1, 2, 3, … S_{WPS} tree species in the project scenario
t	1, 2, 3, … *t** years elapsed since the start of the project activity

It is acceptable to estimate initial stocks (*t*=0) using pre-existing forest inventory data, provided that the pre-existing data (1) represents the project strata, (2) is not more than 10 years old and represents the age and site class, and (3) that the stock estimate derived from the pre-existing data has been validated with limited sampling within the project area. If the estimate is within the 90% confidence interval of the corresponding estimate calculated from pre-existing forest inventory data, the initial stock at *t*=0 is set at the higher bound of the 90% confidence interval of the estimate from pre-existing data. If the validation estimate is outside (i.e., greater than or less than) the corresponding estimate calculated from pre-existing forest inventory data, the estimate from pre-existing data cannot be used.

8.1.3 Greenhouse gas emissions due to peat drainage ($GHG_{drained,i,t}$)

8.1.3.1 The GEST approach

In this methodology, the GEST (Greenhouse Gas Emission Site Type) approach forms the basis for the estimation of GHG fluxes from drained and rewetted peatlands (Couwenberg *et al.* 2011). The GEST approach uses primarily vegetation types as the indicator of annual greenhouse gas fluxes. Vegetation is well qualified for indicating greenhouse gas fluxes (Couwenberg *et al.* 2011) as outlined in Section 9.3.6.

GHG emissions from drained peat, litter and ground vegetation are estimated based on the presence of GESTs with calibrated GHG emission profiles in strata *i*. As a general rule:

- for a <u>non-forested area</u> a GEST will determine average annual net CO_2 equivalent emissions
- for a <u>forested area</u> a GEST in combination with carbon stock changes in tree biomass will

determine average annual net CO_2 equivalent emissions.

In addition, for GESTs in which the vegetation composition does not provide a clear indication of GHG emission-related site conditions (e.g., bare peat), water table depth measurements must be used as additional input to assess GHG fluxes. Areas within the project boundary with different GESTs will be treated as different strata.

For each stratum:

$$GHG_{drained,i,t} = GHG_{GESTbsl,i,t} \quad \textbf{(24)}$$

$$\text{For } t > t_{PDT\text{-}BSL,i}: GHG_{drained,i,t} = 0 \quad \textbf{(25)}$$

Where:

$GHG_{drained,i,t}$	Greenhouse gas emissions from soil, lower ground vegetation and litter in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$t_{PDT\text{-}BSL,i}$	PDT in the baseline scenario in stratum *i* in years elapsed since the project start; yr
$GHG_{GESTbsl,i,t}$	GHG emissions from GESTs in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … *t** years elapsed since the project start

Assessing GHG emissions in the baseline scenario consists of 4 steps (see Section 9.3.6 for additional guidance on each of these steps):

1) Determine GESTs
2) Assess the pre-project spatial distribution of GESTs
3) For the given baseline scenario, derive a time series of GEST development for each stratum; as per Section 6.2, *ex-ante* baseline projections beyond a 10-year period are not required
4) Determine annual GHG emissions per stratum; as per Section 6.2, *ex-ante* baseline projections beyond a 10-year period are not required

To project future GHG emissions due to peat drainage within the project crediting period under the baseline scenario, use the latest version of the VCS module *VMD0019 Methods to Project Future Conditions*, with the following additional guidance.

1. To derive trends and developments in water table management, the baseline scenario must take into account the current and historic layout of the drainage system and the long-term average climate variables influencing water table depths (precipitation, evaporation) prior to project start, on the basis of quantitative hydrological modeling and/or expert judgment. The long-

term average climate variables must be determined using data from two climate stations nearest to the project area and must include at least 20 years' worth of data.

The drainage layout at the start of the project activity must be mapped at scale: 1:10,000 or any other scale justified for estimating water table depths. Historic drainage layout must be mapped using topographic and/or hydrological maps from (if available) the start of the major hydrological impacts but covering at least the 20 years prior to the start of the project activity. Historic drainage structures (collapsed ditches) may (still) have higher hydraulic conductivity than the surrounding areas and function as preferential flow paths. The effect of historic drainage structures on current hydrological functioning of the project area must be assessed on the basis of expert judgment and in a conservative manner. Justification may be based on hydrological models. The baseline scenario may furthermore include re-activation of collapsed ditches. Historic information on the drainage system may serve to set trends in drainage lay-out and depth as well as in frequency of dredging of ditches to maintain required water tables in the field. Derivation of such trends must be done on the basis of expert judgment and in a conservative manner. With respect to hydrological functioning, baseline scenarios must be restricted by climate variables and quantify any impacts on the hydrological functioning as caused by planned measures outside the project area (such as dam construction or groundwater extraction), by demonstrating a hydrological connection to the planned measures (e.g., through ground water carrying soil layers).

2. In case of abandonment of pre-project land use in the baseline scenario, the baseline scenario must also consider - based on expert judgment taking account of verifiable local experience and/or studies and/or scientific literature and in a conservative way - non-human induced rewetting brought about by collapsing dikes or ditches that would have naturally closed over time, and progressive subsidence, leading to raising relative water levels, increasingly thinner aerobic layers and reduced CO_2 emission rates. Unless alternative evidence is provided, annual subsidence (as derived from subsidence - water table observations or models) must be assumed to result in a 1:1 proportional rise the water table relative to the surface in the area between ditches.

In case of continued or re-instated utilization and associated drainage, it must be demonstrated that ditch water tables are controlled (e.g., by weirs and periodic deepening (dredging) of ditches to maintain the water table between ditches at the required level). Documentation may include official plans, but also personal communication with local farmers and historic trends.

Water tables in the baseline may be determined by static (including analytic) hydrologic modeling, using conservative peat hydraulic parameters, including:

- The distance between the ditches
- The water table depth in the ditches
- Hydrological conductivity of the peat

Based on the assessment of changes in water table depth, time series of vegetation composition must be derived (*ex ante*), based on vegetation succession schemes in drained peatlands from scientific literature and/or expert judgment, by defining time series of GESTs, with time steps of, for example, 5 years to allow for the inherent discrete character of the GESTs.

If a *Fire Reduction Premium* is claimed, the project proponent must demonstrate with fire maps and historical databases on fires that the project area is now and in future would be under risk of anthropogenic fires. This is further specified in Section 8.3.

8.1.3.2 Baseline CO_2 and CH_4 emissions estimated by GEST

GHG emissions per stratum as a result of peat drainage (microbial peat oxidation, net fluxes to and from litter and lower ground vegetation) in the baseline scenario are estimated as:

$$GHG_{GESTbsl,i,t} = A_{BSl,i,t} \times (GHG_{GESTbsl\text{-}CO2,i,t} + GHG_{GESTbsl\text{-}CH4,i,t}) \quad \textbf{(26)}$$

Where:

$GHG_{GESTbsl,i,t}$	GHG emissions from GEST in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{BSL,i,t}$	Total area of baseline stratum *i* in year *t*; ha
$GHG_{GESTbsl\text{-}CO2,i,t}$	Emission of CO_2 from baseline GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{GESTbsl\text{-}CH4,i,t}$	Emission of CH_4 from baseline GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3 …M_{BSL} strata[15] in the baseline scenario
t	1, 2, 3, … *t** years elapsed since the project start

If the vegetation composition does not provide a clear indication of GHG emission-related site conditions (e.g., bare peat) the average annual GHG emissions must be related directly to water table depth as follows:

$$GHG_{GESTbsl,i,t} = A_{BSL,i,t} \times (GHG_{WLbsl\text{-}CO2,i,t} + GHG_{WLbsl\text{-}CH4,i,t}) \quad \textbf{(27)}$$

Where:

$GHG_{GESTbsl,i,t}$	GHG emissions from GEST in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{BSL,i,t}$	Total area of baseline stratum *i* in year *t*; ha
$GHG_{WLbsl\text{-}CO2,i,t}$	Emission of CO_2 related to water table depth in the baseline scenario in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{WLbsl\text{-}CH4,i,t}$	Emission of CH_4 related to water table depth in the baseline scenario in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3, … M_{BSL} strata[16] in the baseline scenario

[15] Note that different GESTs result in different strata.

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

The project may establish project-specific values for $GHG_{WLbsl-CO2}$ and $GHG_{WLbsl-CH4}$ (see Section 9.3.6) or apply values from appropriate literature sources pertaining to land use classes, water table depths or water table depth classes and similar project circumstances. For such literature values the accuracy must be defined or conservativeness must be justified in the project description. Project circumstances are defined by pre-project land use (e.g., forestry, peat mining, agriculture, abandonment after such activities) and its intensity, climatic zone, water table depths, and peat type. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used. $GHG_{WLbsl-CH4}$ may be conservatively neglected.

Procedures for the determinations of GHG fluxes and water table depth measurements are provided in Section 9.3.6.

8.2 Project Emissions

8.2.1 General approach

The net CO_2 equivalent emissions in the project scenario may be determined by carbon stock changes in non-peat carbon pools and GHG emissions from rewetted peatland.

GHG emissions from fossil fuel combustion from transport and machinery use in project activities are deemed insignificant.

For the quantification of possible spikes of CH_4 emission during a transient period after rewetting, for which the GEST approach cannot be used, conservative estimates from appropriate literature sources are used.

To demonstrate that N_2O emissions are a) insignificant or b) decrease compared to the baseline scenario, and therefore N_2O emissions need not be accounted for, a) use the CDM A/R methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities*, or b) refer to peer-reviewed literature, respectively.

For *ex-ante* estimates of GHG emissions in the project scenario use the latest version of the VCS module *VMD0019 Methods to Project Future Conditions*.

The net CO_2 equivalent emissions in the project scenario are estimated as:

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[16] Note that different water levels or water level classes result in different strata. Water levels or water level classes (e.g., 0-10 cm, 11-20 cm, etc.) can be used, depending on data availability.

$$GHG_{WPS} = \sum_{t=1}^{t*} \sum_{i=1}^{M_{WPS}} \left(-\frac{44}{12} \times \Delta C_{WPS-NP,i,t} + GHG_{rewetted,i,t} \right) \quad (28)$$

Where:

GHG_{WPS}	Net CO_2 equivalent emissions in the project scenario up to year $t*$; t CO_2e
$\Delta C_{WPS-NP,i,t}$	Net carbon stock change in non-peat carbon pools in the project scenario in stratum i in year t; t C yr^{-1}
$GHG_{rewetted,i,t}$	Greenhouse gas emissions from the peat after rewetting in the project scenario in stratum i in year t; t CO_2e yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the project scenario
t	1, 2, 3, … $t*$ years elapsed since the project start

8.2.2 Net carbon stock changes in non-peat carbon pools ($\Delta C_{WPS-NP,i,t}$)

Under the applicability conditions, the burning of biomass is excluded in the project scenario. This methodology does not provide procedures for estimating GHG emissions from the burning of biomass.

Monitoring procedures for carbon stocks in tree biomass in the project scenario are provided in Section 9.

Net carbon stock changes in non-peat carbon pools in the project scenario will be determined as:

$$\Delta C_{WPS-NP,i,t} = \Delta C_{WPS-biomass,i,t} \quad (29)$$

Where:

$\Delta C_{WPS-NP,i,t}$	Net carbon stock change in non-peat carbon pools in the project scenario in stratum i in year t; t C yr^{-1}
$\Delta C_{WPS-biomass,i,t}$	Net carbon stock change in tree biomass in the project scenario in stratum i in year t; t C yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … $t*$ years elapsed since the project start

$$\Delta C_{WPS-Biomass,i,t} = A_{WPS,i,t} \times \Delta C_{WPS-tree,i,t} \quad (30)$$

$$\Delta C_{WPS-tree,i,t} = \sum_{j=1}^{S_{WPS}} \left(\Delta C_{WPS-tree,j,i,t} \right) \quad (31)$$

$$\Delta C_{WPS-tree,j,i,t} = \Delta C_{WPS-tree-AB,j,i,t} + \Delta C_{WPS-tree-BB,j,i,t} \quad (32)$$

$$\Delta C_{WPS-tree-BB,j,i,t} = \Delta C_{WPS-tree-AB,j,i,t} \times R_j \quad (33)$$

Where:

$\Delta C_{WPS\text{-}biomass,i,t}$	Change in carbon stock in biomass in the project scenario in stratum *i* in year *t*; t C yr^{-1}
$A_{WPS,i,t}$	Area of project stratum *i* in year *t*; ha
$\Delta C_{WPS\text{-}tree,i,t}$	Change in carbon stock in tree[17] biomass in the project scenario in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{WPS\text{-}tree,j,i,t}$	Change in carbon stock in tree biomass in the project scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{WPS\text{-}tree\text{-}AB,j,i,t}$	Change in carbon stock in above-ground tree biomass in the project scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{WPS\text{-}tree\text{-}BB,j,i,t}$	Change in carbon stock in below-ground tree biomass in the project scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
R_j	Root:shoot ratio for tree species *j*; t root t^{-1} shoot d.m.
j	1, 2, 3, … S_{WPS} tree species in the project scenario
i	1, 2, 3, … M_{WPS} strata in the project scenario
t	1, 2, 3, … t^* years elapsed since the project start

Changes in carbon stock in above-ground tree biomass in the project scenario are estimated as:

$$\Delta C_{WPS\text{-}tree\text{-}AB,j,i,t} = (C_{WPS\text{-}tree\text{-}AB,j,i,t} - C_{WPS\text{-}tree\text{-}AB,j,i,(t-T)}) / T \quad (34)$$

Where:

$\Delta C_{WPS\text{-}tree\text{-}AB,j,i,t}$	Net carbon stock change in above-ground tree biomass in the project scenario for tree species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$C_{WPS\text{-}tree\text{-}AB,j,i,t}$	Carbon stock in above-ground tree biomass in the project scenario for tree species *j* in stratum *i* in year *t*; t C ha^{-1}[18]
t	1, 2, 3 … ***t**** years elapsed since the start of the project activity
i	1, 2, 3, … M_{WPS} strata in the project scenario
j	1, 2, 3, … S_{WPS} tree species
T	Number of years between monitoring times t_m *and* t_{m-1}

The mean carbon stock in above-ground biomass per unit area is estimated on the basis of field

[17] With DBH ≥ 5 cm.
[18] May be conservatively set to zero.

measurements in permanent sample plots. Two methods are available: the biomass expansion factors (*BEF*) method and the allometric equations method.

1) <u>*BEF* method</u>

Step 1: Determine on the basis of available data volume tables (*ex ante*) and measurements (*ex post*) of the diameter at breast height (*DBH,* at typically 1.3 m above-ground level), and also preferably height (*H*), of all the trees above some minimum *DBH* in the permanent sample plots. The exact tree dimensions to be measured will be specified by the information obtained in Step 2.

Step 2: Estimate the stem volume of trees

It is possible to combine Steps 1 and 2 if volume tables allow for deriving average volume of trees, or field instruments (e.g., a relascope) that measure the volume of each tree directly are applied.

Step 3: Choose *BEF*

Step 4: Convert the stem volume of trees into carbon stock in above-ground tree biomass via basic wood density, the *BEF* and the carbon fraction:

$$C_{WPS\text{-}tree\text{-}AB,l,j,i,sp,t} = V_{l,j,i,sp,t} \times D_j \times BEF_{2j} \times CF_j \quad \textbf{(35)}$$

Where:

$C_{WPS\text{-}tree\text{-}AB,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* in year *t*; t C tree^{-1}
$V_{l,j,j,sp,t}$	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i* in year *t*; m^3 tree^{-1}
D_j	Basic wood density of species *j*; t d.m. m^{-3}
BEF_{2j}	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*
CF_j	Carbon fraction[19] of dry matter for species *j*; t C t d.m.$^{-1}$
l	1, 2, 3, … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* in year *t*
i	1, 2, 3, … M_{WPS} strata in the project scenario
j	1, 2, 3, … S_{WPS} tree species in the project scenario
t	1, 2, 3, … *t** years elapsed since the start of the project activity

Step 5: Calculate carbon stock in above-ground biomass of all tree species *j* present in plot *sp* in stratum *i* at time *t* (i.e., summation over all trees *l* of species *j* present in plot *sp*).

[19] IPCC default = 0.5

$$C_{WPS-tree-AB,j,i,sp,t} = \sum_{l=1}^{N_{j,i,sp,t}} C_{WPS-tree-AB,l,j,i,sp,t} \qquad (36)$$

Where:

$C_{WPS\text{-}tree\text{-}AB,j,i,sp,t}$	Carbon stock in above-ground biomass of tree species j on plot sp of stratum i at time t; t C
$C_{WPS\text{-}tree\text{-}AB,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree l of species j in plot sp in stratum i at time t; t C tree^{-1}
l	1, 2, 3, … $N_{j,i,sp,t}$ individual trees of species j in sample plot sp in stratum i in year t
i	1, 2, 3, … M_{WPS} strata in the project scenario
j	1, 2, 3, … S_{WPS} tree species in the project scenario
sp	1, 2, 3, … P_i sample plots in stratum i in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the project activity

Step 6: Estimate the mean carbon stock in above-ground tree biomass for species j for each stratum:

$$C_{WPS-tree-AB,j,i,t} = \frac{1}{A_{sp_i}} \sum_{sp=1}^{P_i} C_{WPS-tree-AB,j,i,sp,t} \qquad (37)$$

Where:

$C_{WPS\text{-}tree\text{-}AB,j,i,t}$	Above-ground carbon stock in tree species j in stratum i in year t; t C ha^{-1}
$C_{WPS\text{-}tree\text{-}AB,j,i,sp,t}$	Above-ground carbon stock in tree species j on plot sp of stratum i in year t; t C
$A_{sp,i}$	Total area of all sample plots in stratum i; ha
j	1, 2, 3, … S_{WPS} tree species in the project scenario
i	1, 2, 3, … M_{WPS} strata in the project scenario
sp	1, 2, 3, … P_i sample plots in stratum i in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the project activity

The below-ground tree biomass in the project scenario may be conservatively set to zero. Procedures for including below-ground biomass in total tree biomass estimations are provided in Section 8.1.2.

2) Allometric equations method

Step 1: Same as Step 1 of the *BEF* method.

Step 2: Select or develop an appropriate allometric equation (if possible species-specific, or if not from a similar species) - see Chapter 9 for additional guidance.

Step 3: Estimate carbon stock in above-ground biomass for each individual tree *l* of species *j* in the sample plot *sp* located in stratum *i* using the selected or developed allometric equation applied to the tree dimensions resulting from Step 1, and sum the carbon stocks in the sample plot:

$$C_{WPS-tree-AB,j,i,sp,t} = \sum_{l=1}^{N_{j,i,sp,t}} \left(f_j(X,Y,...) \times CF_j \right) \quad \textbf{(38)}$$

Where:

$C_{WPS\text{-}tree\text{-}AB,j,i,sp,t}$	Carbon stock in above-ground biomass of tree species *j* in sample plot *sp* in stratum *i* in year *t*; t C
$f_j(X, Y, …)$	Allometric equation for species *j* linking measured tree dimension variables (e.g., diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees; t d.m. tree^{-1}
CF_j	Carbon fraction of dry matter for species *j*; t C t^{-1} d.m.
l	1, 2, 3, … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* in year *t*
j	1, 2, 3, … S_{WPS} tree species in the project scenario
i	1, 2, 3, … M_P strata in the project scenario
sp	1, 2, 3, … P_i sample plots in stratum *i* in the project scenario
t	1, 2, 3, … *t** years elapsed since the start of the project activity

Step 4: Proceed with Step 6 of the *BEF* method.

8.2.3 Project greenhouse gas emissions after peat rewetting ($GHG_{rewetted,i,t}$)

The estimation of GHG emissions in rewetted peat follows similar procedures as provided in Section 8.1.3.

For each stratum:

$$GHG_{rewetted,i,t} = GHG_{GESTwps,i,t} \quad \textbf{(39)}$$

Where:

$GHG_{rewetted,i,t}$	Greenhouse gas emissions from soil, lower ground vegetation and litter in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$GHG_{GESTwps,i,t}$	GHG emissions from GESTs in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
i	1, 2, 3, …M_{BSL} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start

8.2.3.1 Project GHG emissions related to GESTs

This approach builds on the procedure described in Section 8.1.3.1. In addition, the GHG emissions during the transient stage after rewetting (i.e., before new vegetation types have established that are in balance with the rewetted conditions and for from which GESTs can be defined) must be determined.

The GEST approach for the project scenario has the following steps (see Section 9.3.6 for additional guidance on each of these steps):

1) Determine GESTs
2) Assess the spatial distribution of GESTs
3) Define the project scenario for GESTs (*ex ante*) or monitor GESTs (*ex post*)
4) Determine annual GHG emissions per stratum for the entire project crediting period

For the quantification of possible spikes of CH_4 emission during a transient period after rewetting where dying off vegetation may lead to substantial methane emissions, for which the GEST approach cannot be used, conservative estimates from appropriate literature sources must be used. The project proponent must demonstrate applicability of that literature on the basis of similarity with respect to pre-project land use (e.g., forestry, peat mining, agriculture) and land use intensity (especially fertilization), superficial peat types (especially nutrient conditions), and climatic zone.

GHG emissions per stratum of peat after rewetting are estimated as:

$$GHG_{rewetted,i,t} = A_{WPS,i,t} \times (GHG_{GESTwps\text{-}CO2,i,t} + GHG_{GESTwps\text{-}CH4,i,t}) \quad \textbf{(40)}$$

Where:

$GHG_{rewetted,i,t}$	Greenhouse gas emissions from soil, lower ground vegetation and litter in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{WPS,i,t}$	Total area of project stratum *i*; ha
$GHG_{GESTwps\text{-}CO2,i,t}$	Emission of CO_2 from project GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$

$GHG_{GESTwps\text{-}CH4,i,t}$	Emission of CH_4 from project GEST in stratum i in year t; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3, …M_{BSL} strata in the project scenario
t	1, 2, 3, … t^* years elapsed since the project start

Ex-ante estimates of $GHG_{rewetted,i,t}$ must be based on *ex-ante* scenario definitions in Step 3.

Ex-post estimates of $GHG_{rewetted,i,t}$ must be based on monitoring results.

If the vegetation composition does not provide a clear indication of GHG emission-related site conditions (e.g., bare peat, transient phases of vegetation development after rewetting) the average annual GHG emissions must be related directly to water table depth. Note that due to a potential hysteresis effect the relationships between water table depth and greenhouse gas emissions in a rewetted peatland can differ from those in a drained peatland.

$$GHG_{GESTwps,i,t} = A_{WPS,i,t} \times (GHG_{WL\text{-}CO2,i,t} + GHG_{WL\text{-}CH4,i,t}) \quad \textbf{(41)}$$

Where:

$GHG_{GESTwps,i,t}$	GHG emissions from GESTs in the project scenario in stratum i in year t; t CO_2e yr^{-1}
$A_{WPS,i,t}$	Total area of project stratum i in year t; ha
$GHG_{WLwps\text{-}CO2,i,t}$	Emission of CO_2 related to water table depth in the project scenario in stratum i in year t; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{WLwps\text{-}CH4,i,t}$	Emission of CH_4 related to water table depth in the project scenario in stratum i in year t; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3, …M_{BSL} strata[20] in the project scenario
t	1, 2, 3, … t^* years elapsed since the project start

The project may establish project-specific values for $GHG_{WLwps\text{-}CO2}$ and $GHG_{WLwps\text{-}CH4}$ or apply values from appropriate literature sources pertaining to land use classes, water table depths or water table depth classes. For such literature values the accuracy must be defined or conservativeness must be justified. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.

Procedures for the determinations of GHG fluxes and water table depth measurements are provided in Section 9.3.6.

[20] Note that different water levels or water level classes result in different strata. Water levels or water level classes (e.g., 0-10 cm, 11-20 cm, etc.) can be used, depending on data availability

8.2.3.2 Direct estimate approach

GEST conversion assessments may provide direct conservative estimates of emission reductions due to rewetting, rather than providing estimates of baseline and project emissions separately (e.g., a conversion of GEST type a to type b is associated with a given emission reduction with a given uncertainty, or the emission reduction is estimated conservatively).

Table 8.1. Suggested table format for conservative estimates of emission reductions for GEST conversions from drained to rewetted.

Table 8.1: Estimated Emission Reductions for GEST Conversions

GEST t_1	GEST t_2	Emission reduction t CO_2e $ha^{-1}yr^{-1}$
…	…	…
…	…	…

Where this approach is applied, equation 55 in Section 8.5 is amended to:

$$NER_{RDP} = 44/12 \times (\Delta C_{BSL} - \Delta C_{WPS}) + \Delta GHG_{rewetting} + \textit{Fire Reduction Premium} - GHG_{LK} \quad \textbf{(42)}$$

The greenhouse gas emission reduction due to rewetting is estimated as:

$$\Delta GHG_{rewetting,i,t} = A_{i,t} \times ((GHG_{GESTbsl\text{-}CO2,i,t} + GHG_{GESTbsl\text{-}CH4,i,t}) - (GHG_{GESTwps\text{-}CO2,i,t} + GHG_{GESTwps\text{-}CH4,i,t})) \quad \textbf{(43)}$$

Where:

$\Delta GHG_{rewetting,i,t}$	Greenhouse gas emission reduction due to rewetting in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{i,t}$	Total area of stratum *i* in year *t*[21];; ha
$GHG_{GESTbsl\text{-}CO2,i,t}$	Emission of CO_2 from baseline GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{GESTwps\text{-}CO2,i,t}$	Emission of CO_2 from project GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{GESTbsl\text{-}CH4,i,t}$	Emission of CH_4 from baseline GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{GESTwps\text{-}CH4,i,t}$	Emission of CH_4 from project GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3, … M_{BSL} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start

[21] Note that if baseline strata are subdivided in the project scenario, areas $A_{i,t}$ are equal to $A_{WPS,i,t}$ of the relevant strata *i*; if baseline strata are merged in the project scenario, areas $A_{i,t}$ are equal $A_{WPS,i,t}$ of strata that include the merged baseline strata *i*. For unaffected strata $A_{i,t}$ equals $A_{WPS,i,t}$

$$\Delta GHG_{rewetting} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{WPS}} \Delta GHG_{rewetting,i,t} \tag{44}$$

For $t > t_{PDT-BSL,i}$:

$$GHG_{rewetting,i,t} = 0 \tag{45}$$

Where:

$\Delta GHG_{rewetting}$	Greenhouse gas emission reduction due to rewetting up to year t^*; t CO_2e
$GHG_{rewetting,i,t}$	Greenhouse gas emission reduction due to rewetting in stratum i in year t; t CO_2e yr^{-1}
Fire Reduction Premium	Greenhouse gas emission reduction from peat combustion due to rewetting and fire management up to year t^*; t CO_2e
GHG_{LK}	Net CO_2 equivalent emissions in the project scenario due to leakage up to year t^*; t CO_2e
$t_{PDT-BSL,i}$	PDT in the baseline scenario in stratum i in years elapsed since the project start; yr
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

$$\Delta C_{BSL} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} \Delta C_{BSL-NP,i,t} \tag{46}$$

Where:

ΔC_{BSL}	Net carbon stock change in non-peat carbon pools in the baseline scenario up to year t^*; t CO_2e
$\Delta C_{BSL-NP,i,t}$	Net carbon stock change in non-peat carbon pools in the baseline scenario in stratum i in year t; t CO_2e yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

$$\Delta C_{WPS} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} \Delta C_{WPS-NP,i,t} \tag{47}$$

Where:

ΔC_{WPS}	Net carbon stock change in non-peat carbon pools in the project scenario up to year t^*; t CO_2e

$\Delta C_{WPS-NP,i,t}$	Net carbon stock change in non-peat carbon pools 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
t	1, 2, 3, … *t** years elapsed since the project start

8.3 Fire Reduction Premium

This methodology addresses anthropogenic peat fires occurring in drained peatland and establishes a conservative default value, based on fire occurrence and extension in the project area 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 anthropogenic 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.

The 20% Fire Reduction Premium

The 20% fire reduction premium is a rapid and conservative approach to acknowledging fire emission reductions as a result of rewetting without having to develop complex baseline 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. Carbon losses from peat fires[22] are per hectare burned area on average ~10 times larger than the annual carbon emissions from microbial peat oxidation per ha drained peatland (i.e., 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 carbon losses from microbial peat oxidation and all carbon 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.

The fire reference period is fixed to a period prior to project start to prevent deliberate fires to meet the eligibility criteria. A minimum period of 10 years must be assessed in order to ensure a representative time period that will reflect frequency of fires in the baseline.

In this procedure, the CO_2 emission reductions from microbial peat oxidation due to rewetting in the project scenario are estimated first (Sections 8.1.3 and 8.2.3 and Equation 48). The default value for reduced emissions from peat fire has a maximum of 20% of the reduced CO_2 emissions from microbial peat oxidation due to rewetting, if the cumulative area[23] burnt in the fire reference period was equal to or exceeded 25% of the project area. This amount of emission reductions

[22] Conservatively assuming that all carbon losses from peat fires occur as CO_2.
[23] The maximum number of times a recurring fire can be counted is 3.

(Equation 48) is denoted '*Fire Reduction Premium*'. The project will only be eligible to claim the premium if the following applies:

1) Over the period of 10 to 15 years, ending 2 years before the project start date, the cumulative area of peat burnt exceeded 10% of the project area (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 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[24] 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.

If peat fires in the baseline scenario are more frequent than once per 10 years or more extensive than 25% of the project area, 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, the premium is not awarded.

If $(A_{peatburn} / A_P) \geq 0.25$ the emission reduction from peat combustion due to rewetting and fire management is estimated as:

$$\textit{Fire Reduction Premium} = 0.20 \times (GHG_{GESTbsl\text{-}CO2} - GHG_{GESTwps\text{-}CO2}) \quad \textbf{(48)}$$

If $(A_{peatburn} / A_P) < 0.1$ then

$$\textit{Fire Reduction Premium} = 0 \quad \textbf{(49)}$$

If $(A_{peatburn} / A_P) < 0.25$ and $A_{peatburn} / A_P \geq 0.1$ then

$$\textit{Fire Reduction Premium} = (A_{peatburn} / A_P) \times 0.8 \times (GHG_{GESTbsl\text{-}CO2} - GHG_{GESTwps\text{-}CO2}) \quad \textbf{(50)}$$

$$GHG_{GESTbsl\text{-}CO2} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} GHG_{GESTbsl\text{-}CO2,i,t} \quad \textbf{(51)}$$

$$GHG_{GESTwps\text{-}CO2} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} GHG_{GESTwps\text{-}CO2,i,t} \quad \textbf{(52)}$$

Where:

Fire Reduction Premium Greenhouse gas emission reduction from peat combustion due to

[24] Verifiable evidence must be provided in the project documentation.

	rewetting and fire management up to year t^*; t CO_2e
$GHG_{GESTbsl\text{-}CO2}$	Emission of CO_2 from GESTs in the baseline scenario up to year t^*; t CO_2e
$GHG_{GESTwps\text{-}CO2}$	Emission of CO_2 from GESTs in the project scenario up to year t^*; t CO_2e
$GHG_{GESTbsl\text{-}CO2,i,t}$	Emission of CO_2 from baseline GEST in stratum i in year t; t CO_2e yr^{-1}
$GHG_{GESTwps\text{-}CO2,i,t}$	Emission of CO_2 from project GEST in stratum i in year t; t CO_2e yr^{-1}
$A_{peatburn}$	Cumulative area burnt; ha
A_P	Total project area; ha
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

Fire Reduction Premium may be calculated on a total project basis, which implies that the documentation referred to in requirements 3 and 4 above are provided at the project level. 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 bogs or fens that have different baseline fire histories, or in case of instances in a Grouped Project.

Ex-ante estimate of *Fire Reduction Premium*: The estimate of $GHG_{GESTwps\text{-}CO2,i,t}$ in Equation 52 must be taken from *ex-ante* calculations (Section 8.2.3.2).

Ex-post estimate of *Fire Reduction Premium*: The estimate of $GHG_{GESTwps\text{-}CO2,i,t}$ in Equation 52 must be taken from monitoring results.

If a) peatland rewetting and b) a best-practices fire management have been implemented, peat fires occurring in the project scenario can be assumed to be catastrophic reversals[25] (i.e. events that would have occurred in the baseline scenario but that would have been unaccounted for). Therefore, provided the above-mentioned 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, as in:

$$\textit{Fire Reduction Premium} = 0 \qquad \textbf{(53)}$$

In case of non-catastrophic fires, adjustments must be made for subsequent changes in carbon store and GHG fluxes (e.g., peat stocks at t=100).

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

8.4 Leakage

Under the applicability conditions of this methodology, market leakage and activity shifting leakage do not occur. Project proponents must demonstrate, based on verifiable information (such as laws and bylaws, management plans, market reports) that in case the pre-project land use is one or a combination of the following:

- Forestry, this forestry is non-commercial in nature;
- Peat extraction, this activity has been abandoned at least 2 years[26] prior to the project start date;
- Agriculture, food, fodder or fiber production has been abandoned at least 2 years prior to the project start date, or will continue in the project scenario, or drainage of additional peatland for new agricultural sites will not occur or is prohibited by law;
- Fuel wood extraction, the activity is non-commercial in nature.

Under the applicability conditions of this methodology, ecological leakage also does not occur, by ensuring that hydrological connectivity with adjacent areas is insignificant (i.e. causing no alteration of mean annual water table depths in such areas). This can be achieved either by an appropriate design (e.g., by establishing an impermeable dam) or by a buffer zone within the project boundary for which conservatively no GHG benefits are accounted. This buffer zone, if employed, must be mapped and is not eligible for carbon crediting. The width of the buffer zone must be determined on the basis of quantitative hydrological modeling, or expert judgment. Procedures for monitoring are provided in Sections 9.3.4 and 9.3.6.

Therefore:

$$GHG_{LK} = 0 \tag{54}$$

8.5 Summary of GHG Emission Reduction and/or Removals

8.5.1 Calculation of net GHG emissions reductions

The total net GHG emission reductions from the RDP project activity are calculated as follows:

$$NER_{RDP} = GHG_{BSL} - GHG_{WPS} + Fire\ Reduction\ Premium - GHG_{LK} \tag{55}$$

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[26] Agents abandoning peat extraction for the purpose of a rewetting project are unlikely to exist, because the investments in making a new area suitable for peat extraction by far exceed the revenues of a carbon project on the same area.

Where the direct estimate approach in estimating emission reductions due to rewetting (Section 8.2.3.2) is adopted, the total net GHG emission reductions are calculated as follows:

$$NER_{RDP} = 44/12 \times (\Delta C_{BSL} - \Delta C_{WPS}) + \Delta GHG_{rewetting} + Fire\ Reduction\ Premium - GHG_{LK} \quad \textbf{(56)}$$

Where:

NER_{RDP}	Total net CO_2 equivalent emission reductions from the RDP project activity up to year t^*; t CO_2e
GHG_{BSL}	Net CO_2 equivalent emissions in the baseline scenario up to year t^*; t CO_2e
GHG_{WPS}	Net CO_2 equivalent emissions in the project scenario up to year t^*; t CO_2e
ΔC_{BSL}	Net carbon stock change in non-peat carbon pools in the baseline scenario up to year t^*; t C
ΔC_{WPS}	Net carbon stock change in non-peat carbon pools in the project scenario up to year t^*; t C
$\Delta GHG_{rewetting}$	Greenhouse gas emission reduction due to rewetting up to year t^*; t CO_2e
Fire Reduction Premium	Greenhouse gas emission reduction from peat combustion due to rewetting and fire management up to year t^*; t CO_2e
GHG_{LK}	Net CO_2 equivalent emissions in the project scenario due to leakage up to year t^*; t CO_2e

NER_{RDP} must be corrected for uncertainty, by estimating the total uncertainty for the RDP project activity (NER_{RDP_ERROR}) as provided in Section 8.5.2.

8.5.2 Estimation of uncertainty

This procedure allows for estimating uncertainty in the estimation of emissions and carbon stock changes (i.e., a procedure for calculating a precision level and any deduction in credits for lack of precision following project implementation and monitoring, by assessing uncertainty in baseline and project estimations).

This procedure focuses on the following sources of uncertainty:

- Uncertainty associated with estimation of stocks in carbon pools and changes in carbon stocks
- Uncertainty in assessment of project emissions

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

Guidance on uncertainty – a precision target of a 90% or 95% confidence interval equal to or less than 20% or 30%, respectively, of the recorded value must be targeted. This is especially important in terms of project planning for measurement of carbon stocks where sufficient measurement plots should be included to achieve this precision level across the measured stocks.

Required conditions:

- Levels of uncertainty must be known for all aspects of baseline and project implementation and monitoring. Uncertainty will generally be known as the 90% or 95% confidence interval expressed as a percentage of the mean.
- Where uncertainty is not known it must be demonstrated that the value used is conservative.

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 values given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), expert judgment, or estimates based of sound statistical sampling.

Alternatively, 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 tool 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 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 procedure at an early stage to identify the data sources with the highest uncertainty to allow the opportunity to conduct further work to diminish uncertainty.

Part 1 – Uncertainty in Baseline Estimates

$$Uncertain_{BSL,i} = \frac{\sqrt{(U_{BSL,SS1,i} * E_{BSL,SS1,i})^2 + (U_{BSL,SS2,i} * E_{BSL,SS2,i})^2 \ldots + \ldots (U_{BSL,SSn,i} * E_{BSL,SSn,i})^2}}{E_{BSL,SS1,i} + E_{BSL,SS2,i} \cdots + \ldots E_{BSL,SSn,i}} \quad \textbf{(57)}$$

Where:

$Uncertain_{BSL,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the baseline case in stratum *i*; %
$U_{BSL,SS,i}$	Percentage uncertainty (expressed as 90% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the baseline case in stratum *i* (1,2, … n represent different carbon pools and/or GHG sources); %
$E_{BSL,SS,i}$	Carbon stock or GHG sources (e.g., trees, down dead wood, etc.) in stratum *i* (1,2, … n represent different carbon pools and/or GHG sources) in the baseline case; t CO_2e
i	1, 2, 3, … M_{BSL} strata in the baseline scenario

To assess uncertainty across combined strata:

$$Uncertain_{BSL} = \frac{\sqrt{(U_{BSL,1} * A_1)^2 + (U_{BSL,2} * A_2)^2 \ldots + \ldots (U_{BSL,M_{BSL}} * A_{M_{BSL}})^2}}{A_1 + A_2 \ldots + \ldots A_{M_{BSL}}} \quad (58)$$

Where:

$Uncertain_{BSL}$	Total uncertainty in baseline scenario; %
$U_{BSL,i}$	Uncertainty in baseline scenario in stratum *i*; %
A_i	Area of stratum *i*; ha
i	1, 2, 3, … M_{BSL} strata in the baseline scenario

Part 2 – Uncertainty Ex-Post in the Project Scenario

$$Uncertain_{WPS,i} = \frac{\sqrt{(U_{WPS,SS1,i} * E_{WPS,SS1,i})^2 + (U_{WPS,SS2,i} * E_{WPS,SS2,i})^2 \ldots + \ldots (U_{WPS,SSn,i} * E_{WPS,SSn,i})^2}}{E_{WPS,SS1,i} + E_{WPS,SS2,i} \ldots + \ldots E_{WPS,SSn,i}} \quad (59)$$

Where:

$Uncertain_{WPS,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the project case in stratum *i*; %
$U_{WPS,SS,i}$	Percentage uncertainty (expressed as 90% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the project case in stratum *i* (1,2, … n represent different carbon pools and/or GHG sources); %
$E_{WPS,SS,i}$	Carbon stock or GHG sources (e.g., trees, down dead wood, etc.) in stratum *i* (1,2, … n represent different carbon pools and/or GHG sources) in the project case; t CO_2e

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

To assess uncertainty across combined strata:

$$Uncertain_{WPS} = \frac{\sqrt{(U_{WPS,1} * A_1)^2 + (U_{WPS,2} * A_2)^2 \ldots + \ldots (U_{WPS,M_{BSL}} * A_{M_{BSL}})^2}}{A_1 + A_2 \ldots + \ldots A_{M_{BSL}}} \quad \textbf{(60)}$$

Where:

$Uncertain_{WPS}$	Total uncertainty in project scenario; %
$U_{WPS,i}$	Uncertainty in project scenario in stratum i; %
A_i	Area of stratum i; ha
i	1, 2, 3, … M_{WPS} strata in the project scenario

Part 3 – Total Error in RDP Project Activity

$$NER_{RDP\_ERROR} = \frac{\sqrt{(Uncertain_{BSL} \times GHG_{BSL})^2 + (Uncertain_{WPS} \times GHG_{WPS})^2}}{GHG_{BSL} + GHG_{WPS}} \quad \textbf{(61)}$$

Where:

NER_{RDP_ERROR}	Total uncertainty for RDP project activity; %
$Uncertain_{BSL}$	Total uncertainty in baseline scenario; %
$Uncertain_{WPS}$	Total uncertainty in the project scenario; %
GHG_{BSL}	Net CO_2 equivalent emissions in the baseline scenario up to year t^*; t CO_2e
GHG_{WPS}	Net CO_2 equivalent emissions in the project scenario up to year t^*; t CO_2e

The allowable uncertainty under this methodology is 20% or 30% of $NER_{RDP,t}$ at a 90% or 95% confidence level, respectively. Where this precision level is met no deduction should result for uncertainty. Where exceeded, the deduction must be equal to the amount that the uncertainty exceeds the allowable level. The adjusted value for $NER_{RDP,t}$ to account for uncertainty must be calculated as:

$$adjusted\_NER_{RDP,t} = NER_{RDP,t} \times (100\% - NER_{RDP\_ERROR} + allowable\_uncert) \quad \textbf{(62)}$$

Where:

$adjusted\_NER_{RDP,t}$	Cumulative total net GHG emission reductions at time t adjusted to account for uncertainty; t CO_2e
$NER_{RDP,t}$	Total net GHG emission reductions from the RDP project activity up to year t; t CO_2e

NER_{RDP_ERROR}	Total uncertainty for RDP project activity; %
$allowable\_unsert$	Allowable uncertainty; 20% or 30% at a 90% or 95% confidence level, respectively; %

8.5.3 Calculation of Verified Carbon Units

The concept of withholding a number of buffer credits in the AFOLU pooled buffer account is based on quantifying the net change in carbon stocks. The proxy for the net change in carbon stocks applied in this methodology is NER (Section 8.5.1). As this proxy includes all net GHG emissions reductions, it provides a conservative (too large) estimate of the buffer withholding.

The number of Verified Carbon Units is calculated as:

$$VCU_{t2} = \left(adjusted\_NER_{RDP,t2} - adjusted\_NER_{RDP,t1}\right) - Bufferw_{t2} \tag{63}$$

Where:

VCU_{t2}	Number of Verified Carbon Units in year *t2*
$NER_{RDP,\ t1}$	Total net GHG emission reductions from the RDP project activity up to year *t1*; t CO_2e
$NER_{RDP,\ t2}$	Total net GHG emission reductions from the RDP project activity up to year *t2*; t CO_2e
NER_{RDP_ERROR}	Total uncertainty for RDP project activity; %
$Bufferw_{t2}$	Number of Verified Carbon Units to be withheld in the VCS Buffer in year *t2*

$$Bufferw_{t2} = \left(NER_{RDP,t2} - NER_{RDP,t1}\right) \times Buffer\%_{t2} \tag{64}$$

Where:

$Bufferw_{t2}$	Number of Verified Carbon Units to be withheld in the VCS Buffer in year *t2*
$NER_{RDP,\ t1}$	Total net GHG emission reductions from the RDP project activity up to year *t1*; t CO_2e
$NER_{RDP,\ t2}$	Total net GHG emission reductions from the RDP project activity up to year *t2*; t CO_2e
$Buffer\%_{t2}$	Percentage of Verified Carbon Units to be withheld in the VCS Buffer in year *t2*; %

The percentage to be withheld in the VCS buffer is to be determined using the latest version of the VCS *AFOLU Non-Permanence Risk Tool*.

The maximum quantity of GHG emission reductions that may be claimed by the project (VCU_{max}) is limited to the difference between project and baseline scenario after a 100-year time frame.

Procedures for estimating the difference between peat carbon stock in the project scenario and baseline scenario in stratum *i* at *t*=100 ($C_{WPS\text{-}BSL,i,t100}$) are provided in Section 5.2.

$$VCU_{max} = \frac{44}{12} \times C_{WPS-BSL,t100} \tag{65}$$

Where:

VCU_{max}	The maximum quantity of GHG emission reductions that may be claimed by the project ; t CO_2e
$C_{WPS\text{-}BSL,t100}$	Difference between peat carbon stock in the project scenario and baseline scenario at *t*=100; t C ha^{-1}

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter:	$Depth_{peat\text{-}BSL,i}$
Data unit:	m
Description:	Peat depth above the drainage limit in the baseline scenario in stratum *i* at project start
Equations	1, 4, 5
Source of data:	Own measurements and/or literature involving the project area
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Peat depths at project start can be derived from • Own measurements (using peat corers, ground penetrating radar or other techniques laid out in scientific literature or handbooks) • Literature involving the project or similar areas.
Purpose of Data	Calculation of baseline emissions Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	$Depth_{peat\text{-}BSL,i,t0} = Depth_{peat\text{-}WPS,i,t0}$ This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$Depth_{peat\text{-}WPS,i}$

Data unit:	m
Description:	Peat depth above the drainage limit in the project scenario in stratum *i* at project start
Equations	6
Source of data:	As for $Depth_{peat\text{-}BSL,i}$
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	As for $Depth_{peat\text{-}BSL,i}$
Purpose of Data	Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	Only for *ex-ante* assessment $Depth_{peat\text{-}BSL,i,t0} = Depth_{peat\text{-}WPS,i,t0}$

Data Unit / Parameter:	$Rate_{peatloss\text{-}BSL,i}$
Data unit:	m yr^{-1}
Description:	Rate of peat loss due to subsidence and fire in the baseline scenario in stratum *i*
Equations	1, 5, 9
Source of data:	Own measurements, expert judgment, datasets and/or literature of historic subsidence
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	The rate of peat loss due to subsidence must be based on verifiable information and can be derived from 1. Expert judgment, datasets and/or literature of historic subsidence involving the project or similar areas, based on surface height measurements relative to a fixed reference point in m asl (e.g., using poles fixed in the underlying mineral soil or rock, or using LiDAR, or similar). Information used must be verifiable. Or 2. CO_2 emissions derived from the prevalent GESTs (Section 8.1.3), in combination with data on volumetric carbon content of the peat. Divide the annual CO_2 emission (t CO_2 ha^{-1}) by 44/12, then divide by volumetric carbon

	content (g C cm^{-3}) to obtain height loss in m. The average depth of burn scars can be derived from expert judgment, datasets and/or literature of historic burn depths involving the project or similar areas, based on surface height measurements (e.g., using field measurements or LiDAR). When using LiDAR data, projects must use a scientifically robust approach, referring to pertinent scientific literature, ensuring a horizontal accuracy in the meter and a vertical accuracy in the centimeter range. In case of tree cover, scientifically accepted methods must be used to distinguish ground points from non-ground points reflected by the vegetation. Projects may, for example, use the procedures described in Ballhorn *et al*. (2009). Projects may deviate from these procedures provided that the accuracy requirements above are met. The areal extent of burn scars can be obtained from statistics and/or maps in official reports and/or field measurements or remote sensing data (similar materials as required under eligibility criteria 1 and 2 in Section 8.3(*Fire Reduction Premium*), A mean annualized burn depth must be calculated and applied to the entire project area. As only part of the project area is likely to burn in the baseline, this constitutes a conservative approach. The project proponent must demonstrate, using expert judgment, datasets and/or scientific literature that the accuracy of the derived rate of peat loss is sufficient to fulfill the criteria set out in Section 5.2(Stratification). Similarity of areas must be illustrated (by own measurements, literature resources, datasets or a combination of these) addressing peat type, climatic conditions, land use (forestry, agriculture, peat extraction, or abandonment after these activities), and average annual water table depth (±20%). In case of dissimilarity, the project proponent must demonstrate that such difference gives a conservative result for the net GHG benefits of the project. Forecasting peat subsidence rates must be based on the conservative extrapolation of a historic trend, or conservative modeling of proxies such as water table depth and land use type.
Purpose of Data	Calculation of baseline emissions

	Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	The use of a relatively low value for a constant rate of peat loss may not be confused with a relatively high value when determining the need for stratification of peat depth. This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$Rate_{peatloss\text{-}WPS,i}$
Data unit:	m yr^{-1}
Description:	Rate of peat loss due to subsidence in the project scenario in stratum *i*
Equations	6, 10
Source of data:	Own measurements, expert judgment, datasets and/or literature of historic subsidence
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	The rate of peat loss due to subsidence must be based on verifiable information and can be derived from 1. Expert judgment, datasets and/or literature of subsidence involving areas representing conditions similar to the project, based on surface height measurements relative to a fixed reference point in m asl (e.g., using poles fixed in the underlying mineral soil or rock, or by using LiDAR following methods such as those described in Ballhorn *et al*. 2009) or similar. Or 2. CO_2 emissions derived from the prevalent GESTs based on *ex-ante* scenario definitions (Section 8.2.3), in combination with data on volumetric carbon content of the peat. Divide the annual CO_2 emission (t CO_2 ha^{-1}) by 44/12, then divide by volumetric carbon content (g C cm^{-3}) to obtain height loss in m. The project proponent must demonstrate, using expert judgment, datasets and/or scientific literature that the accuracy of the derived rate of peat loss is sufficient to fulfill the criteria set out in Section 5.2(Stratification).

	Similarity of areas must be illustrated (by own measurements, literature resources, datasets or a combination of these) addressing peat type, climatic conditions, land use (forestry, agriculture, peat extraction, or abandonment after these activities), and average annual water table depth (±20%). In case of dissimilarity, the project proponent must demonstrate that such difference gives a conservative result for the net GHG benefits of the project.
Purpose of Data	Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	Only for *ex-ante* assessment

Data Unit / Parameter:	VC_{peat}
Data unit:	t C m^{-3}
Description:	Volumetric carbon content of peat
Equations	3, 4, 9, 10
Source of data:	The volumetric carbon content in peat can be taken from own measurements within the project area or from literature involving the project or similar areas.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	N/A

Data Unit / Parameter:	$A_{BSL,i,t}$
Data unit:	ha
Description:	Area of baseline stratum *i* in year *t*
Equations	2, 7, 8, 11, 14, 26, 27, 43
Source of data:	Own assessment
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures	Delineation of strata must be done preferably using a geographical information system (GIS), which allows for integrating data from different sources (including GPS

applied:	coordinates and remote sensing data). Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of baseline emissions
Comments:	In Equations 2, 7, 8 and 11 the parameter is denoted as $A_{BSL,i,t100}$, which is the area of baseline stratum *i* at *t*=100.

Data Unit / Parameter:	R_j
Data unit:	t root d.m. t^{-1} shoot d.m.
Description:	Root:shoot ratio for tree species *j*
Equations	17, 33
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g., from national GHG inventory); (b) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes b) might be preferable to a); (c) Species-specific or group of species-specific from global studies. See also IPCC GPG 2003, Annex 3.A1, Table 3A1.8
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Taken from CDM A/R methodology
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	

Data Unit / Parameter:	CF_j
Data unit:	t C t $d.m.^{-1}$
Description:	Carbon fraction of dry matter for species *j*
Equations	19, 22, 23, 31, 34
Source of data:	IPCC default value

Value applied:	0.5
Justification of choice of data or description of measurement methods and procedures applied:	IPCC is a reputable source approved by the VCS
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$I_{v,j,i,t}$
Data unit:	$m^{-3}ha^{-1}yr^{-1}$
Description:	Average annual increment in merchantable volume for species *j* in stratum *i* in year *t*
Equations	20
Source of data:	Based on monitored parameters (species, yield class, age) to be found in regional forest growth tables.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Common source of data in forestry
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

Data Unit / Parameter:	D_j
Data unit:	t d.m. m^{-3}
Description:	Basic wood density for species *j*
Equations	20, 22, 31
Source of data:	Datasets or literature
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Values for D_j can be taken from tables generally used in the local or regional timber and forest industry, or from peer-reviewed literature applicable to the region. If no species-specific values for D_j are available, the average value across all species can be used, increased by 20% to ensure conservative estimates in the baseline, or decreased by

	20% to ensure conservative estimates in the project scenario. The source of data must be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g., from national GHG inventory); (b) (Group of) Species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (e.g., IPCC GPG-LULUCF 2003). This is taken from a CDM A/R methodology.
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$BEF_{1,j}$
Data unit:	dimensionless
Description:	Biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j*
Equations	20
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: a. Existing local and species-specific or group of species-specific; b. National and species-specific or group of species-specific (e.g., from national GHG inventory) c. Species-specific or group of species-specific from neighbouring countries with similar conditions (might be preferable to b under certain conditions) d. Climatic zone and forest type (eg IPCC literature: Table 3A.1.10 of the GPG-LULUCF (IPCC 2003) and Table 4.5 of the AFOLU Guidelines (IPCC 2006)
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures	Taken from CDM A/R methodology

applied:	
Purpose of Data	Calculation of baseline emissions
Comments:	*BEFs* are age dependent, and they are usually large for young stands and quite small for old stands; *BEFs* in IPCC literature and national inventory data are usually applicable to closed canopy forest. If applied to individual trees growing in open field it is recommended that the selected *BEF* be increased by a further 30%.

Data Unit / Parameter:	K_{ph}
Data unit:	dimensionless
Description:	Alexeyev coefficient, converts volumes of above ground growing stock (m^3ha^{-1}) to above, below ground and bark dry biomass (t d.m. ha^{-1})
Equations	-
Source of data:	Alexeyev *et al*. (1995). Carbon in vegetation in Russian forests: methods to estimate storage and geographical distribution. Water, Air Soil Pollution 82: 271-282
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Peer-reviewed literature is a VCS-approved source
Purpose of Data	Calculation of baseline emissions
Comments:	May be used instead of R_j and BEF_j

Data Unit / Parameter:	$V_{j,i,t}$
Data unit:	m^3 ha^{-1}
Description:	Stem volume of tree species *j* in stratum *i* in year *t*
Equations	22
Source of data:	Datasets or literature
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures	Common source of data in forestry

applied:	
Purpose of Data	Calculation of baseline emissions
Comments:	Note that volume tables from which $V_{j,i,t}$ are obtained may or may not include allowance for losses due to harvesting or mortality. Such losses may be conservatively neglected when estimating baseline removals in pre-project trees. Otherwise $C_{BSL\text{-}tree\text{-}AB,j,i,t}$ must be estimated on the basis of credible and transparent information on the rate at which pre-project activities (and mortality, if applicable) are reducing carbon stocks in existing live trees (e.g., due to harvesting for local timber consumption, or for fuelwood).

Data Unit / Parameter:	BEF_{2j}
Data unit:	dimensionless
Description:	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*
Equations	22, 31
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: a. Existing local and species-specific or group of species-specific; b. National and species-specific or group of species-specific (e.g., from national GHG inventory) c. Species-specific or group of species-specific from neighbouring countries with similar conditions (might be preferable to b under certain conditions) d. Climatic zone and forest type (e.g., IPCC literature: Table 3A.1.10 of the GPG-LULUCF (IPCC 2003) and Table 4.5 of the AFOLU Guidelines (IPCC 2006)
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Taken from CDM A/R methodology
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	

Data Unit / Parameter:	$nTR_{j,i,t}$
Data unit:	trees ha^{-1}
Description:	Tree stand density of species *j* in stratum *i* in year *t*
Equations	23
Source of data:	Field measurement in sample plots or from forest inventory
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

Data Unit / Parameter:	$f_j(X, Y, \ldots)$
Data unit:	t d.m. tree^{-1}
Description:	Allometric equation for species *j* linking measured tree dimension variables (e.g., diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees.
Equations	23
Source of data:	Own measurements or literature, or both
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	The allometric equations are preferably locally derived and species specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of IPCC GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area but outside the sample plots, a few trees of different sizes and estimate their biomass and then compare against a selected equation. If the biomass estimated from the harvested trees is within about □1 by the equation, then it can be assumed that the selected equation is suitable for the project. If this is not the case, it is recommended to develop local allometric equations for the project use. For this, a sample of trees, representing different size classes, is destructively harvested, and its total biomass is determined. The number of trees to be destructively harvested and measured depends on the

	range of size classes and number of species—the greater the heterogeneity the more trees are required.
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	Used for trees known at validation

Data Unit / Parameter:	$GHG_{GESTbsl\text{-}CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CO_2 from baseline GEST in stratum *i* in year *t*
Equations	26, 43
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	See Section 9.3.6 for procedures to describe and quantify this proxy.
Comments:	This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$GHG_{WLbsl\text{-}CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CO_2 related to water table depth in the baseline scenario in stratum *i* in year *t*
Equations	27
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	See Section 9.3.6 for procedures to quantify this proxy. The project may establish project-specific values for $GHG_{WLbsl\text{-}CO2}$ or apply values from appropriate literature sources pertaining to land use classes, or water table depths or water table depth classes and similar project circumstances. For such literature values the accuracy must be defined or conservativeness must be justified. Project circumstances are defined by pre-project land use (e.g., forestry, peat mining, agriculture, abandonment after such

	activities) and its intensity, climatic zone, water table depths, and peat type. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.
Purpose of Data	Calculation of baseline emissions
Comments:	This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$GHG_{GESTbsl\text{-}CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CH_4 from baseline GEST in stratum *i* in year *t*
Equations	26, 43
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	See Section 9.3.6 for procedures to describe and quantify this proxy.
Purpose of Data	Calculation of baseline emissions
Comments:	This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$GHG_{WLbsl\text{-}CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CH_4 related to water table depth in the baseline scenario in stratum *i* in year *t*
Equations	27
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	See Section 9.3.6 for procedures to quantify this proxy. The project may establish project-specific values for $GHG_{WLbsl\text{-}CH4}$ or apply values from appropriate literature sources pertaining to land use classes, or water table

	depths or water table depth classes and similar project circumstances. For such literature values the accuracy must be defined or conservativeness must be justified. Project circumstances are defined by pre-project land use (e.g., forestry, peat mining, agriculture, abandonment after such activities) and its intensity, climatic zone, water table depths, and peat type. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used. $GHG_{WLbsl\text{-}CH4}$ may be conservatively neglected.
Purpose of Data	Calculation of baseline emissions
Comments:	This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$V_{l,j,j,sp,t}$
Data unit:	m^3 $tree^{-1}$
Description:	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i* in year *t*
Equations	35
Source of data:	$V_{l,j,j,sp,t}$ is based on available equations or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate).
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Common source of data in forestry
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

Data Unit / Parameter:	$A_{peatburn}$
Data unit:	ha

Description:	Cumulative area burnt
Equations	50
Source of data:	Statistics and/or maps in official reports and/or remotes sensing data
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	The cumulative area burnt must be provided using statistics and/or maps in official reports and/or remotes sensing data. Repeated burning of the same area adds to the cumulative area. Delineation of the project area must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

Data Unit / Parameter:	A_P
Data unit:	ha
Description:	Total project area
Equations	49, 50
Source of data:	Own assessment
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Delineation of the project area must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

9.2 Data and Parameters Monitored

Data Unit / Parameter:	$A_{WPS,i,t}$
Data unit:	ha
Description:	Area of project stratum *i* in year *t*
Equations:	2, 7, 8, 11, 30, 40, 43
Source of data:	Own assessment
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Delineation of strata must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Frequency of monitoring/recording:	Determined at each monitoring period
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	In Equations 2, 7, 8 and 11 the parameter is denoted as $A_{WPS,i,t100}$, which is the area of project stratum *i* at *t*=100.

Data Unit / Parameter:	$A_{sp,i}$
Data unit:	ha
Description:	Total area of all sample plots in stratum *i*
Equations:	37
Source of data:	Field measurements
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Sample plots may be delineated on a map using a Geographical Information System (GIS). Alternatively, coordinates of sample plots map be stored in a GIS. The database must contain information on plot size and orientation. Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.

Frequency of monitoring/recording:	Determined at first monitoring period
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$f_j(X, Y, \ldots)$
Data unit:	t d.m. tree^{-1}
Description:	Allometric equation for species *j* linking measured tree dimension variables (e.g., diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees.
Equations:	38
Source of data:	Own measurements or literature, or both
Value applied:	n/a
Description of measurement methods and procedures to be applied:	The allometric equations are preferably locally derived and species specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of IPCC GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area but outside the sample plots, a few trees of different sizes and estimate their biomass and then compare against a selected equation. If the biomass estimated from the harvested trees is within about 10% of that predicted by the equation, then it can be assumed that the selected equation is suitable for the project. If this is not the case, it is recommended to develop local allometric equations for the project use. For this, a sample of trees, representing different size classes, is destructively harvested, and its total biomass is determined. The number of trees to be destructively harvested and measured depends on the range of size classes and number of species—the greater the heterogeneity the more trees are required.
Frequency of monitoring/recording:	Determined at first monitoring period
QA/QC procedures to be applied:	See Section 9.3.2

Purpose of Data:	Calculation of project emissions
Comments:	Used for trees monitored

Data Unit / Parameter:	*DBH*
Data unit:	cm
Description:	Diameter at breast height of tree
Equations:	38
Source of data:	Field measurement in sample plots
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Measure all the trees above 5 cm DBH at typically 1.3 m above-ground level in the permanent sample plots. Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Frequency of monitoring/recording:	Determined at each monitoring period
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	*H*
Data unit:	m
Description:	Height of tree
Equations:	38
Source of data:	Field measurement in sample plots
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Frequency of	Determined at each monitoring period

monitoring/recording:	
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$GHG_{GESTwps\text{-}CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CO_2 from project GEST in stratum *i* in year *t*
Equations:	40, 43
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Description of measurement methods and procedures to be applied:	See Section 9.3.6 for procedures to quantify this proxy.
Frequency of monitoring/recording:	See Section 9.3.6
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$GHG_{GESTwps\text{-}CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CH_4 from project GEST in stratum *i* in year *t*
Equations:	40, 43
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Description of measurement methods and procedures to be applied:	See Section 9.3.6 for procedures to quantify this proxy.
Frequency of monitoring/recording:	See Section 9.3.6

QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$GHG_{WLwps\text{-}CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CO_2 related to water table depth in the project scenario in stratum *i* in year *t*
Equations:	41
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Description of measurement methods and procedures to be applied:	See Section 9.3for procedures to quantify this proxy. The project may establish project-specific values for $GHG_{WLwps\text{-}CO2}$ or apply values from appropriate literature sources pertaining to land use classes, or water table depths or water table depth classes. For such literature values the accuracy must be defined or conservativeness must be justified. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.
Frequency of monitoring/recording:	See Section 9.3.5
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$GHG_{WLwps\text{-}CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CH_4 related to water table depth in the project scenario in stratum *i* in year *t*
Equations:	41

Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Description of measurement methods and procedures to be applied:	See Section 9.3.6 for procedures to quantify this proxy. The project may establish project-specific values for $GHG_{WLwps-CH4}$ or apply values from appropriate literature sources pertaining to land use classes, or water table depths or water table depth classes. For such literature values the accuracy must be defined or conservativeness must be justified. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.
Frequency of monitoring/recording:	See Section 9.3.6
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	Water table depth
Data unit:	cm
Description:	Sub-soil or above soil surface of water, relative to the soil surface
Equations:	-
Source of data:	Own measurements
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Procedures for water table depth measurements are provided in Section 9.3.6.
Frequency of monitoring/recording:	See Section 9.3.6
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	Used in Section 9.3.4

Data Unit / Parameter:	*t2* and *t1*
Data unit:	yr
Description:	Years of the monitoring activity
Equations:	63, 64
Source of data:	Field measurement in sample plots
Value applied:	n/a
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Determined at each monitoring period
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	$T = t2 - t1$

9.3 Description of the Monitoring Plan

9.3.1 General

The main objective of project monitoring is to reliably quantify carbon stocks and GHG emissions in the project scenario during the project crediting period, prior to each verification, with the following main tasks:

- Monitoring of project carbon stock changes and GHG emissions
- Estimation of ex-post total net carbon stock changes and greenhouse gas emissions, and GHG emissions reductions

The monitoring plan must contain at least the following sections:

- A description of each monitoring task to be undertaken, and the technical requirements
- Parameters to be measured
- Data to be collected and data collection techniques
- Frequency of monitoring
- Quality Assurance and Quality Control (QA/QC) procedures
- Data archiving procedures
- Roles, responsibilities and capacity of monitoring team and management

9.3.2 Uncertainty and quality management

Quality management procedures are required for the management of data and information, including the assessment of uncertainty, relevant to the project and baseline scenarios. As far as practical, uncertainties related to the quantification of GHG emission reductions and removals by sinks should be reduced.

To help reduce uncertainties in the accounting of emissions and removals, this methodology uses whenever possible the proven methods from the GPG-LULUCF, GPG-2000, the IPCC's Revised 2006 Guidelines and peer-reviewed literature. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from input parameters would result in uncertainties in the estimation of both baseline net GHG emissions and project net GHG emissions - especially when global default values are used. The project proponent must identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values should be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources[27]; or,
- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or
- In the absence of the above sources of information, expert opinion (see Section 9.3.3) may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be briefly noted in the project documentation.

In choosing key parameters, or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, project proponents must select values that will lead to an accurate estimation of net GHG emission reductions, taking into account uncertainties.

If uncertainty is significant, project proponents must choose data such that it indisputably tends to under-estimate, rather than over-estimate, net GHG project benefits. For example, conservativeness in GHG emission reductions based on GESTs could be established by applying too low flux values to GESTs in the baseline. The conservativeness of the value (e.g., applying the value of the next wetter GEST), or any alternative way of ensuring conservativeness, must be demonstrated.

To ensure that carbon stocks are estimated in a way that is accurate, verifiable, transparent, and consistent across measurement periods, the project proponent must establish and document

[27] Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date etc (or a detailed web address). If web-based reports are cited, hardcopies should be included as annexes in the project documentation if there is any likelihood such reports may not be permanently available.

clear standard operating procedures and procedures for ensuring data quality. At a minimum, these procedures must include:

- Comprehensive documentation of all field measurements carried out in the project area. This document must be detailed enough to allow replication of sampling in the event of staff turnover between monitoring periods.
- Training procedures for all persons involved in field measurement or data analysis. The scope and date of all training must be documented.
- A protocol for assessing the accuracy of plot measurements using a check cruise and a plan for correcting the inventory if errors are discovered.
- Protocols for assessing data for outliers, transcription errors, and consistency across measurement periods.
- Data sheets must be safely archived for the life of the project. Data stored in electronic formats must be backed up.

9.3.3 Expert judgment

Expert judgment on methodological choice and choice of input data and to fill gaps in the available data, to select data from a range of possible values or on uncertainty ranges is well established in the IPCC 2006 good practice guidance. Obtaining well-informed judgments from domain experts regarding best estimates and uncertainties of inputs to the quantification of emission reductions is an important aspect in various procedures throughout this methodology. Project proponents must use the guidance provided in Chapter 2, Volume 1 (Approaches to Data Collection), in particular, Section 2.2 and Annex 2A.1 of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

9.3.4 Monitoring of project implementation

Information must be provided, and recorded in the project documentation to establish that:

a) The geographic position of the project boundary is recorded for all areas of land. The geographic coordinates of the project boundary (and any stratification or buffer zones inside the boundary) are established, recorded and archived. This can be achieved by field survey (e.g., using GPS), or by using georeferenced spatial data (e.g., maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images).

   The above also applies to the recording of strata, including strata resulting from peatland fires in the project scenario (Section 8.3).

b) Commonly accepted principles of land use inventory and management are implemented such as the following:

   - Standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for inventories including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national land use monitoring, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended;

- Apply SOPs, especially, for actions likely to cause peat disturbances;
- The project plan, together with a record of the plan as actually implemented during the project must be available for validation or verification, as appropriate.

Continued compliance with the applicability conditions of this methodology must be ensured by monitoring that:

- Burning of biomass within the project boundary in the project scenario does not occur. Small and isolated events (with *de minimis* effects on GHG emissions'), although not permitted, do not fail the project.
- Peatland fires within the project boundary do not occur in the project scenario. If they occur as non-catastrophic events as defined in this methodology, they are accounted for by cancelling the *Fire Reduction Premium* for the entire project or the individual sub-project.
- Water leakage, if occurring, is limited to accidents that can be repaired (e.g., the breaching of a dam). Such accidents and their remediation must be monitored together with justifications that the effect has been temporal and insignificant and has not caused the dieback of woody vegetation in adjacent areas.
- N-fertilizers are not used within the project boundary in the project scenario.

The effectiveness of buffer zones must be demonstrated. This must be done using water level gauges or vegetation assessments (see Section 9.3.6 for procedures), or a combination of these.

a) If a buffer zone has been established, water level gauges must be installed at the boundary of the buffer zone (outer boundary if used against leakage, inner boundary if used against drainage activities outside the project area) and readings must be compared with the hydrological modeling results or expert judgment on which the establishment of the buffer zone was based. The number and spacing of water level gauges must be based on hydrological modeling or expert judgment. Alternatively, a GEST vegetation assessment must be performed in the buffer zone. Results for vegetation types adjacent to the project boundary are compared with the vegetation composition in the same area at project start.

b) In the case of an impermeable dam, to demonstrate its effectiveness, water level gauges must be located outside the dam (if used against leakage) or inside the dam (if used against effects of drainage outside the project boundary). Placing gauges outside the boundary may require agreements with adjacent landowners if the dam is located on the project boundary. Alternatively, a vegetation assessment must be performed in a strip adjacent to and outside the project boundary (leakage) or inside the boundary (outside drainage effects). The width of this strip is determined by the size of the area with homogeneous GEST characteristics nearest to the boundary. Results are compared with the vegetation composition in the same zone at project start.

c) In absence of a buffer zone or an impermeable dam (e.g., in case pump-drained systems are rewetted), water level gauges must be installed or vegetation assessed as described in (a) above, or the proponent must justify in the project documentation that such measurements can be omitted.

9.3.5 Stratification and sampling framework

Stratification of the Project Area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. Project proponents must present in the project documentation an *ex-ante* stratification of the Project Area or justify the lack of it. The number and boundaries of the strata defined *ex ante* may change during the project crediting period (*ex post*).

The *ex-post* stratification must be updated because of the following reasons:

- Unexpected disturbances occurring during the project crediting period (e.g., due to changes in the hydrology, fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;
- Management activities (forestry, agriculture, hydrology) that are implemented in a way that affects the existing stratification.

  Established strata may be merged if the reasons for their establishment have disappeared.

The sampling framework, including sample size, plot size, plot shape, and determination of plot location must be specified in the project documentation. Where changes in carbon stocks are to be monitored (i.e., in trees), permanent sampling plots are used, noting the following:

1) To determine the sample size and allocation among strata, this methodology uses the procedures in Section 9.3.5 and the latest version of the tool for the “Calculation of the number of sample plots for measurements within A/R CDM project activities”, approved by the CDM Executive Board. The targeted confidence interval must be 90% or 95%. Where a 90% confidence interval is adopted and the width of the confidence interval exceeds 20% of the estimated value or where a 95% confidence interval is adopted and the width of the confidence interval exceeds 30% of the estimated value, an appropriate confidence deduction must be applied, as outlined in Section 8.5.2.
2) In order to avoid bias, sample plots should be marked inconspicuously.
3) The sample plot size must be established according to common practice in forest and vegetation inventories.
4) To avoid subjective choice of plot locations, the permanent sample plots must be located either systematically with a random start or completely randomly inside each defined stratum. The geographical position (GPS coordinate), administrative location, stratum and stand, series number of each plot, as well as the procedure used for locating them

must be recorded and archived. The sampling plots are to be as evenly distributed as possible, where larger strata have more plots than smaller strata. However, remote areas and areas with poor accessibility may be excluded for the location of sampling plots. Such areas must be mapped as separate strata and for these strata accounting of carbon stocks in tree biomass in the project scenario is conservatively omitted (Section 8.2.2).

Guidance on plot size for GEST assessments is provided under "Assessing the spatial distribution of GESTs" in Section 9.3.6.

The choice of monitoring frequency must be justified in the project documentation.

9.3.6 Estimating GHG emissions on the basis of GESTs and water table depth

A GEST-indication system is based on a meta-analysis of published and other data of GHG fluxes (emissions or removals) in relation to site characteristics of a wide range of sites in a specific biogeographic and climatic region (Couwenberg *et al.*, 2011). For the analysis of GHG fluxes, only data on yearly net fluxes, based on year-round measurements or on sound model extrapolations are used. With respect to CO_2 fluxes, care has to be taken to include only net CO_2 balances (NEE or NEP) from reliable models using light and dark fluxes as input. The meta-analysis of data is used for the following:

- Classify vegetation data and GHG flux characteristics in a way that the distinguished vegetation types optimally indicate GHG fluxes;
- Develop regression models between GHG fluxes and mean annual water table depth (as this is the prime explanatory variable for annual GHG fluxes from peatland) in order to allow a triangular verification crosscheck between independent datasets: (i) flux data related to the vegetation types, (ii) flux data related to water table depths and (iii) vegetation types related to water table depths.

<u>Determining CO_2 and CH_4 emissions</u>

For project-specific flux values the project proponent may carry out direct measurements of GHG fluxes, such as closed chamber and eddy covariance measurements. Applied techniques must follow international standards of application as laid out in pertinent scientific literature (e.g., Matson & Harriss, 1995, Pattey *et al*. 2006, Alm *et al*. 2007, Evans *et al*. 2011).

<u>Determining GESTs</u>

GESTs can be classified and specified with respect to their GHG flux values using the following step-wise protocol for meta-analysis of collected data (cf. Couwenberg *et al.*, 2011):

1) Develop regression models between GHG fluxes and mean annual water table depth on the basis of all available data from the relevant biogeographic and climatic region;
2) Classify relevant vegetation types that are actually found and potentially expected in the region on the basis of plant species or species groups indicative for water table depth,

using for example the bio-indication data of Ellenberg *et al.* (1992) and Koska *et al.* (2001);

3) Compare the distinguished vegetation types with the vegetation data from sites in the relevant region for which reliable GHG flux data are available. If vegetation of a type is sufficiently similar (e.g., with respect to presence and absence of species groups (Koska, 2007; Koska *et al.* 2001); similarity is defined on the basis of floristic composition or plant functional types and expert judgment and must be justified) to vegetation for which the GHG flux values are reported in literature, the range of GHG values from literature is ascribed to the type;

4) The results of step 3 may be verified and refined by comparing the water table depth data (acquired from field observation, vegetation form indication (Koska *et al.* 2001) and/or Ellenberg values) of the sites used under Step 3 above with the regression models from Step 1 above to verify and refine the flux values found under Step 3 above. After verification and refinement of the flux values, the vegetation type is a GEST.

5) In case a distinguished vegetation type does not have sufficient similarity (see above) with vegetation described in GHG literature, use the mean annual water table depth data and the regression models to establish its preliminary flux values.

6) Optimize the GHG flux value of the vegetation type by expert judgment using the matrix of all distinguished vegetation types and taking into account the emission-relevant site characteristics of the vegetation type (incl. the proportion of shunt species in case mean water table depths are higher than 20 cm below surface; water table depth, soil reaction, C/N of the peat, type and intensity of land use) and the emission and site characteristics of related vegetation types. As soon as the GHG flux values of a type can be consistently and unequivocally defined, the type is considered a GEST (Table 3), independent from the deduced range of GHG fluxes. Later expansion of the GHG flux/vegetation dataset may lead to further refining the GESTs and to narrowing GHG flux ranges.

7) Flux values associated with vegetation types must comply with QA/QC requirements outlined in Section 9.3.2 and are subject to the uncertainty assessment. Where an uncertainty value is not known or cannot be simply calculated the project proponent must justify that a conservative value is used.

The results of this procedure must be described in the project documentation. An example of this can be found in Table 9.1 below.

Table 9.1: Example of GESTs Related to Water Table Depth Class and CH_4 and CO_2 Emission Values (after Couwenberg *et al.* 2008, 2011).

GEST	Typical/differentiating species	Water table depth class	CO_2 emission t CO_2e $ha^{-1}yr^{-1}$	CH_4 emission t CO_2e $ha^{-1}yr^{-1}$	Reference
Moist bog heath	*Calluna, Vaccinium myrt., Ledum + Dicranum scop., Pleurozium* (+ *Molinia*)	Moist	12.5	0	Couwenberg et al. 2008, 2011
Wet reeds and sedge fens	*Carex paniculata, Epilobium hirsutum, Lycopus, Lythrum, Berula erecta*	Wet	-4	12.5	Couwenberg et al. 2008, 2011

Water table depth classes refer to water supply: +: wetlands and aquatic habitats; -: non-hydric terrestrial habitats. They are characterised by: WLw: long-term median water table depth wet season; WLd: long term median water table depth dry season; and WD: water supply deficiency. Seasonally alternating wetness is indicated by a combination of different water table depth classes (e.g., 5+/4+ refers to a WLw within 5+ range and a WLd within 4+ range). Strongly alternating wetness is indicated by a tilde-sign (e.g., 3~ refers to a WLw within 4+ range and a WLd within 2+ range).

Class		Water table depth related to surface (+ above, - below)
7+	Upper sublitoral	WLm: +250 to +140 cm
6+	Lower eulitoral	WLm: +140 to +20 cm
5+	Wet (upper eulitoral)	WLm: +20 to 0 cm
4+	Very moist	WLm: 0 to -20 cm
3+	Moist	WLm: -20 to -45 cm
2+	Moderately moist	WLm: -45 to -80 cm
2-	Moderately dry	WD: < 60 l/m²
3-	Dry	WD: 60 – 100 l/m²
4-	Very dry	WD: 100 – 140 l/m²
5-	Extremely dry	WD: > 140 l/m²

Assessing the spatial distribution of GESTs

For assessing the spatial distribution of GESTs in the field, project proponents must apply the following procedure:

1) Map units of more or less homogenous vegetation using common approaches (incl. remote sensing, see Box) and specify mapping resolution. Use units larger than 3000 m^2. Include areas < 3000 m^2 with deviating vegetation in an adjacent mapping unit, when the water table depth is identical and the soil relief differences smaller than 1 dm. Map strongly deviant units (much higher, much lower, forested, open spots in forest) > 1000 m^2 but < 3000 m^2 separately. Include deviant areas < 1000 m^2 in the adjacent mapping unit to which it is most related.
2) Map vegetation units < 3000 m^2 with soil relief differences of more than 1 decimeter (fine-scaled peat extraction sites, string/flark and hummock-hollow complexes) to mosaic mapping units > 3000 m^2. Describe their relief pattern (i.e. proportion, extent and height of various elements).
3) Assess within each mapping unit the cover of the living parts of “shunt species” (see Box) in five cover classes: 0-20%, 20-40%, 40-60%, 60-80%, 80-100%.
4) Mark the borders of the mapping units with GPS waypoints or track-routes or depict borders directly on a topographical map or aerial picture (with GPS reference points).
5) Record relevés (5 m × 5 m) of characteristic homogenous vegetation in each mapping unit to facilitate later (a posteriori) identification of the GESTs.
6) Assign the herb layer of shrub or tree-dominated peatland to non-forested vegetations types.

This procedure must be applied for both the pre-project spatial distribution of GESTs and monitoring. When monitoring, assess whether the range of GESTs with their specific GHG emission levels as obtained in Section 8.1.3.1sufficiently covers the vegetation types expected in the project scenario. If not, expand the system using the same procedure by collecting more literature or field data

Shunt species

Shunt species are species with aerenchyma (open stem and root tissue) that pump air into the rhizosphere and transport methane from the anaerobic soil layer directly into the atmosphere. As a consequence, an area with many shunt species may have a two times higher methane emission than other areas with a similar water table depth. Important shunt species are: *Blysmus* species, *Bolboschoenus* species, *Carex* species (tall and small sedges), *Cladium mariscus*, *Eleocharis* species, *Eriophorum angustifolium*, *Eriophorum vaginatum*, *Juncus* species, *Scheuchzeria palustris*, *Schoenoplectus* species, *Scirpus* species.

Vegetation mapping with high spatial resolution satellite imagery, for example:

- Use satellite imagery with a minimum spatial resolution of 5 m × 5 m and a minimum of four spectral channels, which includes visible and at least one infrared band.
- Derive the mapping units by vegetation indexes analysis or a simple unsupervised classification.

- Select in every mapping unit three random points for vegetation analysis (e.g., ISODATA classification).
- In each clearly distinguished mapping unit select three centrally located points for vegetation analysis.
- Visit these points and record representative vegetation relevés (using high accuracy GPS devices and record water table depth).
- Conduct a supervised classification (e.g., a maximum likelihood classification of 90%), minimum distance classifier or spectral angle mapper, if necessary include vegetation indexes.
- To improve the classification result, high quality geo-referencing is favourable and training areas can be added/removed on the base of site knowledge; the training areas or regions of interest based on groundtruthing data should be outlined on minimum 5 pixels
- Relate the classes to vegetation forms or additional vegetation types based on relevés and site knowledge.
- Conduct an accuracy assessment, by checking the classification result via visiting additional ground control points. These additional points must be selected so that each class is represented by more than one point. Accuracy must be at least 60%, any activities to increase the accuracy are recommended.

Deriving time series of GEST development for each stratum for the entire project crediting period

Predict (*ex ante*), based on vegetation succession schemes in drained and rewetted peatlands from scientific literature or expert judgment, or monitor GESTs (*ex post*), for each stratum and for the entire project crediting period, the development of GESTs over time by defining a time series of GESTs, with time steps of a reasonable time period (e.g., 5 years) to allow for the inherent discrete character of the GESTs.

Determining annual GHG emissions per stratum for the entire project crediting period

Obtain annual GHG emissions per stratum by extrapolation between the typical emissions of two subsequent GESTs in a time series. Extrapolation can be linear, skewed, or conservative. If the chosen interpolation method is not inherently conservative, the project proponent must provide conclusive argumentation why the chosen method would apply.

For each stratum, the annual results can be reported in the formatting of Table 9.2. Italics indicate interpolated values.

Table 9.2: Time Series of Emissions from GESTs.

Year	Stratum 1	Total emissions t CO_2e yr^{-1}
1	GEST1	15
2		*16*
3		*17*

4		*18*
5	GEST2	19
…		…
…		…
15	GEST3 | GEST4	22*
…		…

* Area-weighted average of GEST 3 and GEST 4 emissions. Stratum 1 is subdivided into 1a and 1b.

For areas for which the vegetation composition does not provide a clear indication of GHG emissions (bare peat, transient phases of vegetation development after rewetting) water table depth measurements must be used as additional input to assess GHG fluxes. However, project proponents may also opt to choose water table depth as a proxy for the entire project area.

Strata can be defined on the basis of (amongst others) water table depth (e.g., at 0 cm defining a level of zero emissions, a deep water table depth defining the high end of emissions, and arbitrary levels in between, or expected changes in these). Water table depths or water table depth classes (e.g., 0-10 cm, 11-20 cm, etc.) can be used, depending on data availability.

Water table depth measurements can be continuous with data loggers and using min-max devices (Bragg *et al*., 1994) or simple water level gauges.

Normally, the vegetation mapping can be conducted during the entire vegetation period. The water table depth measurements must be done at least throughout the seasons (spring to winter) to capture seasonal variation. The frequency of monitoring vegetation changes must be based on expert judgment, taking into account expected and observed changes in vegetation composition upon rewetting. A recommended monitoring schedule for temperate climate zones is provided below:

- Mapping vegetation types: before rewetting, 2nd year after rewetting, 5th year after rewetting, then every 5th year after rewetting
- Monitoring water table depth: continuously from 1 year before rewetting, to the end of the project crediting period.

9.3.7 Monitoring of fire events in the project scenario

As laid out in Section 8.3, if peatland rewetting and a best-practices fire management have been implemented, peat fires occurring in the project scenario can be assumed to be catastrophic events. If such fires occur, the project proponent must demonstrate that rewetting and fire management have been carried out as proposed at validation. Peat losses associated with such fires must be added to the *ex-ante* estimate of peat loss in the project scenario as they may affect the number of eligible credits (Section 5.2 – Peatland areas eligible for carbon crediting). The assessment of peat losses must follow the fire-specific procedures and criteria used to derive $Rate_{peatloss\text{-}BSL}$ (Section 9.1).

10 REFERENCES

Alexeyev, V., Birdsey, R., Stakanov, V., Korotkov, I. (1995). Carbon in vegetation in Russian forests: methods to estimate storage and geographical distribution. Water, Air Soil Pollution 82: 271-282.

Alm J., Shurpali N. J., Tuittila E.-S., Laurila T., Maljanen M., Saarnio S. & Minkkinen K. 2007. Methods for determining emission factors for the use of peat and peatlands -flux measurements and modelling. Boreal Environment Research 12: 85-100.

Ballhorn U., Siegert F., Mason M. & S. Limin (2009). Derivation of burn scar depths and estimation of carbon emissions with LIDAR in Indonesian peatlands. Proc Natl Acad Sci USA, Vol. 106 no. 50, 21213-21218

Couwenberg, J., J. Augustin, D. Michaelis & H. Joosten (2008). Emission Reductions from Rewetting of Peatlands. Towards a Field Guide for the Assessment of Greenhouse Gas Emissions from Central European Peatlands. Duene/RSPB, Greifswald/Sandy.

Couwenberg, J., Thiele, A., Tanneberger, F., Augustin, J., Bärisch, S., Dubovik, D., Liashchynskaya, N., Michaelis, D., Minke, M., Skuratovich, A. & Joosten, H. (2011). Assessing greenhouse gas emissions from peatlands using vegetation as a proxy. Hydrobiologia, 674, 67-89.

Couwenberg J., Dommain R., Joosten H. (2010). Greenhouse gas fluxes from tropical peatlands in south-east Asia. Global Change Biology, 16, 1715-1732.

Ellenberg H, Weber HE, Düll E, Wirth V, Werner W, 1992. Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica, 18, 1–258.

Evans, C., Worrell, F., Holden, J., Chapman, P., Smith, P. & Artz, R. 2011. A programme to address evidence gaps in greenhouse gas and carbon fluxes from UK peatlands. JNCC Report No. 443.

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Koska, I., 2007. Weiterentwicklung des Vegetationsformenkonzeptes. Ausbau einer Methode für die vegetationskundliche und bioindikative Landschaftsanalyse, dargestellt am Beispiel der Feuchtgebietsvegetation Nordostdeutschlands. PhD thesis, Greifswald University, Greifswald.

Koska, I., Succow, M., Clausnitzer, U., Timmermann, T. & Roth, S. (2001). Vegetationskundliche Kennzeichnung von Mooren (topische Betrachtung). In Succow, M. & Joosten, H. (eds), Landschaftsökologische Moorkunde. Schweizerbart, Stuttgart: 112–184.

Matson PA & Harriss RC (eds) 1995. Biogenic Trace Gases: Measuring Emissions from Soil and Water. Blackwell Science, Oxford. 394 p.

Pattey E., Edwards G., Strachan I. B., Desjardins R. L., Kaharabata S. and Wagner-Riddle C. 2006 Towards standards for measuring greenhouse gas fluxes from agricultural fields using instrumented towers Can.J. Soil Sci. 86: 373–400.

Stephens JC, Allen LH, Chen E (1984) Organic soil subsidence. In: Man Induced Land Subsidence (ed. Holzer TL), pp. 107–122. Geological Society of America, Boulder.

Van der Werf GR, Dempewolf J, Trigg SN *et al.* (2008) Climate regulation of fire emissions and deforestation in equatorial Asia. Proceedings of the National Academy of Sciences USA, 105, 20350–20355.

Turetsky, M.R., Donahue, W.F. & Benscoter, B.W. (2011). Experimental drying intensifies burning and carbon losses in a northern peatland. Nature Communication 2 Article number: 514; doi:10.1038 / ncomms1523.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	17 July 2017	Initial version released.