3.5 WETLANDS

Wetlands include land that is covered or saturated by water for all or part of the year (e.g. peatland) and that does not fall into the forest land, cropland, grassland or settlements categories defined in Chapter 2 of this report (Section 2.2, Land Categories)[1]. This category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed subdivision and natural rivers and lakes as unmanaged subdivisions. Forest land, cropland, and grassland that are established on peaty or wet soils are addressed in Sections 3.2, 3.3, and 3.4, respectively, of this chapter. Rice paddies are addressed in the Agriculture chapter of the *IPCC Guidelines* and *GPG2000*. Flooding and wetland drainage are included in the *IPCC Guidelines* in Section 5.4.3 Other Possible Categories of Activity.

For purposes of estimating greenhouse gas emissions, it is necessary to distinguish between managed and unmanaged wetlands. In this report, managed wetlands are those in which the water table is artificially changed (e.g. drained peatlands) or those that are created through human activity (e.g., damming a river). Major greenhouse gas emissions from managed wetlands, and the sections of this report in which they are estimated, are summarised in Table 3.5.1.

TABLE 3.5.1
SECTIONS AND APPENDICES
ADDRESSING MAJOR GREENHOUSE GAS EMISSIONS FROM MANAGED WETLANDS IN THIS REPORT

	Peatland	Flooded Land[2]
Wetlands Remaining Wetlands		
CO_2	Appendix 3a.3	Appendix 3a.3
CH_4	Not addressed	Appendix 3a.3
N_2O	Appendix 3a.3	Appendix 3a.3
Land Converted to Wetlands		
CO_2	Section 3.5	Section 3.5
CH_4	Not addressed (drainage and rewetting of forest soils is discussed in Appendix 3a.2)	Covered in Appendix 3a.3 (no distinction is made based on the age of the reservoir)
N_2O	Appendix 3a.3 (drainage and rewetting of forest soils is discussed in Appendix 3a.2)	Covered in Appendix 3a.3 (no distinction is made based on the age of the reservoir)

3.5.1 Wetlands Remaining Wetlands

This category is addressed in Appendix 3a.3 Wetlands Remaining Wetlands: Basis for future methodological development.

3.5.2 Land Converted to Wetlands

In this section, CO_2 emissions associated with either peat extraction or flooding are addressed. The conversion of lands to wetlands may be an important component of national estimates of deforestation (or other nationally important land use conversions). For conversions related to peat extraction, carbon stock changes associated with living biomass and soil are addressed below. For conversions related to flooding, only the carbon stock change associated with the loss of living biomass is addressed.

Lands converted to wetlands include conversions from forest land, cropland, grassland and settlements to this category. The most likely conversions are conversions from forest land to wetlands (e.g. rewetting of peatlands

[1] The definition used in this report agrees with common definitions used in the Ramsar Convention on Wetlands and the Convention on Biological Diversity (CBD).

[2] Flooded lands are defined as water bodies regulated by human activities for energy production, irrigation, navigation, recreation, etc. and where substantial changes in water area due to water regulation occur. Regulated lakes and rivers, where the main pre-flooded ecosystem was a natural lake or river, are not considered as flooded lands. Rice paddies are addressed in the Agriculture Chapter of the *IPCC Guidelines* and *GPG2000*.

drained for forestry purposes), conversions related to peat extraction (conversion of natural peatlands to managed lands), or conversions to flooded land (for hydroelectric or other purposes). Methodologies for rewetting are not included due to the scarcity of available data (Appendix 3a.2 addresses emissions of non-CO_2 greenhouse gases from drainage and rewetting, with emphasis on drainage). As shown in Equation 3.5.1, guidance on estimating carbon stock change in land converted to wetlands covers conversion to two possible land uses: peat extraction and flooding.

EQUATION 3.5.1
CHANGE IN CARBON STOCKS IN LAND CONVERTED TO WETLANDS

$$\Delta C_{LW} = \Delta C_{LW\ peat} + \Delta C_{LW\ flood}$$

Where:

ΔC_{LW} = change in carbon stocks in land converted to wetlands, tonnes C yr^{-1}

$\Delta C_{LW\ peat}$ = change in carbon stocks in land converted to peat extraction (Section 3.5.1), tonnes C yr^{-1}

$\Delta C_{LW\ flood}$ = change in carbon stocks in land converted to flooded land (Section 3.5.2), tonnes C yr^{-1}

The carbon stock change in tonnes C is converted to Gg CO_2 emissions by multiplying the value with 44/12 and 10^{-3} to correspond to the reporting requirements. Emissions are reported as positive values and removals as negative values (Equation 3.5.1 is expected to result in a loss of carbon). For more details on reporting and the rule on the signs, see Section 3.1.7 and Annex 3A.2 (Reporting Tables and Worksheets).

Figure 3.1.2 provides a general decision tree to select the appropriate tier for land conversion and is applicable for land converted to wetlands. If data are available, the choice of tier should be performed separately for each land conversion type (forest land to wetlands, grassland to wetlands, cropland to wetlands, other land to wetlands).

3.5.2.1 CHANGE IN CARBON STOCKS IN LAND CONVERTED TO PEAT EXTRACTION

3.5.2.1.1 METHODOLOGICAL ISSUES

A method to estimate emissions from land converted to peat extraction is given below. Neither emissions from organic soils managed for peat extraction nor land-use changes associated with organic soils managed for peat extraction are dealt with explicitly in the *IPCC Guidelines*. Emissions from peat combustion are dealt with in the Energy section of the *IPCC Guidelines*. Therefore, the method below addresses only emissions from removal of vegetation from land prepared for peat extraction and changes in soil organic matter due to oxidation of peat in the aerobic layer on the land during the extraction. The removal of peat is covered by the estimates from peat combustion in the energy section and is not considered in this section. This method, and the associated default values used for Tier 1 estimates, can be applied for both lands with ongoing peat extraction (to be reported under Wetlands remaining wetlands subcategory) and land converted to peat extraction.

3.5.2.1.1.1 Choice of Method

The estimate of carbon stock changes from land converted to peat extraction has two basic elements, as shown in Equation 3.5.2. Equation 3.5.2 calculates a loss of carbon.

EQUATION 3.5.2
ANNUAL CHANGE IN CARBON STOCKS IN LAND CONVERTED TO PEAT EXTRACTION

$$\Delta C_{LW\ peat} = \Delta C_{LW\ peat_{LB}} + \Delta C_{LW\ peat_{Soils}}$$

Where:

$\Delta C_{LW\ peat}$ = annual change in carbon stocks in land converted to peat extraction, tonnes C yr^{-1}

$\Delta C_{LW\ peat_{LB}}$ = annual change in carbon stocks in living biomass, tonnes C yr^{-1}

$\Delta C_{LW\ peat_{Soils}}$ = annual change in carbon stocks in soils, tonnes C yr^{-1}

It is assumed that the dead organic matter pool is not significant. If a country has data on dead organic matter, it can be included in the estimate under Tier 2 or 3 methods.

Carbon stock changes in living biomass associated with the conversion of land to peat extraction are estimated by Equation 3.5.3.

EQUATION 3.5.3
ANNUAL CHANGE IN CARBON STOCKS IN LIVING BIOMASS IN LAND CONVERTED TO PEAT EXTRACTION

$$\Delta C_{LW\ peat_{LB}} = \Sigma\ A_i \bullet (B_{After} - B_{Before})_i \bullet CF$$

Where:

$\Delta C_{LW\ peat_{LB}}$ = annual change in carbon stocks in living biomass in land converted to peat extraction, tonnes C yr^{-1}

A_i = area of land converted annually to peat extraction from original land use *i*, ha yr^{-1}

B_{Before} = aboveground biomass immediately before conversion to peat extraction, tonnes d.m. ha^{-1}

B_{After} = aboveground biomass immediately following conversion to peat extraction, tonnes d.m. ha^{-1} (default = 0)

CF = carbon fraction of dry matter (default = 0.5), tonnes C (tonnes d.m.)$^{-1}$

The method follows the approach in *IPCC Guidelines* Section 5.2.3 (Forest and Grassland Conversion) and is consistent with the tiered approaches for estimating carbon stock changes in living biomass outlined in Sections 3.2.2, 3.3.2, and 3.4.2. As the equation shows, the amount of living aboveground biomass that is cleared for peat extraction is estimated by multiplying the land area converted annually to peat extraction by the difference in carbon stocks between biomass in the original land use prior to conversion and in the peatland after conversion. Where forests are converted to peatlands and the timber cleared is reflected in harvesting statistics, the latter should be adjusted by the amount of timber harvested from B_{Before} to avoid double-counting.

The default assumption for a Tier 1 estimate of carbon stock changes in living biomass on land converted to peat extraction are that all aboveground biomass present before conversion to peat extraction will be lost in the same year as the conversion takes place and that carbon stocks in living biomass following conversion (B_{After}) are equal to zero. It is *good practice* for countries to estimate the area of land converted to peat extraction from forest, by major forest categories and to use default carbon stock values from Annex 3A.1, Tables of default values for Section 3.2 (Forest land), to develop estimates of B_{Before} for each initial forest category, and each initial other land-use category including unmanaged peatland. Where grassland is the previous land use, default values for aboveground biomass should be taken from Table 3.4.2.

In cases where fires are used to clear vegetation, emissions of non-CO_2 gases, i.e., CH_4 and N_2O will also occur. These emissions can be estimated under Tiers 2 and 3 following guidance provided in Section 3.2.1.4. Drainage of peatland also increases N_2O emissions. These emissions can be estimated following guidance provided in Appendix 3a.3, N_2O emissions from organic soils managed for peat extraction.

CO_2 emissions from soils occur at several stages in the peat process, as shown in Equation 3.5.4.

EQUATION 3.5.4
ANNUAL CHANGE IN CARBON STOCKS IN SOILS IN LAND CONVERTED TO PEAT EXTRACTION

$$\Delta C_{LW\ peat_{Soils}} = \Delta C_{drainage} + \Delta C_{extraction} + \Delta C_{stockpiling} + \Delta C_{restoration}$$

Where:

$\Delta C_{LW\ peat_{Soils}}$ = annual change in carbon stocks in soils in land converted to peat extraction, tonnes C yr^{-1}

$\Delta C_{drainage}$ = annual change in carbon stocks in soils during drainage, tonnes C yr^{-1}

$\Delta C_{extraction}$ = annual change in carbon stocks in soils during peat extraction (excluding the amount of carbon in the extracted peat), tonnes C yr^{-1}

$\Delta C_{stockpiling}$ = annual change in carbon stocks in soils during stockpiling of peat prior to removal for combustion, tonnes C yr^{-1}

$\Delta C_{restoration}$ = annual change in carbon stocks in soils due to practices undertaken to restore previously cultivated lands, tonnes C yr^{-1}

Tier 1: In the case of land converted to peat extraction, only the effect of peat drainage ($\Delta C_{drainage}$) is considered under Tier 1**.** The Tier 1 method relies on basic area identification and default emission factors and the basic method for estimating carbon emissions from organic soils converted to peat extraction is shown in Equation 3.5.5. This equation is applied at an aggregate level to a country's entire area of organic soils converted to peat extraction, divided into nutrient-rich and nutrient-poor, using default emission factors. At this time, it is only possible to provide a method and data for estimating the average changes in carbon stocks associated with peat drainage over longer periods, although the emissions will be higher in the first year of drainage than in later years.

EQUATION 3.5.5
ANNUAL CHANGE IN CARBON STOCKS IN SOILS
DUE TO DRAINAGE OF ORGANIC SOILS CONVERTED TO PEAT EXTRACTION

$$\Delta C_{\text{drainage}} = A_{Nrich} \bullet EF_{Nrich} + A_{Npoor} \bullet EF_{Npoor}$$

Where:

$\Delta C_{\text{drainage}}$ = annual change in carbon stocks in soils due to drainage of organic soils converted to peat extraction, tonnes C yr^{-1}

A_{Nrich} = area of nutrient rich organic soils converted to peat extraction, ha

A_{Npoor} = area of nutrient poor organic soils converted to peat extraction, ha

EF_{Nrich} = emission factor for changes in carbon stocks in nutrient rich organic soils converted to peat extraction, tonnes C ha^{-1} yr^{-1}

EF_{Npoor} = emission factor for changes in carbon stocks in nutrient poor organic soils converted to peat extraction, tonnes C ha^{-1} yr^{-1}

Tier 2: The Tier 2 method can extend the Tier 1 method, if area data and country-specific emission factors are available. In this case, countries may be able to subdivide activity data and emission factors according to peat fertility, peat type and drainage intensity, and/or previous land use or land cover.

Tier 3: Tier 3 methods require statistics on the area of organic soils managed for peat extraction according to site type, fertility, time since drainage, and/or time since restoration, which could be combined with appropriate emission factors, and/or process-based models. Studies utilising information on changes in soil bulk density, carbon content and peat depth could also be used to detect changes in soil C stocks provided the sampling intensity was sufficient and covered the entire peat layer. Such data should be corrected for carbon losses due to dissolved organic carbon leaching, losses of dead organic matter through runoff, or as CH_4 emissions.

3.5.2.1.1.2 Choice of Emission/Removal Factors

Tier 1: When estimating the carbon stock change for organic soils converted to peat extraction under Tier 1, it is *good practice* to use the default emission factors presented in Table 3.5.2.

TABLE 3.5.2
EMISSION FACTORS AND ASSOCIATED UNCERTAINTY FOR ORGANIC SOILS AFTER DRAINAGE

Region/Peat Type	Emission Factor tonne C ha yr^{-1}	Uncertainty [a] tonne C ha yr^{-1}	Reference/Comment [b]
Boreal and Temperate			
Nutrient Poor (EF_{Npoor})	0.2	0 to 0.63	Laine and Minkkinen, 1996; Alm *et al.*, 1999; Laine *et al.*, 1996; Minkkinen *et al.*, 2002
Nutrient Rich (EF_{Nrich})	1.1	0.03 to 2.9	Laine *et al.*, 1996; LUSTRA, 2002; Minkkinen *et al.*, 2002; Sundh *et al.*, 2000
Tropical	2.0	0.06 to 6.0	Calculated from the relative difference between temperate (nutrient poor) and tropical in Table 3.3.5.

[a] Range of underlying data

[b] The boreal and temperate values have been developed as the log-normal mean from a review of paired plot measurements, assuming that conditions on organic soils converted to peat extraction are lightly drained only. Most of the data are from Europe.

Boreal countries that do not have information on areas of nutrient-rich and nutrient-poor peatland areas should use the emission factor for nutrient-poor peatlands. Temperate countries that do not have such data should use the emission factor for nutrient-rich peatland. For tropical countries, only a single default can be provided at this time.

Tier 2: Tier 2 requires country-specific data that takes into account management practices such as drainage of different peat types, and drainage intensity.

Tier 3: Under Tier 3, all parameters should be country-defined using more accurate values rather than the defaults. The literature is sparse and results are sometimes contradictory, so it is *good practice* to derive country-specific emission factors by measurements against appropriate reference virgin sites. Data should be shared between countries with similar environmental conditions.

3.5.2.1.1.3 Choice of Activity Data

Tier 1: The activity data required for all tiers is the area of organic soil converted to peat extraction. For the estimation of carbon stock change from living biomass, this overall area value is used, while for the estimate of carbon stock change from organic soil, a distinction between nutrient-rich and nutrient poor organic soils is needed. Ideally, under Tier 1, countries will obtain national data on the areas converted to peat extraction and their original land uses. Possible sources of such data are national statistics, peat mining companies and government ministries responsible for land use. It can be assumed that the proportion of nutrient-rich versus nutrient-poor soils is similar to the relative importance of these peatland types at national level.

Tier 2: Under Tier 2, countries can incorporate information based on the original land use, peat type and fertility, and intensity of peat disturbance and drainage of the areas of organic soils converted to peat extraction. This information could be gathered from regular updates of the national peatland inventory.

Tier 3: Under Tier 3, detailed information on the original land use, peat type and fertility, and intensity of peat disturbance and drainage of the areas of organic soils converted to peat extraction may be needed. The modeling approach used will determine specific data needs and level of disaggregation.

3.5.2.1.1.4 Uncertainty Assessment

For the estimation of emissions from land conversions to peat, the principal uncertainties are related to area estimates and emission factors.

Tier 1: The sources of uncertainty in the Tier 1 method are from the use of global or national averages for carbon stocks in forests before conversion and coarse estimates of land areas and their original use converted to peat extraction, although most of the converted area is likely to be more or less densely treed peatland. Most default values in this method do not have corresponding error ranges associated with them. The default emission factors provided for Tier 1 have been developed from only a few (less than 10) data points only, which may not be representative for large areas or climate zones. Therefore, a default uncertainty level of +/- 75% of the estimated carbon emission or removal has been assumed based on expert judgement. The uncertainty probability distribution of the emissions is likely to be non-normal, so the 95% interval of a log-normal distribution is assumed here as default uncertainty (Table 3.5.2). It is *good practice* to use this range rather than a symmetrical standard deviation.

The area of drained peatlands is estimated to have an uncertainty of 50% in Europe and North America, but may be a factor of 2 in the rest of the world. Uncertainty in Southeast Asia is extremely high since peatlands are under particular pressure, mainly because of urbanisation and intensification of agriculture and forestry, and maybe also for peat extraction. It is assumed that the data of land conversion to peatland has the same uncertainty although countries with a predominance of commercial peat extraction will have better data.

Tier 2: Under Tier 2, actual area estimates for land conversion will enable more transparent accounting and allow experts to identify gaps and avoid double counting of land areas. The Tier 2 method uses at least some country-defined defaults, which will improve the accuracy of estimates, provided they better represent conditions relevant to the country. When country-specific defaults are developed, countries should use sufficient sample sizes and techniques to minimize standard errors. Probability density functions (i.e. providing mean and variance estimates) should be derived for all country-defined parameters. Such data can be used in advanced uncertainty analyses such as Monte Carlo simulations. Refer to Chapter 5 of this report for guidance on developing such analyses. At a minimum, Tier 2 approaches should provide error ranges for each country-defined parameter.

Tier 3: Under Tier 3, activity data from a land use and management inventory system should provide a basis to assign estimates of uncertainty to areas associated with land conversion. Combining emission and activity data and their associated uncertainties can be done using Monte-Carlo procedures to estimate means and confidence intervals for the overall inventory. Process-based models will probably provide more realistic estimates but need to be calibrated and validated against measurements. Generic guidance on uncertainty assessment for advanced methods is given in Chapter 5 (Section 5.2, Identifying and Quantifying Uncertainties) of this report. Since drainage of peatlands leads to peat compaction and oxidation and carbon losses other than as CO_2 the stock change approach to monitor CO_2 fluxes can be imprecise. If used, it should be calibrated with appropriate flux measurements.

3.5.2.2 CHANGE IN CARBON STOCKS IN LAND CONVERTED TO FLOODED LAND (RESERVOIRS)

The method for estimating carbon stock change due to land conversion to flooded land is shown in Equation 3.5.6. As with the method described in the previous section for peatland, this method assumes that the carbon stock of land prior to conversion is lost in the first year following conversion. The carbon stock of the land prior to conversion can be estimated following the method for living biomass described for various land-use categories in other sections of this chapter. In Tier 1, it is assumed that the carbon stock after conversion is zero.

EQUATION 3.5.6
ANNUAL CHANGE IN CARBON STOCKS IN LIVING BIOMASS IN LAND CONVERTED TO FLOODED LAND

$$\Delta C_{LW\ flood_{LB}} = [\Sigma\ A_i \bullet (B_{After} - B_{Before})_i] \bullet CF$$

Where:

$\Delta C_{LWflood_{LB}}$ = annual change in carbon stocks in living biomass in land converted to flooded land, tonnes C yr^{-1}

A_i = area of land converted annually to flooded land from original land use i, ha yr^{-1}

B_{Before} = living biomass in land immediately before conversion to flooded land, tonnes d.m. ha^{-1}

B_{After} = living biomass immediately following conversion to flooded land, tonnes d.m. ha^{-1} (default = 0)

CF = carbon fraction of dry matter (default = 0.5), tonnes C (tonnes d.m.)$^{-1}$

In actuality, it is possible that the carbon remaining on the converted land prior to flooding may be emitted over several years after flooding. Under Tier 2, this emission process can be modelled. Countries will need to develop country-specific emission factors and can refer to the discussion of ongoing emissions from flooded land remaining flooded land in Appendix 3a.3 for general guidance on how to implement such a method.

No guidance is provided on carbon stock changes from soils due to land conversion to flooded land at this time. Emissions of non-CO_2 gases from land converted to flooded land are covered in Appendix 3a.3.

3.5.3 Completeness

A complete estimate of emissions from land converted to wetlands should include all land converted to either peat extraction or flooded land. For organic soils managed for peat extraction, a complete inventory should cover all land converted to industrial peatlands. It should be consistent with a complete inventory of all industrial peatlands including abandoned peat mining areas in which drainage is still active, and areas drained for future peat extraction, but omitting areas reverting to wetland status.

3.5.4 Developing a Consistent Time Series

General guidance on consistency in time series can be found in Section 5.6 (Time Series Consistency and Recalculation). The emission estimation method should be applied consistently to every year in the time series, at the same level of disaggregation. Moreover, when country-specific data are used, national inventories agency should use same measurements protocol (sampling strategy, method, etc.) over time, following the guidance in Section 5.3, Sampling. If it is not possible to use the same method or measurement protocol throughout the time series, the guidance on recalculation in Chapter 5 should be followed.

The area of organic soils converted to peat extraction may need to be interpolated for longer time series or trends. If this is required, consistency checks should be made (i.e., by contacting peat-mining companies), to gather temporal information about areas affected by former or future peat extraction. Differences in greenhouse gas emissions between inventory years should be explained, e.g. by demonstrating changes in areas of industrial peatlands or by updated emission factors.

3.5.5 Reporting and Documentation

It is appropriate to document and archive all information required to produce the national emissions / removals inventory estimates as outlined in Chapter 5 of this report subject to the following specific considerations. Emissions from land converted to peat extraction or flooding have not been explicitly mentioned in the *IPCC Guidelines*. They can be reported in using the reporting tables in Annex 3A.2.

Emission factors: Since the literature data are so sparse, the scientific basis of new determinations of emission factors, parameters and models should be completely described and documented. This includes defining the input parameters and describing the process by which the emission factors, parameters and models were derived, as well as describing sources of uncertainties.

Activity data: Sources of all activity data used in the calculations (data sources, databases and soil map references) should be recorded, plus (subject to any confidentiality considerations) the communication with companies dealing with peat extraction. This documentation should cover the frequency of data collection and estimation, and estimates of accuracy and precision, and reasons for significant changes in emission levels.

Emission results: Significant fluctuations in emissions between years should be explained. A distinction should be made between changes in activity levels and changes in emission factors, parameters and methods from year to year, and the reasons for these changes documented. If different emission factors, parameters and methods are used for different years, the reasons for this should be explained and documented.

3.5.6 Inventory Quality Assurance/Quality Control (QA/QC)

It is appropriate to implement quality assurance/quality control (QA/QC) checks as outlined in Chapter 5 (Section 5.5) of this report, and to conduct expert review of the emission estimates. Given the shortage of data, these reviews should be conducted regularly to take account of new research findings. Additional quality control checks, as outlined in Tier 2 procedures in Chapter 8, QA/QC, of *GPG2000*, and quality assurance procedures may also be applicable, particularly if higher tier methods are used to quantify emissions from this source category. Where country-specific emission factors are used, they should be based on high quality experimental data, developed using a *good practice* measurement programme, and be adequately documented.

It is, at present, not possible to cross-check emissions estimates from organic soils managed for peat extraction with other measurement methods. However, the inventory agency should ensure that emission estimates undergo quality control by:

- Cross-referencing reported country-specific emissions factors with default values and data from other countries; and
- Check plausibility by cross-referencing areas of organic soils managed for peat extraction with data of peat industries and peat production.