CHAPTER 1

INTRODUCTION

Coordinating Lead Authors

Tom Wirth (USA) and Chengyi Zhang (China)

Lead Authors

Gusti Zakaria Anshari (Indonesia), Kenneth Byrne (Ireland), Elke Hodson (Switzerland), Hans Joosten (EC/WI/FAO), J. Boone Kauffman (IUCN/UNESCO), Leif Klemedtsson (Sweden), Tuija Elina Lapvetelainen (Finland), Christoph Mueller (Germany), Phillip O'Brien (Ireland) and Mitsuru Osaki (Japan)

Contributing Authors

Tonya Del Sontro (Switzerland), Mark Flugge (USA), Stephen Ogle (USA), Riitta Pipatti (Finland), Rachel Steele (USA), Victoria Thompson (USA) and Kiyoto Tanabe (TFI TSU)

Review Editors

Fatih Evrendilek (Turkey) and Steen Gyldenkærne (Denmark)

Contents

Figures

Tables

1 INTRODUCTION

1.1 BACKGROUND

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*) acknowledged that the guidance on Wetlands in Volume 4, Chapter 7 is incomplete and limited to estimating emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O) from 'peatlands cleared and drained for production of peat for energy, horticultural and other uses' (Vol. 4, Sec. 7.2). The *2006 IPCC Guidelines* also include an approach for estimating greenhouse gas emissions from 'reservoirs or impoundments, for energy production, irrigation, navigation, or recreation, and CO_2 emissions from all lands converted to permanently Flooded Lands' (Vol. 4, Sec. 7.3). In October 2010, an IPCC expert meeting on harvested wood products, wetlands, and N_2O emissions from soils concluded that there is sufficient new scientific information available to provide additional methodological guidance and fill gaps in the existing guidelines for the rewetting and restoration of peatlands; emissions from fires, ditches, and waterborne carbon; and constructed wetlands for waste water disposal (IPCC 2011). In December 2010, the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the United Nations Framework Convention on Climate Change (UNFCCC) invited the IPCC to undertake further methodological work on wetlands, focusing on the rewetting and restoration of peatland, with the objective of filling in the gaps in the *2006 IPCC Guidelines* in these areas.

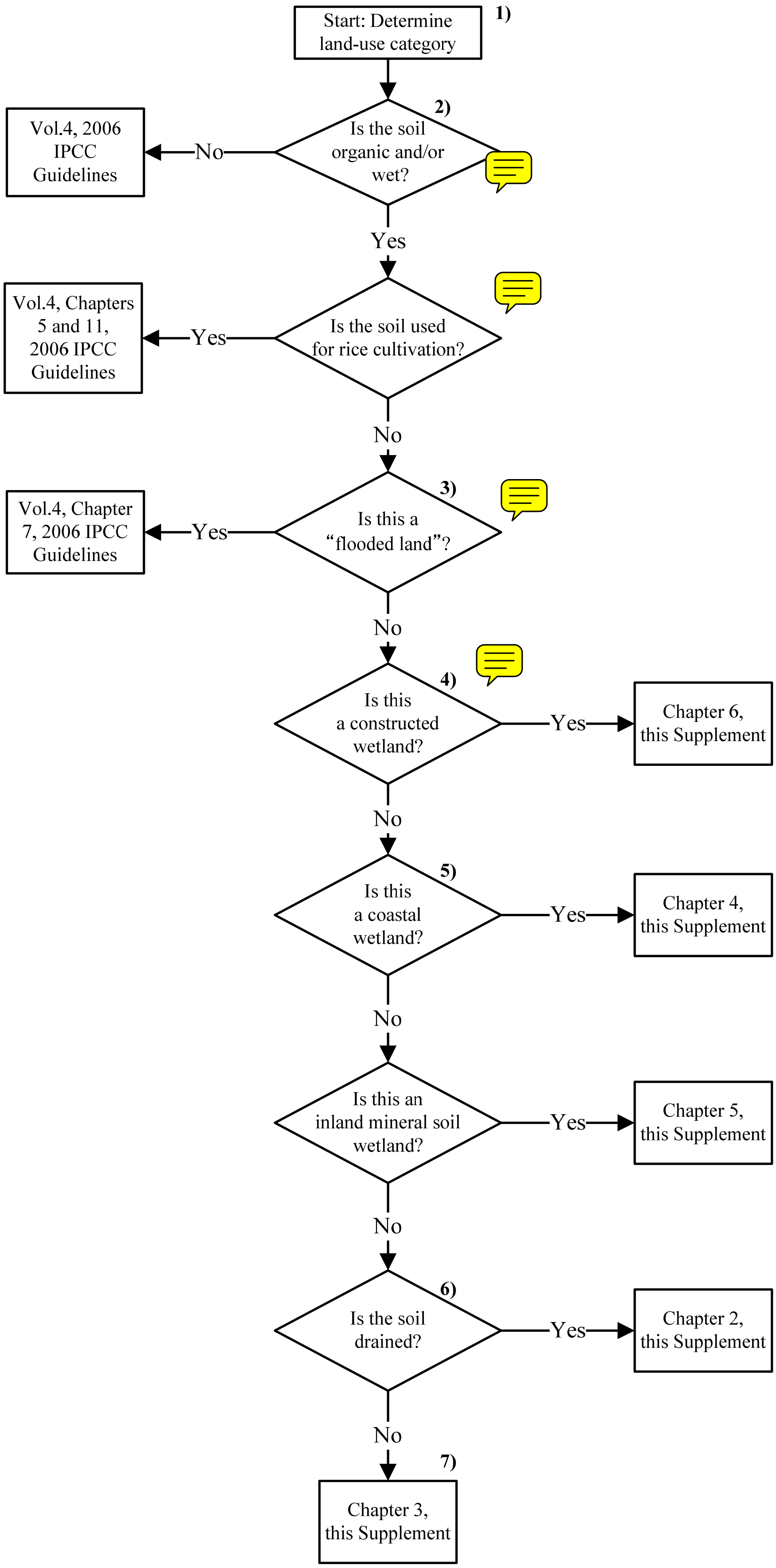
In response to the invitation of SBSTA, this *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*: *Wetlands - Methodological Guidance on Organic and Wet Soils across IPCC Land-use Categories* - (*Wetlands Supplement*) provides new and supplementary guidance on estimating and reporting greenhouse gas emissions and removals from lands with organic and wetland mineral soils in Wetlands and other land uses with these soil types that are subject to human activities ('managed') in the following chapters:

- Chapter 2: Drained Inland Organic Soils
- Chapter 3: Cross-cutting guidance on Rewetted Organic Soils and Restored Peatlands
- Chapter 4: Coastal Wetlands
- Chapter 5: Inland Wetland Mineral Soils
- Chapter 6: Constructed Wetlands – Wastewater Treatment
- Chapter 7: Cross-Cutting Issues and Reporting

1.2 SCOPE OF THIS SUPPLEMENT

This introductory chapter is intended to provide guidance on how to use this *Wetlands Supplement* in conjunction with the existing *2006 IPCC Guidelines* when preparing a greenhouse gas inventory that includes land with organic and/or wetland mineral soils across all IPCC land-use categories (Forest Land, Cropland, Grassland, Settlements, Wetlands and Other Land). The decision tree (Figure 1.1) can be used as a guide to the relevant chapters within this *Wetlands Supplement* or the *2006 IPCC Guidelines*.

Figure 1.1 Decision tree for finding the appropriate guidance chapter within this Supplement or the 2006 IPCC Guidelines



Guidance on using the decision tree:

1) Start with classifying all land into the six IPCC land use categories as specified in Chapter 3, Volume 4 of the *2006 IPCC Guidelines* "*Consistent Representation of Lands*". If using approach two or three for the land representation, land-use conversions (e.g., Forest Land converted to Cropland, Cropland converted to Settlements) should also be identified. This land-use classification should not differ from the classification countries would have developed without this *Wetlands Supplement*.

   Each land use category should be subdivided into subcategories with similar characteristics, as is indicated in the *2006 IPCC Guidelines*. In each of the six IPCC land-use categories, managed land area should be reported separately from unmanaged land area and emissions/removals should only be estimated for managed land. It is *good practice* to sub-divide each of the six managed land-use categories into four subcategories: wet organic soil, dry organic soil, wet mineral soil and dry mineral soil. In the case where dry mineral soil remains dry mineral soil, use the *2006 IPCC Guidelines* guidance on soil carbon estimation in the Forest Land, Cropland or Grassland Chapters as appropriate. In all other cases (including in the case of conversion from dry mineral soil to wet mineral soil, and vice versa), use the decision tree in Figure 1.1 to identify the appropriate guidance chapter within this *Wetlands Supplement* or the *2006 IPCC Guidelines*.

2) 'Organic soils' are soils with a high concentration of organic matter (> 20%), consistent with established definitions of organic soils in the *2006 IPCC Guidelines* (see further details in section 1.5). All other types of soils are classified as 'mineral', following the *2006 IPCC Guidelines* (Chapter 3, Annex 3A.5, Volume 4). The mineral soils found in wetlands are referred to as 'wetland mineral soils'.

   'Wet soils' are inundated or saturated by water for all or part of the year to the extent that biota, particularly soil microbes and rooted plants, adapted to anaerobic conditions control the greenhouse gas emissions and removals**.** Collectively these soils are referred to as Hydric soils – soils formed under conditions of saturation, flooding, or ponding long enough to develop anaerobic conditions in the upper part during the growing season.

3) 'Flooded Land' is defined as reservoirs or impoundments, for energy production, irrigation, navigation, or recreation. Flooded Land excludes regulated lakes and rivers unless a substantial increase in water area has occurred. This *Wetlands Supplement* does not include additional guidance for Flooded Land. Estimating emissions from this category of land use is discussed in Section 7.1, Chapter 7, Volume 4 of the *2006 IPCC Guidelines*

4) 'Constructed wetlands' are human-made wetlands. Synonymous terms include 'man-made', 'engineered' or 'artificial' wetlands. Chapter 6 of this *Wetlands Supplement* only provides guidance for constructed wetlands for wastewater treatment. Other constructed wetlands are not included in this *Wetlands Supplement* or the *2006 IPCC Guidelines.*

5) 'Coastal wetlands' are wetlands at or near the coast, that are influenced by saline or brackish water and/or astronomic tides (see Chapter 4). Their seaward limit is the deepest occurrence of rooted vascular plants. Coastal wetlands may occur on both organic and mineral soils. Brackish/saline water is water that contains 500 or more parts per million (ppm) of dissolved salts. 'Inland wetlands' (cf. Chapter 5) are not 'coastal'.

6) 'Drained' refers to formerly 'wet' soils (see note 2 above) where the water table has been lowered as a result of human intervention. 'Rewetted' refers to soils that were formerly 'drained' but are 'wet' because the original hydrology has been re-established.

7) Chapter 3 focuses on rewetted organic soils and restored peatlands, but also covers undrained inland organic soils. While chapter 3 does not provide Tier 1 methods for 'wet' management practices such as paludicultures etc., these are discussed in the general discussion and in the sections dealing with higher tiers.

1.3 EMISSION CHARACTERISTICS OF WETLAND MINERAL SOILS AND ORGANIC SOILS UNDER HUMAN MANAGEMENT

Lands with wetland mineral soils and organic soils are crucial in maintaining the Earth's carbon balance, with soils in peatlands, mangroves, and marshes containing the largest carbon stocks of the terrestrial biosphere (Gorham 1991; Mitra et al., 2005; Joosten and Couwenberg 2008; Donato et al., 2011; Pendleton et al., 2012). Human interventions and practices (e.g., agriculture, forestry, peat extraction, aquaculture) and their consequences (e.g., oxidation of soil organic matter, anthropogenic fires) may significantly affect their carbon and nitrogen balance as well as their greenhouse gas emissions.

Emissions from land with wetland mineral soils and organic soils are largely controlled by the degree of water saturation, climate and nutrient availability (Couwenberg et al., 2010; Hodson et al., 2011) as well as by vegetation (Blodau 2002; Limpens et al., 2008; Lafleur 2009; Couwenberg and Fritz 2012).

Undrained or rewetted wetlands with water levels at or near the soil surface emit methane (CH_4) (Couwenberg and Fritz 2012; Xu and Tian 2012), but generally have very low fluxes of CO_2 to the atmosphere (Couwenberg et al., 2011). Nitrous oxide (N_2O) emissions from undrained wetlands are typically low, unless an outside source of nitrogen enters the wetland, such as from nearby agricultural lands.

Drained wetlands, in contrast, generally have negligible CH_4 fluxes but emit increased levels of CO_2. Nitrous oxide emissions can be higher as well, with the emissions regulated by nitrogen availability (soil fertility, peat decomposition, atmospheric deposition), oxygen status and carbon availability (Strack 2008; Couwenberg et al., 2010). Other losses resulting from drainage waters that conduct dissolved and particulate waterborne carbon out of the organic soil (Joosten and Couwenberg 2008) are also included in this *Wetlands Supplement* along with the significant CH_4 emissions that can take place in ditches made for draining organic soils.

Aggregate fluxes of CO_2 and N_2O (in CO_2 equivalents) from drained wetlands are generally larger than the aggregate CH_4, CO_2, and N_2O fluxes (in CO_2 equivalent) from water saturated soils (Wilson et al., 2012). The global carbon emissions (by microbial peat oxidation and peat fires) from drained peatland over the last decade are estimated at 0.5 Pg carbon annually. In other words, 0.3% of the global land area may be responsible for >5% of the global anthropogenic CO_2 emissions (Victoria et al., 2012). Another global hotspot is mangrove deforestation (i.e., land-use *change*), which generates emissions of 0.02–0.12 Pg carbon per year—up to 10% of emissions from deforestation globally, despite accounting for just 0.7% of the area of tropical forests (Donato et al., 2011).

While rewetting of drained wetlands generally increases CH_4 emissions, it can decrease CO_2 and N_2O emissions (Wilson et al., 2012). The actual magnitude of human-influenced emissions and removals from wetlands depends on numerous variables, including wetland type, wetland area, management practice, vegetation composition, water table depth, growing season length, precipitation, and temperature (Fenner and Freeman 2011).

1.4 DEFINITION, DISTRIBUTION AND EXTENT OF WETLAND ECOSYSTEMS

Wetland ecosystems, i.e. ecosystems with wet soils (Chapter 1.2), may naturally occur throughout the world in inland and coastal areas, and near shore environments, as saline and freshwater ecosystems (e.g., swamps, marshes, fens, bogs, riparian forests, mangroves, tidal freshwater wetlands and seagrass beds). Wetland ecosystems can also be man-made, (e.g., fish ponds, wetlands for wastewater treatment, drainage canals, dams and reservoirs). Estimates of the total area of wetlands on Earth vary considerably (see Table 1.1) reflecting not only differences in accounting accuracy, but also different approaches to defining wetlands. The Global Lakes and Wetlands Database (GLWD) estimates the maximum global wetland extent to be 12.8 million km^2 including lakes and reservoirs (Lehner and Döll 2004). Table 1.2 presents the classification of wetlands as represented in GLWD.

TABLE 1.1
GLOBAL DISTRIBUTION OF WETLANDS (IN 1,000 KM^2) FROM DIFFERENT AUTHORS
(ADAPTED FROM LEHNER AND DÖLL, 2004)

Region	Matthew and Fung (1987)	Cogley (1994)	Stillwell-Soller et al. (1995)	GLCC[a)]; Loveland et al. (2000)	MODIS[b)]; Hodges et al. (2001)	Gross wetlands map[c)]	GLWD Level-3; Lehner and Döll (2004)
Africa	718	368	265	152	296	1431	1314
Asia	1688	2043	1183	587	659	3997	2856
Australia & Pacific Region	188	67	8	1	108	342	275
Europe	811	413	432	22	18	1195	260
North America	1126	872	1542	248	153	2609	2866
South America	727	578	1365	80	58	2132	1594
Total	**5260**	**4340**	**4795**	**1093**	**1291**	**11,711**	**9167**

a) Global Land Cover Characteristics (GLCC) dataset

b) MODerate resolution Imaging Spectroradiometer (MODIS) land cover product

c) Derived as maximum wetland area per cell identified in either Matthews and Fung, Cogley, Stillwell-Soller et al., GLCC, or MODIS

TABLE 1.2
CLASSIFICATION AND EXTENT OF WETLANDS AS REPRESENTED IN GLWD-3
(ADAPTED FROM LEHNER AND DÖLL, 2004)[A]

ID	Class	Global area	
		10^3 km^2	% of total global land surface area[B]
1	Lake	2428	1.8
2	Reservoir	251	0.2
3	River	360	0.3
4	Freshwater Marsh, Floodplain	2529	1.9
5	Swamp Forest, Flooded Forest	1165	0.9
6	Coastal Wetland	660	0.5
7	Pan, Brackish/Saline Wetland	435	0.3
8	Bog, Fen, Mire	708	0.5
9	Intermittent Wetland/ Lake	690	0.5
	Total lakes and reservoirs (classes 1 and 2)	2679	2
	Total Wetlands (classes 3 – 9)	6547	4.9
	Total All Classes	9226	6.9

[A] In developing a global database of lakes, reservoirs, and wetlands, Lehner and Döll, 2004 combined existing maps, data and information using Geographic information systems (GIS).

[B] Total global land surface area (excluding Antarctica and Glaciated Greenland) is 133 million km^2.

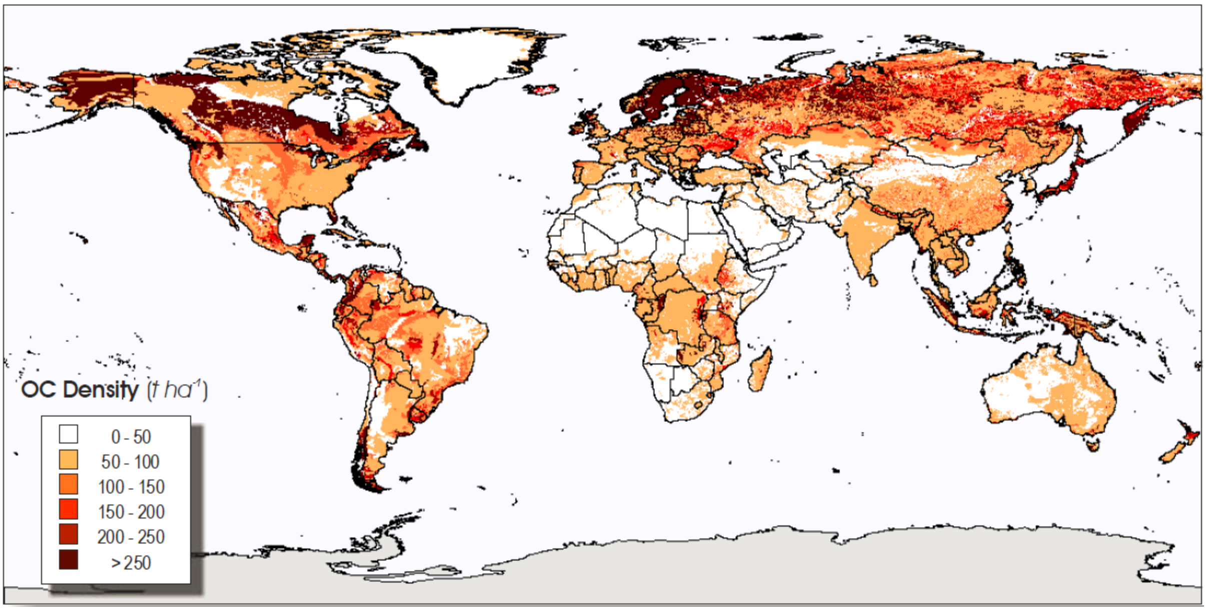
1.5 DEFINITION, DISTRIBUTION AND EXTENT OF ORGANIC SOILS

This *Wetlands Supplement* follows the definition of organic soils as used in the *2006 IPCC Guidelines* (Volume 4, Chapter 3, Annex 3A.5): "Organic soils are identified on the basis of criteria 1 and 2, or 1 and 3 listed below (FAO 1998):

1. Thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12 percent or more organic carbon when mixed to a depth of 20 cm.
2. Soils that are never saturated with water for more than a few days must contain more than 20 percent organic carbon by weight (i.e., about 35 percent organic matter).
3. Soils are subject to water saturation episodes and has either:
   a. At least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soil has no clay; or
   b. At least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soil has 60% or more clay; or
   c. An intermediate proportional amount of organic carbon for intermediate amounts of clay."

The *2006 IPCC Guidelines* definition for organic soils thus largely follows the FAO (1998/2006) definition of a 'Histosol[1]' and links (and even largely equates) organic soils to peat soils. For peat soils, no globally accepted definition exists. Apart from soils with shallow (10-40 cm thick) organic horizons overlying ice or rock, organic soils (Histosols) are identical with peat soils with at least 40 cm of peat within the uppermost 100 cm of the soil profile, and with the peat containing at least 12 percent organic carbon (~20 percent organic matter) by weight. The latter criteria deviate from most European definitions, which require a slightly thinner organic layer for 'peatland' (30 cm) and a slightly higher organic matter content for 'peat' (30 percent) (Joosten and Clarke, 2002). The *2006 IPCC Guidelines* have omitted the thickness criterion from the FAO definition to allow for country specific approaches[2] to define organic soils. Figure 1.2 presents the distribution of soil organic carbon throughout the world. A total of around 4 million km^2 of peatlands occur in the world (Lappalainen 1996; Joosten and Clarke 2002) of which some 10% are found in tropical regions (Page et al., 2011). The total soil carbon stock in peatlands amounts to 500 Gt (Joosten and Couwenberg 2008; Page et al., 2011).

Figure 1.2 World map of the distribution of soil carbon (to 1m depth)



The highest three classes give a fair indication of the occurrence of organic soils. (From Hiederer and Köchy (2011)).

[1] More information on histosols is provided by FAO in the World Reference Base for Soil Resources (FAO, 2006).

[2] It is important that whatever definition is used by the country that definition is applied consistently across the entire national land area.

1.6 MANAGED WETLANDS AND ORGANIC SOILS

According to the *2006 IPCC Guidelines,* it is *good practice* that, when preparing a greenhouse gas inventory, a country produces a complete and consistent land-use representation that divides the land-uses into six major categories: Forest Land, Grassland, Cropland, Wetlands, Settlements and Other Land. The *2006 IPCC Guidelines* provide definitions for each of these land-use categories. Only general definitions are provided, which can be modified by the country to better represent their unique conditions. Except for Cropland and Settlements, which are always considered to be "managed", all IPCC land-use categories can be subdivided into managed and unmanaged sub-categories based upon the definition used within each country.

The *2006 IPCC Guidelines* provides methods to estimate anthropogenic emissions and removals of greenhouse gases. In the Agriculture, Forestry and Other Land Use (AFOLU) Sector, emissions and removals on managed land are taken as a proxy for anthropogenic emissions and removals. Inter-annual variations in natural background emissions and removals, which can be significant, are assumed to average out over time. That is, the Guidelines assume that all emissions and removals from managed land are anthropogenic (the so-called "managed land proxy") (Section 1.1, Chapter 1, Volume 1 and Section 1.1, Chapter 1, Volume 4 of the *2006 IPCC Guidelines*).

According to the *2006 IPCC Guidelines* (Volume 4, Chapter 3, Section 3.2) 'managed land is land where human interventions and practices have been applied to perform production, ecological or social functions'. Section 7.1, Chapter 7, Volume 4 of the *2006 IPCC Guidelines* ("Wetlands"), however, restricts 'managed Wetlands' to 'Wetlands where the water table is artificially changed (e.g., drained or raised) or those created through human activity (e.g., damming a river).' It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.

This *Wetlands Supplement* extends the coverage to also include wetlands where the water table has not been altered or that have not been created as long as emissions and removals are directly influenced by human activity. Emissions and removals should be estimated for all land-use categories within a country that are designated as managed.

Where emissions and removals from lands with wetland mineral soils or organic soils are directly impacted by human activities, the respective areas should be considered managed. Table 1.3 provides some examples of interventions and practices related to production, ecological and social functions that – according to country-specific national definitions - may result in lands with wetland mineral soils and organic soils being considered part of the managed land base. Figure 1.3 illustrates some typical human interventions and practices and associated greenhouse gas emissions and removals on managed lands with wetland mineral soils and organic soils.

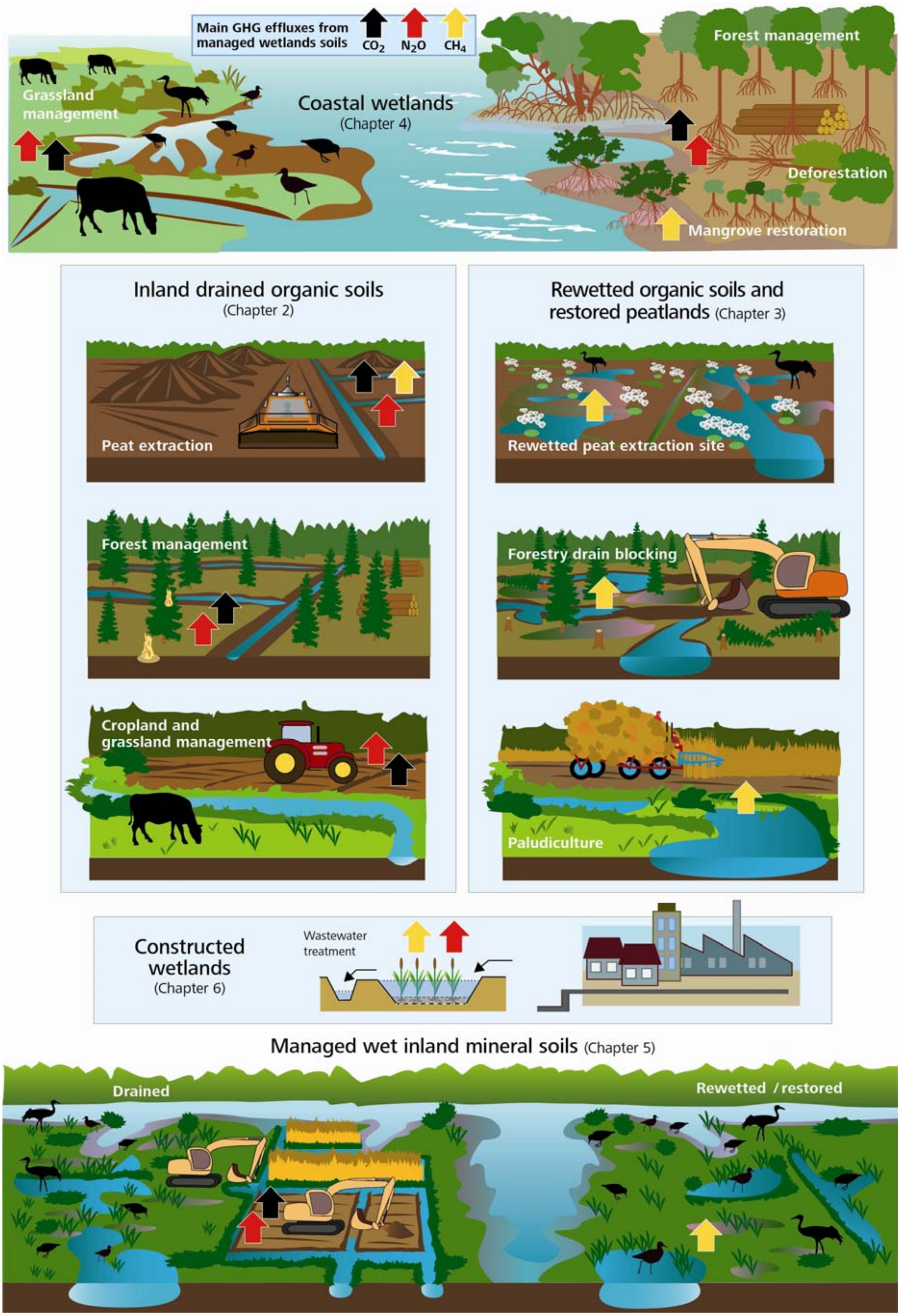
TABLE 1.3
EXAMPLES OF INTERVENTIONS AND PRACTICES RELATED TO PRODUCTION, ECOLOGICAL AND SOCIAL FUNCTIONS THAT RESULT IN MANAGED WETLANDS AND ORGANIC SOILS

	Production functions	**Ecological functions**	**Social functions**
Benefits	Provision of water, food, raw materials, energy, and genetic materials	Regulation of climatic, water, soil, ecological, and genetic conditions	Provision of non-material sensations that are pleasant, agreeable or beneficial or identify one's position in the world
Interventions and practices	Protection, conservation, restoration and management for: • Hunting/fishing/gathering • Protection of genetic resources • Water procurement • Aquaculture (fish, shrimps, snails) • Paludiculture • Agriculture and horticulture • Forestry and agroforestry • Peat extraction • Extraction of mineral resources	Protection, conservation, restoration and management for: • global (greenhouse gas fluxes, C-storage), regional and local climates (evaporation cooling) • air quality (capturing dust) • natural hazard mitigation • catchment hydrology (flood control, baseflow), water purification and waste water treatment • erosion control, soil formation and permafrost conservation • pollination and pest control	Protection, conservation, restoration and management for: • social amenity • recreation and tourism, • aesthetics and inspiration, • education and science, • signalisation • heritage and identity, • symbolisation, spirituality and religion.

Source: Joosten and Clarke 2002; De Groot et al., 2010; Elmqvist and Maltby 2010

The use of the managed land proxy to identify anthropogenic emissions and removals has some drawbacks, in particular with respect to inclusion of emissions or removals that would have occurred regardless of anthropogenic influences (IPCC 2010). However, no alternative approach has been agreed upon by the authors of the *2006 IPCC Guidelines* or this *Wetlands Supplement*. While in some circumstances it may be possible to estimate these non-anthropogenic emissions and removals and subtract them from the total emissions estimates for some wetland types and activities, this would introduce a number of problems. These problems include (1) lack of consistency with reporting for other land-use categories where the guidance does not adopt this approach, (2) lack of comparability between countries dealing with this issue in different ways, (3) high uncertainty associated with estimation of these emissions and removals, and (4) difficulty of capturing these emissions using Tier 1 or 2 methods. Therefore, for consistency, the managed land proxy for anthropogenic emissions should be applied uniformly across all land uses.

Figure 1.3 Some typical management activities and associated greenhouse gas emissions and removals on wetlands and organic soils



(Figure by Riikka Turunen, Statistics Finland)

1.7 COHERENCE AND COMPATIBILITY WITH 2006 IPCC GUIDELINES

1.7.1 Guidance in the 2006 IPCC Guidelines

CARBON STOCK CHANGES IN MINERAL AND ORGANIC SOILS

The *2006 IPCC Guidelines* provide guidance for estimating carbon stock changes from mineral soils and/or drained organic soils within the land use categories Forest Land, Cropland, Grassland, Wetlands, Settlements and Other land. In Section 2.3.3, Chapter 2, Volume 4 of the *2006 IPCC Guidelines*, complete guidance is provided at the Tier 1 level, with additional guidance for Tiers 2 and 3. For mineral soils, the default method is based on changes in soil carbon stocks over a finite period of time. The change is computed based on the carbon stock after the management change relative to the carbon stock in a reference condition. To estimate CO_2 emissions from drained organic soils an area-based annual emission factor is applied that is differentiated by climate region and land use.

BIOMASS AND DEAD ORGANIC MATTER CARBON STOCK CHANGES

The generic methodologies for estimating above-ground and below-ground biomass carbon stock changes for all land use categories are available in Section 2.3.1, Chapter 2, Volume 4 of the *2006 IPCC Guidelines*. Guidance to estimate the dead organic matter pool is provided in Section 2.3.2, Chapter 2, Volume 4of the *2006 IPCC Guidelines*. More specific guidance by land-use categories can be found in Volume 4 of the *2006 IPCC Guidelines* under the specific land-use category Chapters: 4 (Forest Land), 5 (Cropland), 6 (Grassland), 7 (Wetlands), 8 (Settlements), and 9 (Other Land).

DIRECT AND INDIRECT N_2O EMISSIONS FROM MANAGED SOILS

In Section 11.2, Chapter 11, Volume 4 of the *2006 IPCC Guidelines,* methodologies are provided to estimate both direct and indirect N_2O emissions from managed soils. Generic equations are presented, which can be applied to all land areas in aggregate or to specific land-use categories if activity data are available. N_2O emissions from drained organic soils are estimated using an area-based annual emission factor differentiated by climate region. Indirect N_2O emissions from managed soils arising from agricultural inputs (which may end up in wetlands via hydrological transport or deposition from agricultural sites) are addressed in Chapter 11, Volume 4 of the *2006 IPCC Guidelines*. Indirect N_2O emissions from combustion-related and industrial sources of nitrogen deposition are described in Section 7.3, Chapter 7, Volume 1 of the *2006 IPCC Guidelines*. To prevent double-counting, the N input into wetlands as a result of leaching/runoff or deposition from other land-use categories or activities (e.g., combustion for energy) should not be accounted for in the Wetlands category as these emissions are included in the estimation of indirect emissions of N_2O from other managed soils. In addition, the average annual loss of soil carbon from mineral soils for each land-use type (referred to as ΔCmineral,LU, an output of the estimates in Chapter 5) must be included in the soil N_2O estimates as shown in Equation 11.8 of Chapter 11, Volume 4 of the 2006 GLs. This ΔCmineral,LU values is used to calculate $F_{SOM,}$ which is the annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management. The F_{SOM} value is used in Equation 11.1 to estimate direct N_2O emissions from managed soils.

NON-CO_2 EMISSIONS FROM BIOMASS BURNING

Generic guidance for non-CO_2 emissions due to burning of live and dead biomass on managed lands (Forest Land, Cropland and Grassland) is provided under Section 2.4, Chapter 2, Volume 4 of the *2006 IPCC Guidelines*. Existing guidelines do not include burning of peat and other soil organic matter, which is a large emission source for some countries.

RICE CULTIVATION

Methane emissions from rice cultivation are included in Section 5.5, Chapter, 5, Volume 4 of the *2006 IPCC Guidelines*. Soil carbon stock changes are accounted for using guidance as described above in Section 2.3.3, Chapter 2, Volume 4 of the *2006 IPCC Guidelines*.

WETLANDS

In the Wetlands chapter of the *2006 IPCC Guidelines* (Volume 4, Chapter 7), methodologies are provided to estimate greenhouse gas emissions and removals from peatlands cleared and drained for extracting peat for energy, horticulture and other uses (Section 7.2). Emissions from the use of horticultural peat are accounted for in Chapter 7, while peat used for energy generation is estimated under the Energy Sector (Volume 2 of the *2006*

IPCC Guidelines). Guidance for peat extraction that does not include drainage is not provided. The *2006 IPCC Guidelines* (Volume 4, Chapter 7) furthermore provide guidance for estimating CO_2 emissions from reservoirs or impoundments used for hydroelectricity production, irrigation, navigation, or recreation (Section 7.3). This guidance, however, is restricted to CO_2 emissions from land converted to Flooded Land, i.e., where human activities have caused an increase in area covered by water. Regulated lakes and rivers that do not have substantial changes in water area in comparison with the pre-flooded ecosystem are not considered Flooded Land.

WASTEWATER TREATMENT

Chapter 6, Volume 5 of the *2006 IPCC Guidelines* (wastewater treatment and discharge) provides a methodology to estimate CH_4 and N_2O emissions from domestic and industrial wastewater treatment. CO_2 emissions from wastewater are not considered in the *IPCC Guidelines* and should not be included in national total emissions because of their biogenic origin.

1.7.2 Supplementary guidance in this report

CHAPTER 2—DRAINED INLAND ORGANIC SOILS

Chapter 2 provides supplementary guidance on estimating greenhouse gas emissions and removals from inland drained organic soils for all land-use categories: Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land. The Tier 1 guidance provided by land-use category includes the impact of drainage depth (water-table level) on the emission estimates. New emission factors to estimate the release of CH_4 from drainage ditches are also provided.

Chapter 2 also identifies additional pathways by which carbon is lost from the soil: namely carbon loss as Dissolved Organic Carbon (DOC), as Particulate Organic Carbon (POC), and as Dissolved Inorganic Carbon (DIC). These waterborne carbon losses can lead to offsite emission of CO_2 from organic soils. *Good practice* guidance to estimate these carbon losses separately from the direct emissions is provided. The loss of carbon from managed organic soils via DOC can be estimated using the Tier 1 methodology and emission factors set out in Chapter 2 of this *Wetlands Supplement*. The Tier 1 methodology assumes that the carbon lost via DOC is emitted into the atmosphere in the form of CO_2. The application of a higher Tier methodology may identify a portion of this carbon released to the atmosphere in another form (e.g. as methane).

Fire on peatlands or drained organic soils causes not only on-site CO_2, CH_4, and N_2O emissions directly from the burning, but also has a high potential to increase the off-site carbon loss from the waterborne organic matter. Chapter 2 of this Wetlands Supplement provides supplementary methodological guidance to estimate these emissions (refer to Chapter 2 for detail).

Chapter 2 does not provide Tier 1 methodologies for emissions associated with POC or DIC. However, the Annex 2A.1 sets out the basis for future methodology development for POC.

CHAPTER 3—CROSS-CUTTING GUIDANCE ON REWETTED ORGANIC SOILS AND RESTORED PEATLANDS

Lands with organic soils that have been drained for forestry, crop production, grazing, or peat extraction may be rewetted and restored/rehabilitated. While restoration may take place on undrained site (e.g., restoration of vegetation cover), in the majority of cases restoration is accompanied by rewetting.

Chapter 3 of the *Wetlands Supplement* provides guidance for assessing the greenhouse gas (CO_2, CH_4 and N_2O) emissions and removals from various types of rewetted and restored peatlands and organic soils by climate region and peat type. Chapter 3 covers but only provides generic guidance for higher tiered methodology on undrained inland organic soils, and peatlands undergoing wet management or restoration not necessitating rewetting.

CHAPTER 4—COASTAL WETLANDS

Chapter 4 provides methodologies for estimating and reporting greenhouse gas emissions and removals associated with specific activities on managed coastal wetlands, such as mangrove forests, tidal marshes and sea-grass meadows at or near the coast that are influenced by saline or brackish water. Both organic and mineral soils can occur in coastal wetlands. Separate guidance is given for land remaining in a land-use category, conversion from a land-use category that includes coastal wetlands, and conversion to a land-use category that includes coastal wetlands.

CHAPTER 5—INLAND WETLAND MINERAL SOILS

Chapter 5 deals with inland managed lands with wetland mineral soils not included in Chapters 4 and 6. The chapter provides methodologies for reporting greenhouse gas emissions and removals, gives updated default reference values for Soil Organic Carbon Stocks and offers a default Stock Change Factor for long term cultivation of croplands. It also gives guidance not contained in the *2006 IPCC Guidelines*, including a default Stock Change Factor for wetland restoration on croplands, and methodologies and emission factors for CH_4 emissions for mineral soils in any land-use category that have undergone wetland restoration or have been inundated for the purpose of wetland creation. Methods for estimating N_2O emissions are not included in this chapter.

CHAPTER 6—CONSTRUCTED WETLANDS—WASTEWATER TREATMENT

Chapter 6 provides guidance on estimating CH_4 and N_2O emissions from constructed wetlands used for wastewater treatment. The guidance supplements the *2006 IPCC Guidelines*, Volume 5, Chapter 6 on wastewater treatment. Default emission factors for different types of constructed wetlands, e.g., those with surface, subsurface vertical or subsurface horizontal flows, are provided by the Tier 1 method. To avoid double-counting, nitrous oxide emissions from wetlands managed for the filtration of non-point source agricultural effluents, such as fertilizers and pesticides, are included in indirect emissions from soil amendments (*2006 IPCC Guidelines,* Volume 4, Chapter 11) as part of the leaching/ runoff and volatilization components of indirect emissions, and are not considered within this supplement.

CHAPTER 7—CROSS-CUTTING ISSUES AND REPORTING

Chapter 7 provides guidance on reporting and crosscutting issues, including uncertainties, key category analysis, completeness, time series consistency, quality control, and quality assurance. The chapter summarizes relevant sections from the 2006 IPCC Guidelines and addresses the cross-cutting issues specific to the wetlands sub-categories in Chapters 2 to 6 of this Wetlands Supplement. Worksheets, which can be used for estimating the emissions and removals for each category using the Tier 1 guidance, and revised background tables are included in the annex of the chapter.

GENERAL LINKAGES BETWEEN THE WETLANDS SUPPLEMENT AND THE 2006 GUIDELINES

Chapters 2, 3 and 6 do not provide specific guidance on estimating carbon stock changes and greenhouse gas emissions and removals related to above/below-ground biomass and dead organic matter pools (dead wood and litter). Generic guidance for estimating carbon stock changes and greenhouse gas emissions and removals related to biomass and dead organic matter pools (i.e. dead wood and litter) can be found in the *2006 IPCC Guidelines*. Chapters 4 and 5 provide new emission factors for carbon stock changes in biomass and dead organic matter in addition to soils and new stock change factors associated with activities that occur in these systems. Chapters 4 provides methodologies for estimating CO_2 and non-CO_2 emissions from specific practices, and Chapter 5 provides guidance on estimating CH_4 emissions in wetland mineral soils..

It is *good practice* for countries to avoid double-counting emissions that have already been estimated elsewhere in the greenhouse gas inventory. This is especially relevant because various wetland types (e.g., aquaculture ponds, irrigated land, seasonally flooded agricultural land not including rice cultivation, canals and drainage channels, ditches) can be included under various land categories.

In particular, care should be taken that using the guidance provided in Chapters 4, 5, and 6 of the *Wetlands Supplement* does not result in any double-accounting of specific emission sources, such as N_2O emissions from wetlands, that result from non-point source agricultural effluents and are already addressed as indirect emissions from the soil amendments (e.g., nitrogen fertilizers) within Chapter 4, Volume 4 of the *2006 IPCC Guidelines*.

Furthermore, waterborne carbon may already be included in a country’s emission estimates if the country uses a methodology in which soil carbon stock changes are measured in situ (e.g., soil sampling associated with forest inventories).

Table 1.4 shows how the guidance and categories in the *2006 IPCC Guidelines* and the supplementary guidance and categories in this *Wetlands Supplement* are linked and summarises the changes introduced in the Supplement.

TABLE 1.4
MAPPING BETWEEN THE CATEGORIES AND GUIDANCE IN THE *2006 IPCC GUIDELINES* AND THE CHANGES TO THOSE INTRODUCED BY THE *WETLANDS SUPPLEMENT*.

Source of emissions/ sink for removals	2006 IPCC Guidelines		Wetlands Supplement	
	Category	**Guidance by**	**Category**	**Guidance by**
Drained Inland Organic Soils				
CO_2	3B1 to 3B6 (except 3B4) Forest Land, Cropland, Grassland, Settlements and Other Land Category 3B4ai: *Peatlands Remaining Peatlands* Category 3B4bi: *Land Converted for Peat Extraction*	• land-use category and climate domain ,for all land-use categories except Peatlands (lands managed for peat extraction) • For Peatlands climate domain and nutrient status (for boreal/temperate climate only)	3B1 to 3B6 Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land Category 3B4ai renamed as *Peat Extraction Lands Remaining Peat Extraction Lands* and 3B4bi *Land Converted for Peat Extraction*	• land-use category • vegetation type (such as plantations and shrublands) • climate domain • nutrient status • drainage depth (deep vs. shallow) • precipitation regime (DOC)
CH_4	-	-	3B1 to 3B6 Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land or 3C8 Non-CO_2 greenhouse gas emissions not included elsewhere, Other	• land-use category • vegetation type • climate domain • land-use intensity
N_2O	3C4 Direct N_2O emissions from managed soils - drainage/management of organic soils	• by land-use category and climate domain for drained organic soils in all land-use categories except Forest Land and Peatlands (lands managed for peat extraction) • by land-use, climate domain and nutrient status for Forest Land and Peatlands (lands managed for peat extraction) for temperate and boreal climate domains only	3C4	• land-use category • vegetation type (acacia, palm oil, sago plantation) • climate domain • nutrient status for Forest Land for temperate/boreal climate domains and Grassland for temperate climate domain • drainage depth for Grassland
Cross-cutting Guidance on Rewetted Organic Soils and Restored Peatlands				
CO_2,	-	-	3B1 to 3B6 Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land Subcategories for	• climate domain • nutrient status • precipitation regime (DOC)

			rewetted land remaining rewetted lands and lands converted to rewetted lands should be introduced for the land-use categories under which the activity takes place.	
CH_4			3B1 to 3B6 Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land or 3C8 Non-CO_2 greenhouse gas emissions not included elsewhere, Other	• climate domain • nutrient status
N_2O			3B1 to 3B6 Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land or 3C8 Non-CO_2 greenhouse gas emissions not included elsewhere, Other	Assumed negligible at Tier 1
Coastal Wetlands				
CO_2	-	-	3B4aiii (Other wetlands remaining wetlands) or 3B4biii (Land converted to other wetlands) or 3B1 to 3B6 Forest land, Cropland, Grassland, Wetlands, Settlements and Other land	• management activity including restored and drained coastal wetlands and aquaculture use • climate domain • vegetation type: mangrove forest, tidal marsh and sea grass meadow • salinity (where EF applicable)
CH_4 and N_2O			3B1 to 3B6 Forest land, Cropland, Grassland, Wetlands, Settlements and Other land or 3C8 Non-CO_2 greenhouse gas emissions not included elsewhere, Other	• management activity including restored and drained coastal wetlands and aquaculture use • vegetation type: mangrove forest, tidal marsh and seagrass meadow • salinity (where EF applicable)
Inland Wetland Mineral Soils				
CO_2,	3B1 to 3B6 Forest land, Cropland, Grassland, Wetlands, Settlements and	-land-use category - climate zone -management practices	3B1 to 3B6 Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land	• land-use • climate domain • management activity (restored, created or drained)

	Other land			
CH_4	-	-	3B1 to 3B6 Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land or 3C8 Non-CO_2 greenhouse gasemissions not included elsewhere, Other	• climate domain • management (only raising of water table)
Constructed wetlands				
CH_4, N_2O	-	-	4 D Wastewater treatment and discharge	• Wastewater type • Type of constructed wetland

1.8 RELEVANT DATABASES FOR WETLANDS AND ORGANIC SOILS

To generate estimates of emissions and removals from wetlands, inventory compilers will need to gather activity data or determine appropriate proxy data, such as soil type (organic or mineral), wetland type, size, water table depth, vegetation composition, precipitation, temperature, and management practices. Guidance on data collection is provided in Chapter 2, Volume 1 of the *2006 IPCC Guidelines*. It is *good practice* to focus these efforts on collecting data needed to improve estimates of key categories, which will vary by country depending on which emission sources are the largest, have the largest potential to change or have the greatest uncertainty (*2006 IPCC Guidelines*). Chapters 2-6 of this *Supplement* provide specific guidance on where and how to obtain activity data for the relevant emission estimates. Additionally, Chapter 7 provides general guidance for producing consistent times series when activity data is not available for all years.

After determining which lands with wetland mineral soils and organic soils to include in the inventory, inventory compilers may be able to collect data such as size, type, and management practice from in-country natural resource agencies or national experts. If national wetland and soil databases do not exist, data on lands of interest may be available from individual land managers, organizations, or interest groups. Data on wetland rewetting or restoration, in particular, are likely to be available through conservation organizations. Depending on the conservation/land administration structure within a country, wetland managers or interest groups could be individually contacted or surveyed to acquire data for the inventory. For wetlands created for wastewater treatment purposes, data are likely available from the operators of such systems.

To supplement in-country data on lands with wetland mineral soils and organic soils, or if in-country data are not readily available, inventory compilers may use internationally available data. Although availability of data needed to accurately estimate emissions and removals is limited, certain meta-databases may prove useful. The most notable wetlands dataset is the Ramsar Wetland Data Gateway (see list of global databases below). For most ‘wetlands of international importance,’ the Ramsar database provides relevant characteristics, as of 2004, including wetland type, area, elevation, persistence of water, salinity, soil type, land use inside and adjacent to the wetland, and vegetation types. This database has the level of detail necessary to provide inputs to the methods in this *Wetlands Supplement*, but does not contain every wetland mineral soil or all organic soils in the world. However, the information contained in the database could be used to find proxy data for areas known to be similar. The type of management activity on each wetland (e.g. drainage, restoration) is typically tracked by natural resource agencies within individual countries. *Wetlands International* also tracks wetland drainage practices at an international scale.

Below is a list of resources that may prove useful to inventory compilers in obtaining activity data for estimating greenhouse gas emissions and removals from wetlands and organic soils included in this guidance.

GLOBAL AND REGIONAL DATABASES

- Ramsar Wetland Data Gateway - http://sedac.ciesin.columbia.edu/ramsardg/ and www.ramsar.org
    - Data for 2004

  - Wetland type, area, elevation, persistence of water, salinity, soil type, land uses inside site, land uses outside site, noteworthy flora values, noteworthy fauna values, internal threats, and external threats

- IPCC Emission Factor Database - http://www.ipcc-nggip.iges.or.jp/EFDB/main.php
  - Default emission data for wetlands and organic soils
  - Emission or removal data for specific types of wetland and organic soils
- UNEP Global Resources Information Database (GRID) - http://www.grid.unep.ch
  - Metadataset
- WWF Global Lakes and Wetlands Database - http://worldwildlife.org/pages/conservation-science-data-and-tools
  - Geospatial dataset
  - Data for multiple years
- UNEP-WCMC Wetlands database - http://www.unep-wcmc.org/
  - Geospatial dataset
  - Data for 1993
- ISRIC World Soil Information http://www.isric.org/
  - Web based soil maps
  - World soil database
  - Training on global soils, soil and terrain classification, soil mapping and soil information systems
- International Mire Conservation Group (IMCG) Global Peatland Database

  http://www.imcg.net/pages/publications/imcg-materials.php?lang=EN.

  For all countries/regions of the World and for the years 1990 and 2008, data on
  - Occurrence, ecology, history and area of peatland
  - Land use and drainage status of peatlands
  - Carbon stocks of peatlands
  - CO_2 emissions from peatlands
- International Peat Society - http://www.peatsociety.org/
  - Areas of peatland at end 1999
  - Peat resources and reserves 1999
  - Peat extraction and combustion 1999
- European soil data base- http://eusoils.jrc.ec.europa.eu/

OTHER POTENTIAL RESOURCES

- National Soil Surveys
- National Geological Surveys
- Research institutions of relevant former colonial powers
- Land tax authorities
- Chambers of Agriculture
- National Forest Bureaux
- National environmental or natural resources agencies
- National statistics agencies
- Sector experts

- Wastewater treatment wetland managers
- Stakeholder organizations (e.g., Wetlands International, Ramsar Bureau)
- Natural resource or wetlands conservation organizations
- Universities
- Scientific literature
- Verified Carbon Standard: Requirements and methodologies for quantifying and crediting carbon projects in peatlands, mangroves and coastal and tidal wetlands, and other wetlands

References

Bonn, A., Allott, T., Evans, M., Joosten, H. and Stoneman, R (eds.) (2013). Peatland restoration and ecosystem services: Science, policy and practice. Cambridge University Press, Cambridge.

Cogley, J.G. (1987/1991/1994). GGHYDRO: global hydrographic data, Release 2.1. Department of Geography, Trent University, Peterborough, Ont., Canada.

Couwenberg, J. and Fritz, C. (2012). Towards developing IPCC methane 'emission factors'for peatlands (organic soils). Mires and Peat, Volume 10 (2012), Article 03, 1–17. http://www.mires-and-peat.net/map10/map_10_03.pdf

Couwenberg, J., Dommain, R. and Joosten, H. (2010). Greenhouse gas fluxes from tropical peatlands in south-east Asia. Global Change Biology 16: 1715- 1732. http://circa.europa.eu/Public/irc/env/biodiversity_climate/library?l=/ghgfluxestropicalpeatlan/_EN_1.0_&a=d

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

de Groot, R.S., Alkemade, R., Braat, L., Hein, L. and Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7: 260–272.

Donato, D.C., Kauffman, J.B., Murdiyarso, D., Kurnianto, S., Stidham, M., Kanninen, M. (2011). Mangroves among the most carbon-rich forests in the tropics. Nature Geosciences 4: 293-297. http://mangroveactionproject.org/files/resources/Donato.etal_2011_NatureGeo_MangroveCarbonStorage.pdf

Elmqvist, T. and Maltby, E (CLAs) (2010). Biodiversity, ecosystems and ecosystem services. In: The Economics of Ecosystems and Biodiversity : The Ecological and Economic Foundations (TEEB D0) Chapter 2, 96 p.

FAO (1998). World Reference Base for Soil Resources. World Soil Resources Reports, 84, 88 pp.

FAO (2006). World reference base for soil resources 2006: A framework for international classification, correlation and communication. Food and Agriculture Organization of the United Nations, Rome. World Soil Resources Report 103. Retrieved from: ftp://ftp.fao.org/agl/agll/docs/wsrr103e.pdf

Fenner, N., and C. Freeman. C. (2011). Drought-induced carbon loss in peatlands. Nature Geoscience, doi: 10.1038/ngeo1323. http://www.eenews.net/assets/2011/11/21/document_cw_01.pdf

Gorham, E. (1991). Northern peatlands: Role in the carbon cycle and probable responses to climatic warming. Ecological Applications 1: 182–195.

Hiederer, R. and Köchy1, M. (2011). Global Soil Organic Carbon Estimates and the Harmonized World Soil Database. EUR 25225 EN. Publications Office of the European Union.79pp.

Hodges, J.C.F., Friedl, M.A., Strahler, A.H. (2001). The MODIS global land cover product: new data sets for global land surface parameterization. Proceedings of the Global Change Open Science Conference, Amsterdam, 2001. Documentation at http://www.bu.edu/lcsc/. Data downloaded from http://duckwater.bu.edu/lc/mod12q1.html.

Hodson, E. L., Poulter, B., Zimmermann, N. E., Prigent, C. and Kaplan, J. O. (2011). The El Niño–Southern Oscillation and wetland methane interannual variability, *Geophys. Res. Lett.*, 38, L08810, doi:10.1029/2011GL046861. http://www.wsl.ch/staff/niklaus.zimmermann/papers/GRL_Hodson_2011.pdf

IPCC. (2006). *2006 IPCC Guidelines* for National Greenhouse Gas Inventories. Retrieved November 21, 2011, from: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

IPCC. (2010). Revisiting the Use of Managed Land as a Proxy for Estimating National Anthropogenic Emissions and Removals, eds: Eggleston H.S., Srivastava N., Tanabe K., Baasansuren J. Meeting Report, 5 -7 May, 2009, INPE, São José dos Campos, Brazil, Pub. IGES, Japan 2010 http://www.ipcc-nggip.iges.or.jp/meeting/pdffiles/0905_MLP_Report.pdf

IPCC. (2011). IPCC Expert Meeting on HWP, Wetlands and Soil N2O. Geneva, Switzerland: eds:Eggleston, H.S.; Srivastava, N.; Tanabe, K; Baasansuren, J.; Fukuda, M. IGES, Japan 2011. http://www.ipcc-nggip.iges.or.jp/meeting/pdffiles/1010_MeetingReport_AdvanceCopy.pdf

Joosten, H. and Clarke, D. (2002). Wise use of mires and peatlands – Background and principles including a framework for decision-making. International Mire Conservation Group / International Peat Society, 304 p. http://www.peatsociety.org/sites/default/files/files/WUMP_Wise_Use_of_Mires_and_Peatlands_book.pdf

Joosten, H. and Couwenberg, J. (2008). Peatlands and carbon. In: Parish, F., Sirin, A., Charman, D., Joosten, H., Minaeva, T. and Silvius, M. (eds) 2008. Assessment on peatlands, biodiversity and climate change. Global Environment Centre, Kuala Lumpur and Wetlands International Wageningen, pp. 99-117.

Lafleur, P.M. (2009). Connecting atmosphere and wetland: Trace gas exchange. Geography Compass 3: 560–585.

Lappalainen, E. (ed.) (1996). Global peat resources. International Peat Society and Geological Survey of Finland, Jyskä.

Lehner, B. and Döll, P. (2004). Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology 296: 1-22. http://www.geo.uni-frankfurt.de/ipg/ag/dl/f_publikationen/2004/lehner_doell_JHydrol2004_GLWD.pdf

Limpens, J., Berendse, F., Blodau, C., Canadell, J.G., Freeman, C., Holden, J., Roulet, N., Rydin, H. and Schaepman-Strub, G. (2008). Peatlands and the carbon cycle: from local processes to global implications - a synthesis. Biogeosciences 5: 1475-1491.

Loveland, T.R., Reed, B.C., Brown, J.F., Ohlen, D.O., Zhu, J., Yang, L., Merchant, J.W. (2000). Development of a global land cover characteristics database and IGBP DISCover from 1-km AVHRR data. Int. J. Remote Sensing 21(6/7), 1303–1330.

Matthews, E., Fung, I. (1987). Methane emission from natural wetlands: global distribution, area, and environmental characteristics of sources. Global Biogeochem. Cycles 1, 61–86.

Mitra, S., Wassmann, R. and Vlek, L.G. (2005). An appraisal of global wetland area and its organic carbon stock. Current Science 88: 25–35.

Page, S.E., Rieley, J.O. and Banks, C.J. (2011) Global and regional importance of the tropical peatland carbon pool. Global Change Biology 17: 798–818.

Pendleton L., D. C. Donato, S.Crooks, B.C. Murray, W. A. Jenkins, S. Sifleet, A. Baldera, C. Craft, J. W. Fourqurean, J. B. Kauffman, N. Marbà, P.Megonigal, E. Pidgeon, V. Bilbao-Bastida, R. Ullman, D. Herr. 2012. Estimating global ''blue carbon'' emissions from conversion and degradation of vegetated coastal ecosystems. PLoS ONE 7(9): e43542. doi:10.1371/journal.pone.0043542

Schumann, M. & Joosten, H. 2008. Global peatland restoration manual. Online www.imcg.net/media/download_gallery/books/gprm_01.pdf, 68 p.

Soil Survey Staff. 2010. Keys to Soil Taxonomy. Eleventh edition. USDA., Natural Resources Conservation Service, Washington, D.C.

Stillwell-Soller, L.M., Klinger, L.F., Pollard, D., Thompson, S.L.(1995). The Global Distribution of Freshwater Wetlands. NCAR Technical Note TN-416 þ STR, National Center for Atmospheric Research, Boulder, CO.

Strack, M. (ed.) (2008). Peatlands and climate change. International Peat Society, Jyväskylä, 223pp. http://www.peatsociety.org/sites/default/files/files/PeatlandsandClimateChangeBookIPS2008.pdf

Victoria, R., Banwart, S., Black, H., Ingram, J., Joosten, H., Milne, E. and Noellemeyer, E. (2012). The benefits of soil carbon. Managing soils for multiple economic, societal, and environmental benefits. UNEP Yearbook 2012, UNEP, Nairobi, pp. 18-33. http://www.unep.org/yearbook/2012/pdfs/UYB_2012_CH_2.pdf

Wilson, D., Renou-Wilson F,, Farrell, C., Bullock, C., and Müller, C.. (2012). Carbon Restore – the potential of restored Irish peatlands for carbon uptake and storage. Climate Change Research Programme (CCRP) 2007-2013. Wexford, Environmental Protection Agency (EPA). Report Series No. 15: 32.

Xu, X. and Tian H. (2012). Methane exchange between marshland and the atmosphere over China during 1949-2008, Global Biogeochemical Cycles, 26, GB2006, DOI 10.1029/2010GB003946.