CHAPTER 1

INTRODUCTION

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1 INTRODUCTION

1.1 BACKGROUND

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*) recognize that the guidance on Wetlands in Volume 4, Chapter 7 is incomplete and restricted 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' (Volume 4, Chapter 7, Section 7.2) and CO_2 emissions from 'reservoirs or impoundments, for energy production, irrigation, navigation, or recreation (Flooded Land)' (Volume 4, Chapter 7, Section 7.3).

In October 2010, an IPCC expert meeting on harvested wood products, wetlands and N_2O emissions from soils concluded that there was sufficient new scientific information available to provide additional methodological guidance and fill gaps in the existing guidelines (IPCC 2011) for the rewetting and restoration of peatlands; emissions from fires, ditches, and waterborne carbon; and constructed wetlands for waste water disposal. In December 2010, the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) invited the IPCC to undertake further methodological work on wetlands, focusing on the rewetting and restoration of peatland, with the view of filling in the gaps in the *2006 IPCC Guidelines* in these areas.

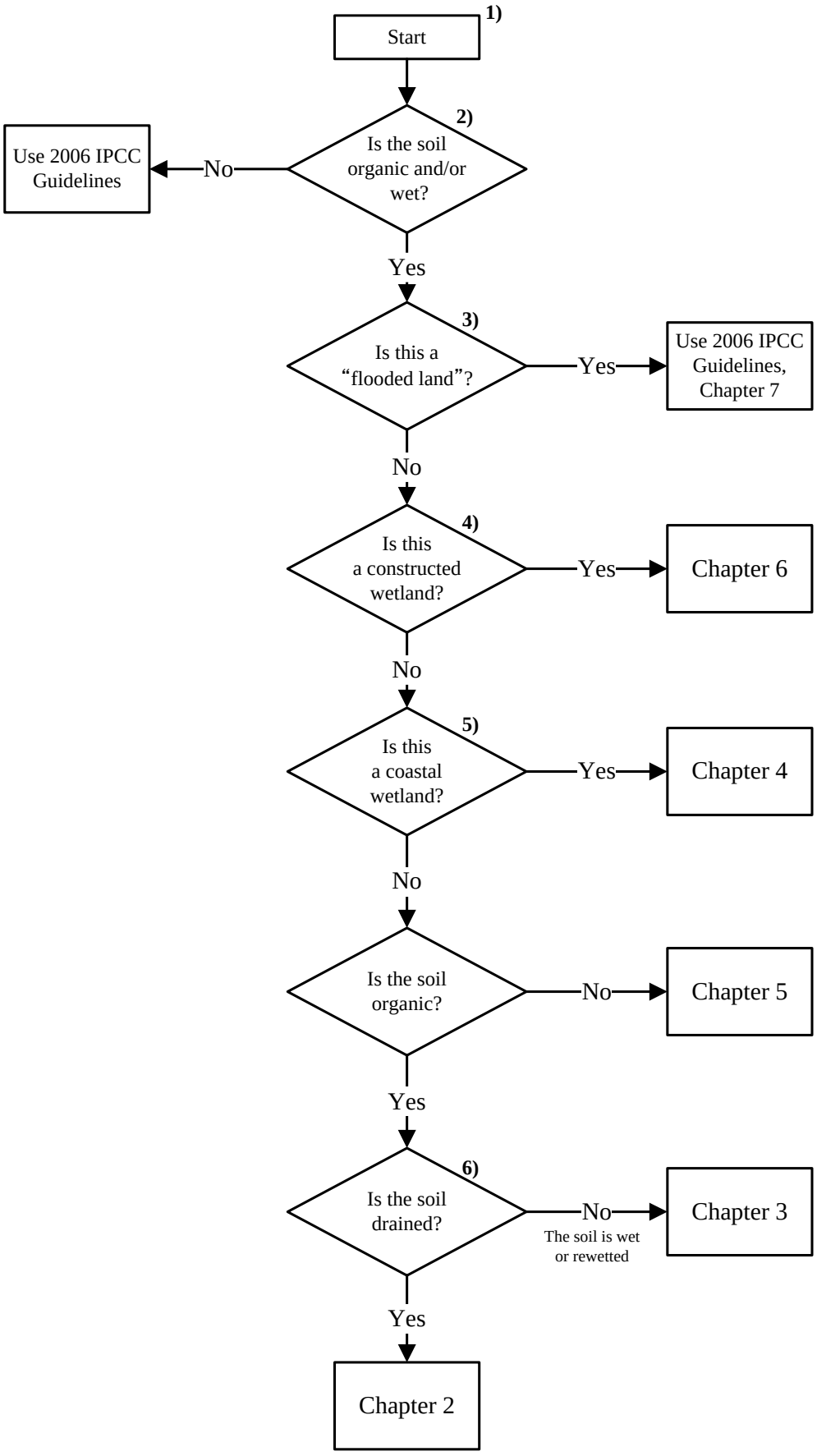
This *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (*Wetlands Supplement*) provides new guidance on estimating and reporting greenhouse gas emissions from organic soils and from wetlands, in so far as they are (directly) impacted by human activities ('managed'). The following chapters are included:

- Cross-cutting guidance on organic soils (supplemental guidance to *2006 IPCC Guidelines*, Volume 4, Chapter 2, on generic methods relating to organic soils on all land-use categories, especially Forest Land, Cropland and Grassland)
- Rewetting and restoration of peatlands and other organic soils
- Managed coastal wetlands
- Managed inland mineral soil wetlands
- Constructed wetlands—wastewater treatment systems
- Good practice and implications for reporting

1.2 USING THIS SUPPLEMENT IN CONJUNCTION WITH THE 2006 IPCC GUIDELINES

This introductory chapter is intended to provide guidance to the inventory compiler on how to use this *Wetlands Supplement* in conjunction with the existing *2006 IPCC Guidelines* when preparing a greenhouse gas inventory that includes wet and/or organic soils. The decision tree (Figure 1.1) can be used to guide the inventory compiler to the appropriate guidance 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



1) All land should be classified into the six IPCC land-use categories, which are defined in the 2006 IPCC Guidelines (Volume 4, Chapter 3, Section 3.2). These are Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land. These categories will need to be subdivided into sub-categories with similar vegetation, use and properties for the purpose of estimating emissions and removals. This Wetlands Supplement covers land that may be classified into any of the six IPCC land-use categories.

2) Organic soils are soils with a substantial layer of organic matter at or near the surface (see section 1.4). Wet soils are inundated or saturated by water for all or part of the year to the extent that soil microbes and rooted plants adapted to anaerobic conditions control the greenhouse gas emissions.

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 (*2006 IPCC Guidelines*, Volume 4, Chapter 7, page 7.5)

4) 'Constructed wetlands' are fully human-made wetlands for wastewater treatment. Synonymous terms include 'man-made', 'engineered' or 'artificial' wetlands.

5) 'Coastal wetlands' are defined here as wetlands at or near the coast that are influenced by saline or brackish water and/or astronomic tides. Their seaward limit is the deepest occurrence of rooted vascular plants. Coastal wetlands may occur both on organic and mineral soils. Brackish/saline water is water that contains 500 or more parts per million (ppm) of dissolved salts.

6) 'Drained' refers to formerly 'wet' soils (see footnote 2 above) where the water table has been lowered. 'Rewetted' refers to soils that were 'drained' but are currently 'wet'.

1.3 DEFINITION AND COVERAGE OF WETLANDS

For the purpose of this Supplement, Wetlands includes "any land that is covered or saturated by water for all or part of the year and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories" (*2006 IPCC Guidelines* Volume 4, Chapter 3). Wetlands may naturally occur in inland and coastal areas, and near shore environments, e.g., swamps, marshes, fens, peatlands, bogs, riparian forests, mangroves, tidal freshwater wetlands and seagrass beds. Wetlands can be man-made, e.g., fish ponds, wastewater treatment plants, dams and reservoirs.

BOX 1.1
DEFINITIONS OF WETLANDS IN THE 2006 IPCC GUIDELINES AND THE RAMSAR CONVENTION

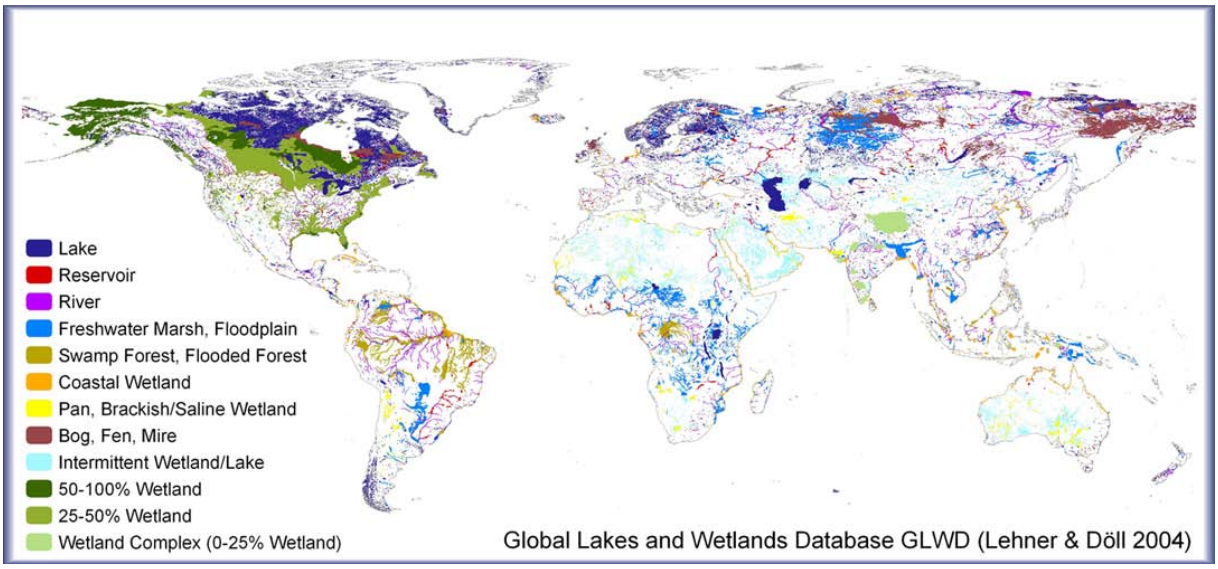
2006 IPCC Guidelines, Volume 4, Chapter 7: "Wetlands include any land that is covered or saturated by water for all or part of the year (e.g., peatlands), and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs and areas of peat extraction as a managed sub-division, and natural rivers and lakes as unmanaged sub-divisions."

Ramsar Convention on Wetlands, Article 1.1: "Wetlands are areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."

Wetlands should be subdivided into managed and unmanaged sub-categories based upon the national definition used within the country. Managed wetlands can be wetlands where the water table is artificially changed (e.g., lowered or raised) or those created through human activity (e.g., damming a river) (*2006 IPCC Guidelines*). Managed wetlands also include wetlands where resource extraction takes place without alteration of hydrology or vegetation (e.g., selective logging of mangrove trees in coastal wetlands, mowing of reeds in inland wetlands).

Wetlands occur from the tundra to the tropics (see Figure 1.2) and are extremely diverse and variable. The total area of wetlands on Earth is not precisely known. Lehner and Doll (2004) estimate that global wetlands (excluding lakes and reservoirs) cover about 8-10 million km^2, or 6.2-7.6% of the total global land surface.

Figure 1.2 Global distribution of wetlands according to the Global Lakes and Wetlands Database (Lehner and Doll, 2004)



Wetlands are crucial in maintaining the Earth's carbon balance, with peatlands, mangroves, and marshes containing the largest carbon stocks of the terrestrial biosphere (Joosten and Couwenberg, 2008, Donato et al., 2011). Wetlands can be either a source or sink of greenhouse gases to the atmosphere. The emissions are largely controlled by the degree of water saturation as well as climate and nutrient availability (Hodson et al., 2011; Couwenberg et al., 2010). Un-drained or rewetted wetlands with water levels at or near the soil surface emit methane (CH_4) (Couwenberg & Fritz, 2012), but have very low fluxes of CO_2 and N_2O (Couwenberg et al., 2011), while drained wetlands emit CO_2 and N_2O, but have generally negligible CH_4 fluxes (Couwenberg, 2010).

The balance of greenhouse gas emissions from managed wetlands and organic soils is largely controlled by the trade-off between CH_4 emissions under saturated soil conditions versus CO_2 emissions under dry soil conditions. Nitrous oxide emissions from wetlands are typically low, unless an outside source of nitrogen enters the wetland, such as from nearby agricultural lands. If wetlands are drained, N_2O emissions are controlled by the fertility of the soil as well as the addition of nitrogen fertilizers. Aggregate fluxes of CO_2 and N_2O (in CO_2 equivalent) from dry soils are generally larger than the aggregate CH_4, CO_2, and N_2O (in CO_2 equivalent) fluxes from saturated soils.

Human activities (agriculture, forestry, peat extraction, anthropogenic fires) may significantly affect the carbon and nitrogen balance of wetlands. It is estimated that as much as 50% of the Earth's wetlands have been converted (Mitch and Gosselink, 2007). Drainage or vegetation degradation/loss changes wetlands from a source of CH_4 emissions (due to anaerobic decomposition of organic matter) to a source of CO_2 and N_2O emissions (due to oxidation of soil organic matter and nitrification/denitrification). Joosten (2010) estimates the global carbon emissions from drained peatland (by microbial peat oxidation and peat fires) at 0.5 Pg annually, i.e. 0.3% of the global land area being responsible for >5% of the global anthropogenic CO_2 emissions. According to Donato et al. (2011), mangrove deforestation generates emissions of 0.02–0.12 Pg carbon per year—as much as around 10% of emissions from deforestation globally, despite accounting for just 0.7% of tropical forest area.

While rewetting of wetlands increases CH_4 emissions, it decreases CO_2 and N_2O emissions. The actual magnitude of human-influenced wetlands emissions and removals depends on numerous variables, including wetland type, wetland area, management practice, vegetative composition, water table depth, growing season precipitation, and temperature (Fenner and Freeman, 2011).

151

TABLE 1.1
GLOBAL DISTRIBUTION OF WETLANDS (IN 10,000 KM^2; NOT MUTUALLY EXCLUSIVE; AFTER LEHNER AND DÖLL, 2004 [3)]; JOOSTEN, 2010[4)])

Region	Coastal[1)]	Constructed[2)]	Freshwater (inland, non-marine)[3)]	Peatland[4)]
Africa			131	13
Asia			286	155
Australia and Pacific Region			28	7
Europe			26	50
North America			287	140
South America			159	16

[*The data for "Coastal" and "Constructed" will be included in this table and explanation about them will be provided in this section in the Second Order Draft.*]

152 # 1.4 DEFINITION AND COVERAGE OF ORGANIC
153 # SOILS

154 According to the *2006 IPCC Guidelines*, soils are organic if they satisfy the requirements 1 and 2, or 1 and 3
155 below:

156 1. Thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12
157 percent or more organic carbon when mixed to a depth of 20 cm;

158 2. Soils that are never saturated with water for more than a few days must contain more than 20 percent
159 organic carbon by weight (i.e., about 35 percent organic matter); and

160 3. Soils are subject to water saturation episodes and have either:

161 a. At least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soil has
162 no clay; or

163 b. At least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soil has
164 60% or more clay; or

165 c. An intermediate proportional amount of organic carbon for intermediate amounts of clay.'

166 Annex 3A.5 in Volume 4 of the *2006 IPCC Guidelines* offers criteria for the identification of organic (peat) soils
167 based on the FAO (1998) key to soil types.

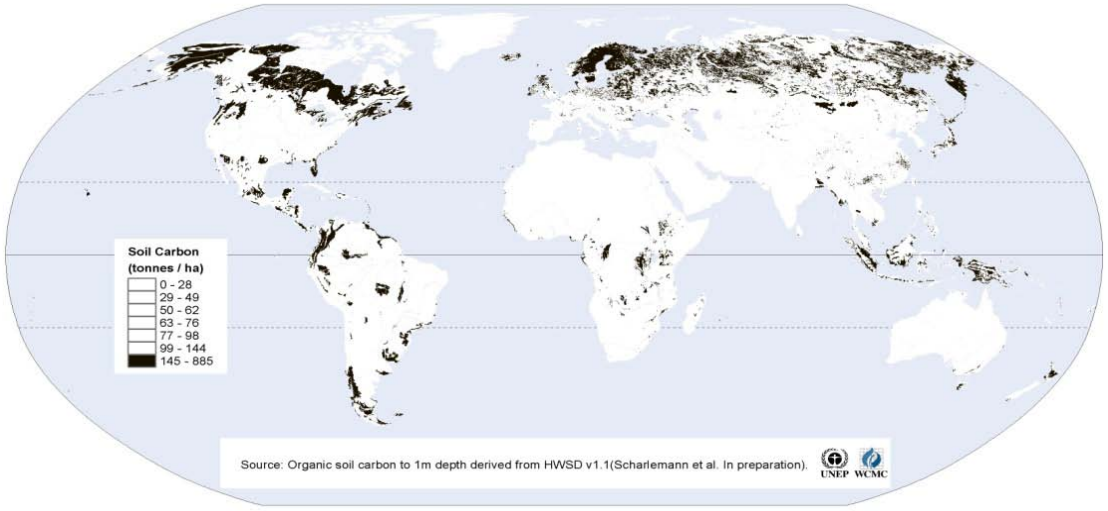
168 The *2006 IPCC Guidelines* thus largely follow the FAO (1998/2006) definition of 'Histosol' and link (and even
169 equate) organic soils to peat soils (Table 1.2). Indeed, apart from shallow (≥10 cm) organic -rich soils overlying
170 ice or rock, organic soils (Histosols) are identical with peat and peaty soils of at least 40 cm total thickness
171 within the uppermost 100 cm, containing at least 12 percent organic carbon (~20 percent organic material) by
172 weight. This definition deviates from most European definitions of peatland in that it stipulates a slightly thicker
173 organic layer and slightly lower organic matter content (Joosten and Clarke, 2002). IPCC (2003, 2006) omits the
174 40 cm criterion from the FAO definition to allow for country specific approaches.

TABLE 1.2
FAO 2006 SUMMARY DESCRIPTION OF HISTOSOLS/ORGANIC SOILS

Connotation	Peat and muck soils; from Greek *histos*, tissue
Parent material	Incompletely decomposed plant remains, with or without admixtures of sand, silt or clay
Environment	Histosols occur extensively in boreal, arctic and subarctic regions. Elsewhere, they are confined to poorly drained basins and depressions, swamp and marshlands with shallow groundwater, and highland areas with a high precipitation–evapotranspiration ratio
Profile development	Mineralization is slow and transformation of plant remains through biochemical disintegration, and formation of humic substances creates a surface layer of mould with or without prolonged water saturation. Translocated organic material may accumulate in deeper tiers but is more often leached from the soil

Figure 1.3 presents the occurrence of organic soils in the world. A total of around 4 million km^2 of peatland occur in the world (Lappalainen 1996, Joosten 2010) of which some 10% are found in tropical regions (Page et al., 2011). The total carbon stock in peatlands amounts to 500 Gt (Joosten 2010, Page et al. 2011).

Figure 1.3 Indicative map of the occurrence of organic soils in the world



Modified from Victoria et al. (2012)

Drainage of organic soils lowers the water table, exposes formerly water-saturated organic layers to oxidation and increases CO_2 and N_2O emissions, while generally reducing CH_4 emissions (Strack 2008). Drainage waters conduct dissolved and particulate waterborne carbon out of organic soil (Joosten & Couwenberg 2008). The significant CH_4 emissions from human-made ditches in organic soils were not addressed in the *2006 IPCC Guidelines* due to insufficient scientific information available at that time. In this *Wetlands Supplement*, new guidance also takes the intensity of the drainage of organic soils and the associated losses of waterborne carbon into account when estimating emissions and removals.

1.5 MANAGED WETLANDS

According to the *2006 IPCC Guidelines* it is *good practice* that, when preparing a greenhouse gas inventory, a country first produces a complete and consistent land-use representation that divides the land-uses into six major land-use categories: Forest Land, Grassland, Cropland, Wetlands, Settlements and Other Lands. The *2006 IPCC Guidelines* provide definitions for each of these land-use categories; however, these are not prescriptive, and can be adjusted by the country to better represent their unique conditions.

The *2006 IPCC Guidelines* provide methods to estimate anthropogenic emissions and removals of greenhouse gases (Section 1.1, Chapter 1 in Volume 1 of the *2006 IPCC Guidelines*). The *Guidelines* have adopted as a

proxy (the 'managed land proxy') that all emissions and removals occurring on managed land are considered to be anthropogenic (Section 1.1, Chapter 1 in Volume 1 and Section 1.1, Chapter 1 in Volume 4 of the *2006 IPCC Guidelines*). An IPCC expert meeting held in May 2010 examined this issue further but was unable to recommend an improved, globally applicable, alternative way of estimating anthropogenic emissions and removals (IPCC 2010). 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'. Chapter 7 in 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.'

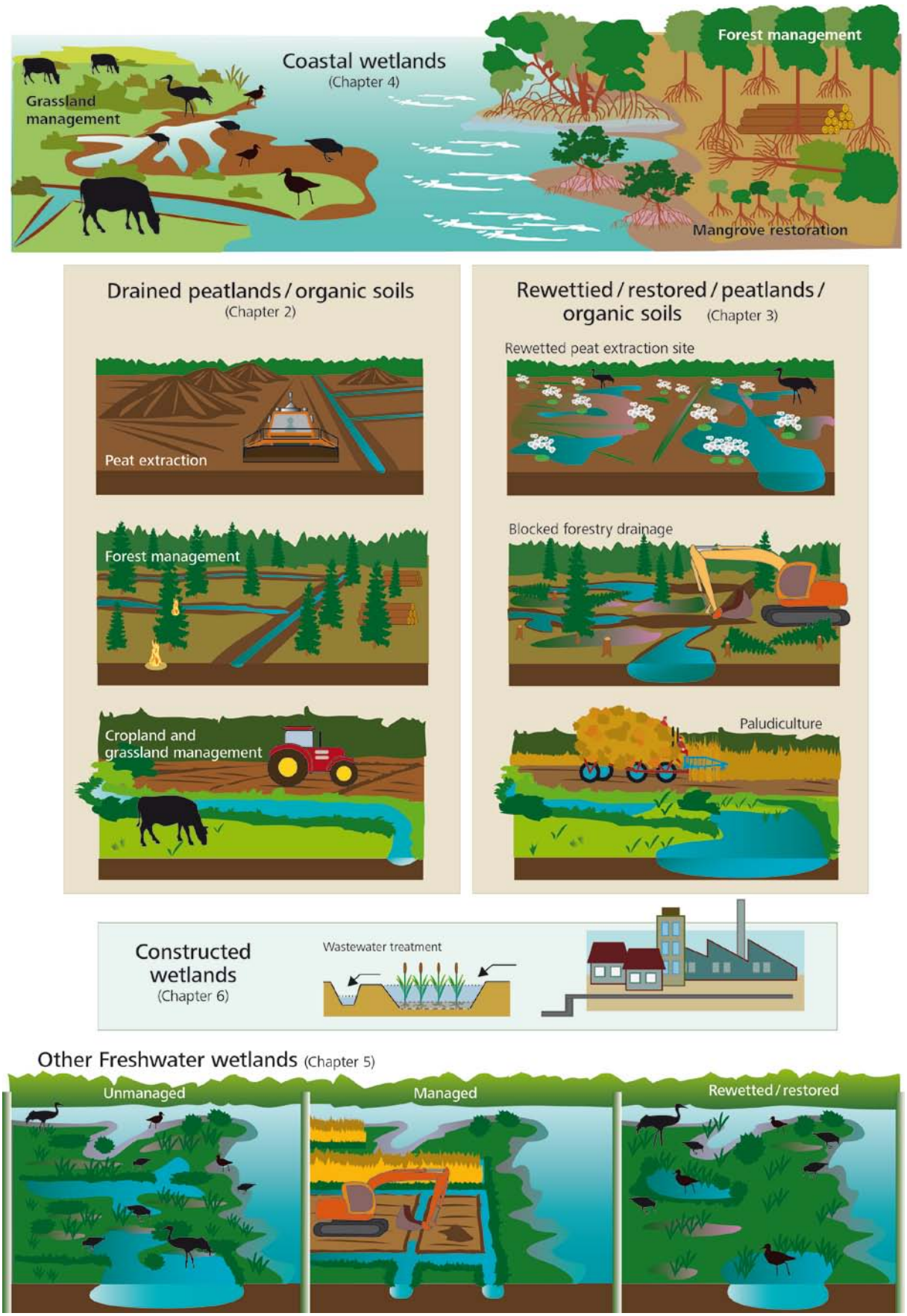
This *Wetlands Supplement* includes activities and land-use subcategories where the water table is not changed, and so the restriction imposed by Chapter 7 in Volume 4 of the *2006 IPCC Guidelines* is no longer applicable. Therefore, emissions and removals should be estimated for all land in a country that is designated as managed. Where wetlands are impacted by human activities, they should be considered managed. Figure 1.4 illustrates some typical human activities and associated GHG emissions and removals on managed wetlands. Table 1.3 provides some examples of production, ecological and social functions that can result in 'managed' wetlands.

TABLE 1.3
EXAMPLES OF ACTIVITIES RELATED TO PRODUCTION, ECOLOGICAL AND SOCIAL FUNCTIONS THAT RESULT IN MANAGED WETLANDS (JOOSTEN & CLARKE, 2002; DE GROOT ET AL., 2010; ELMQVIST & MALTBY, 2010)

Function	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
Activities	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.

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 it may be possible in some circumstances 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.

Figure 1.4 Some typical management activities and associated GHG emissions and removals on the wetlands



1.6 COHERENCE AND COMPATIBILITY WITH 2006 IPCC GUIDELINES

1.6.1 Existing guidance in the 2006 IPCC Guidelines

ORGANIC SOILS

The *2006 IPCC Guidelines* provide guidance for estimating greenhouse gas emissions from drained organic (managed) soils within the land use categories Forest Land, Cropland, Grassland, and Settlements. In Volume 4, Chapter 2, Section 2.3.3 of the *2006 IPCC Guidelines*, guidance is provided at the Tier 1 level (with limited additional guidance for Tiers 2 and 3) to estimate CO_2 emissions from drained organic soils using an area based annual emission factor differentiated by climate type.

BIOMASS C STOCKS

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

DIRECT AND INDIRECT N2O EMISSIONS FROM MANAGED SOILS

In Volume 4, Chapter 11 of the *2006 IPCC Guidelines* methodologies to estimate both direct and indirect N_2O emissions from managed soils are provided. Generic equations are presented, which can be applied to specific land categories if activity data are available. Nitrous Oxide emissions from drained organic soils use an area based annual emission factor differentiated by climate type. For temperate forest lands, soil fertility (nutrient rich/nutrient poor) is also a criterion for determining the appropriate emission factor. Also, indirect N_2O emissions from managed soils arising from agricultural inputs (which may end up in wetlands through volatilization or leaching and run-off of N) are addressed in Chapter 11. Indirect N_2O emissions from combustion-related and industrial sources are described in Volume 1, Chapter 7, Section 7.3. In order to prevent double-counting, the N input into wetlands as a result of leaching/runoff or volatilization/deposition from other land use categories or activities (e.g., combustion for energy) should not be accounted for in the Wetlands category.

BURNING

Generic guidance for non-CO_2 emissions from fires due to burning of live and dead biomass on managed lands (Forest Land, Cropland and Grassland) is provided under Volume 4, Chapter 2 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

In addition CH_4 emissions from rice cultivation are included in Volume 4, Chapter 5 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 involve vegetation removal (e.g., 'sausage peat extraction') or drainage (e.g., 'hydrotorf' procedures) is not provided. The *2006 IPCC Guidelines* (Volume 4, Chapter 7) furthermore provide guidance for estimating emissions from reservoirs or impoundments used for hydroelectricity production, irrigation, navigation, or recreation (Section 7.3). The scope of the assessment includes CO_2 emissions from all lands converted to permanently Flooded Lands, i.e., where human activities have caused an increase in the amount of surface 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 Lands.

WASTEWATER TREATMENT

In Volume 5, Chapter 6 of the *2006 IPCC Guidelines* (waste water 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 at all in the *IPCC Guidelines* and should not be included in national total emissions because of their biogenic origin and rapid turnover.

1.6.2 Need for supplementary and updated guidance

The *2006 IPCC Guidelines* recognize the need for future methodological guidance concerning rewetting and restoration of drained managed wetlands (Volume 4, Chapter 7). Also, manure management ponds, industrial effluent ponds, and aquaculture ponds are mentioned in the *2006 IPCC Guidelines* as examples of wetlands, for which methodologies were at that time inadequate to produce general guidance.

Insofar as the science has evolved, this *Wetlands Supplement* does the following:

- Fills in some of the recognized gaps, and provides methodologies for estimating emissions and removals from wetland types and activities/management practices not included in the *2006 IPCC Guidelines*.
- Provides updated emission factors for organic soils under different land-use categories and sub-categories already included in the *2006 IPCC Guidelines*.

The *Wetlands Supplement* does not provide any additional guidance for Flooded Lands compared to the *2006 IPCC Guidelines*, which currently only provides guidance to estimate CO_2 emissions and removals from land converted to flooded land. This is because the science has not advanced enough on this issue since publication of the *2006 IPCC Guidelines*.

1.6.3 Content of the Wetlands Supplement

CHAPTER 2—CROSS-CUTTING GUIDANCE ON GREENHOUSE GAS EMISSIONS AND REMOVALSFROM ORGANIC SOILS IN ALL LAND-USE CATEGORIES

In Chapter 2, methodologies for calculating emissions from managed organic soils are elaborated to take into account intensity of drainage, ditches, waterborne carbon, and peat fires. This *Wetlands Supplement* provides updated default emission factors (CO_2, CH_4, N_2O) for all inland land-use categories on organic soil (Forest Land, Cropland, Grassland, and Wetlands). 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 is provided and indirect CO_2 emissions associated with dissolved organic carbon release from peat to drainage waters are covered (see Table 1.4).

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

Formerly drained peatlands and organic soils that have been used for example for forestry, crop production, grazing, or peat extraction may be rewetted and restored/rehabilitated by raising the water table (e.g., by ditch-filling) and re-establishing a functional vegetation layer. Chapter 3 of the *Wetlands Supplement* provides Tier 1 level generic guidance for assessing the greenhouse gas emissions (CO_2, CH_4 and N_2O) and removals from various types of rewetted, restored, and rehabilitated peatlands and organic soils by climate region and peat type. (see Table 1.4)

CHAPTER 4—COASTAL WETLANDS

Chapter 4 provides methodologies for reporting greenhouse gas emissions and removals associated with managed coastal wetlands, such as mangroves, salt marshes, sea-grass meadows and tidal freshwater systems. Coastal wetlands are wetlands at or near the coast that are influenced by saline or brackish water and/or astronomic tides. Their seaward limit is the deepest occurrence of rooted vascular plants, e.g. sea-grasses. Coastal wetlands may occur both on organic and mineral soils. Separate guidance is given for coastal wetlands with unaltered hydrology, rewetted and drained coastal wetlands (see Table 1.4).

CHAPTER 5—INLAND MINERAL SOIL WETLANDS

Chapter 5 provides methodologies for reporting greenhouse gas emissions and removals from inland wetlands on mineral soils not included in Chapters 4 and 6 (see Table 1.4).

CHAPTER 6—CONSTRUCTED WETLANDS

Chapter 6 provides guidance on estimating greenhouse gas emissions and removals from constructed wetlands used for wastewater treatment. Chapter 6 provides supplementary guidance to the *2006 IPCC Guidelines*, Volume 5, Chapter 6 on wastewater treatment on constructed wetlands considering different types of constructed wetlands (e.g., vertical or horizontal flows). Some new emission factors for CH_4 emissions related to wastewater treatment are provided. 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 (Volume 4, Chapter 11) as part of the leaching/ runoff and volatilization components of indirect emissions.

CROSS CHAPTER ISSUES

Chapters 2 through 6 do not provide wetland-specific guidance on estimating carbon stock changes and greenhouse gas emissions and removals related to biomass and dead organic matter pools (dead wood and litter). Generic guidance for estimating these pools can be found in the *2006 IPCC Guidelines*. However, Chapters 4 and 5 provide new emission factors for biomass and dead wood in addition to soils and new stock change factors associated with activities that occur in these systems.

Countries should take care to avoid double-counting emissions that have already been estimated elsewhere in the inventory report. In addition, care should be taken that 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 are the result of non-point source agricultural effluent and already addressed as indirect emission from the soil amendments (e.g., nitrogen fertilizers) within Volume 4, Chapter 11 of the *2006 IPCC Guidelines*. This is especially relevant because various wetland types (e.g., aquaculture ponds, irrigated land, seasonally flooded agricultural land, salt exploitation sites, water storage areas, excavations, wastewater treatment areas, canals and drainage channels, ditches) can feature under various land categories (Figure 1.4).

It should be noted that waterborne carbon may already be included in a country's emission estimates if the country uses a methodology where soil C stock change is directly measured on site (e.g., soil sampling associated with forest inventories).

Table 1.4 represents an overview of the chapters of the *Wetlands Supplement* that provide specific new guidance and how the chapters link to the *2006 IPCC Guidelines*.

TABLE 1.4
SPECIFIC NEW GUIDANCE PROVIDED IN WETLANDS SUPPLEMENT

	Wetlands Supplement		**Linkage to *2006 IPCC Guidelines***
Chapter	**Specific guidance provided in *Wetlands Supplement***	**Separate Tier 1 level guidance provided by**	
Chapter 2 Cross-cutting guidance on greenhouse gas emissions and removals from organic soils in all land-use categories	Supplementary information on greenhouse gas emissions and removals from drained organic land		Generic methodologies applicable to multiple land use categories to estimate the carbon stock change and non-CO_2 emissions from AFOLU Sector (Volume 4, Chapter 2) including N_2O emissions from managed land (Volume 4, Chapter 11)
2.1.3	CO_2 emissions from drained organic soils, updated EFs by water-table level provided	Land use category (FL, CL, GL, WL)	Change in Carbon stock in soils Volume 4, Chapter 2, Section 2.3.3 Chapter 4 (Forest land), Chapter 5 (Cropland), Chapter 6 (Grassland), Chapter 7 (Wetlands)
2.1.4.1	CH_4 emissions from drainage ditches, new guidance	Land use category (FL, CL, GL, WL)	Volume 4, Chapter 2, Section 2.4 (non-CO_2 emissions))
2.1.4.2	N_2O emissions from organic drained soils, updated EFs provided	Climate zone (boreal, temperate, tropical)	Direct N_2O emissions Volume 4, Chapter 11, Section 11.2.1 (Table 11.1)
2.1.5	Emissions from water-borne carbon (including fire), new guidance	Climate zone (boreal,temperate), Peatland type (bog/fen, blanket bog)	Change in Carbon stock in soils Volume 4, Chapter 2, Section 2.3.3
Chapter 3 Cross-cutting guidance on rewetted peatlands and organic soils	New guidance for estimating greenhouse gas emissions and removals from re-wetted and restored peatlands and organic soils		Guidance on estimating greenhouse gas emissions from managed wetlands Volume 4, Chapter 7 (Wetlands)

3.2.1	CO_2 emissions from rewetted peatlands/organic soils, new guidance	Climate zone (boreal, temperate), Peatland type (bog, fen)	(Volume 4, Chapter 7, Section 7.5) (Future methodological development)
3.2.2	CH_4 emissions and removals from rewetted peatlands/organic soils, new guidance	Climate zone (boreal, temperate, tropical), Peatland type (bog, fen)	(Volume 4, Chapter 7 Section 7.5) (Future methodological development)
3.2.3	N_2O emissions and removals from rewetted peatlands and organic soils, completely new guidance	insignificant (Tier 1 level)	(Volume 4, Chapter 7, Section 7.5) (Future methodological development)
Chapter 4 Coastal wetlands	New guidance for estimating greenhouse gas emissions and removals from managed coastal wetlands		Guidance on estimating greenhouse gas emissions from managed wetlands Volume 4, Chapter 7 (Wetlands), Generic methodologies applicable to multiple land use categories to estimate the carbon stock change and non-CO_2 emissions from AFOLU Sector (Volume 4, Chapter 2)
4.2.1	Biomass and soil C stock change, relative stock change factors for different management activities on coastal wetlands soils provided, new supplementary guidance	Coastal wetland with unchanged hydrology (mangrove, saltmarsh, seagrasses),	Volume 4 , Chapter 2, Chapter 7
4.2.2	N_2O emissions from coastal wetlands, new supplementing guidance	Coastal wetland with unchanged hydrology and receiving nutrient loading, Wetland type (pristine, N-fertilized, eutrophic))	Volume 4 , Chapter 2, Chapter 7
4.3	CO_2, CH_4, N_2O emissions from rewetted coastal wetlands	Rewetted coastal wetlands (mangrove, saltmarsh, sea-grasses)	Volume 4 , Chapter 2, Chapter 7 new supplementary guidance
4.4	CO_2, CH_4, N_2O emissions from drained coastal wetlands	Drained coastal wetlands (mangrove, saltmarsh, seagrasses)	Volume 4 , Chapter 2, Chapter 7 new supplementary guidance
Chapter 5 Inland mineral soil wetlands	New guidance for estimating greenhouse gas emissions and removals from other managed inland wetlands on mineral soils	Managed inland wetlands on mineral soils	Guidance on estimating greenhouse gas emissions from managed wetlands Volume 4, Chapter 7 (Wetlands), Generic methodologies applicable to multiple land use categories to estimate the carbon stock change and non-CO_2 emissions from AFOLU Sector (Volume 4, Chapter 2)

5.2	CO_2, CH_4, N_2O	Wetlands remaining wetlands, no change at Tier 1 level	Volume 4, Chapter 2, Chapter 7 new supplementary guidance
	CO_2, CH_4, N_2O	Land converted to wetlands	Volume 4, Chapter 2, Chapter 7 new supplementary guidance
	CO_2, CH_4, N_2O	Wetlands converted to other land use	Volume 4, Chapter 2, Chapter 7 new supplementary guidance
Chapter 6 Constructed wetlands	Supplementing Guidance for emissions and removals from constructed wetlands and seminatural treatment wetlands used for wastewater treatment		CH_4 and N_2O emissions from wastewater treatment and discharge (Volume 5 (Waste), Chapter 6)
	CH_4 emissions from wastewater ; MCF and correction factor for temperature and vegetation provided new, supplementary guidance	Type of waste water (domestic, industrial, leachate from landfill)	Volume 5, Chapter 6, Section 6.2
	N_2O emissions from waste water, EF provided new, supplementary guidance	Type of waste water (domestic, industrial including leachate from landfill)	Volume 5, Chapter 6, Section 6.3 Volume 4, Chapter 11, Section 11.2 (N_2O from agricultural wastewater)

1.7 ESTIMATING AND REPORTING OF EMISSIONS AND REMOVALS FROM MANAGED WETLANDS

CASE STUDY

The following approach is taken by an Annex 1 country in reporting of emissions and removals associated with land use and land use change of Wetlands and organic soils. The approach is consistent with the general principles of the *1996 IPCC guidelines* and was adopted in the absence of a default Tier 1 methodology.

Although emissions and removals of greenhouse gases are observed in both natural and managed wetland ecosystems, only those associated with human activities on wetlands are reported. In principle, this includes wetlands directly managed for forestry, agriculture and peat extraction and adjacent lands that are impacted by drainage. However, data of the extent and on-going influence of activities on emissions and removals on lands indirectly impacted by drainage is very limited.

ACTIVITY DATA

In this case study example, wetlands are nearly completely synonymous with peatlands. A number of estimates of the extent of peatlands have been made, based on different methodologies and classification criteria. The estimated peatland extent ranges from 14% to 20% of the total land area. The wide range of estimates is mainly due to differences in definitions when considering either land cover, land use, habitat type or and/soil type. Peatland extent based on land/soil type tends to produce estimates at the high end of the range, whilst estimates based on habitat tend to produce estimates at the low end. This is consistent with land use change and conversion from Wetlands on peat soil to Cropland, Grassland or Forest Land on peat soil. Emissions and removals associated with these peat soils are reported under the appropriate land category.

Three management activities are reported under Wetlands

1. peat extraction

2. rewetting/restoration after peat extraction

3. conversion from other land use (notably rewetting and restoration from Forest Land)

Both 1 and 2 are reported within the Wetlands remaining Wetlands category, 3 is reported as Forest Land converted to Wetlands.

Activity data for 1 and 2 are based on information received in consultation with the state owned commercial body responsible for much of the industrial peat extraction (for energy and horticultural use) within the jurisdiction. This body submits periodic reports on its land holdings and management practices. The state company holds detailed spatial records of land holdings; however these are not included in the data submission for inventory purposes. They also provide an analysis of the activities of private commercial activity based on market share.

In addition to commercial peat extraction, historically there has been significant non-commercial extraction of peat for domestic combustion, but this practice is in decline. The extent of the activity is estimated based on the national household energy/fuel use survey and the land area required to meet this demand. The area of peatland assumed to be drained for domestic peat extraction is assumed to be equal to five times the area required for extraction. This is to allow for drainage of additional peatland in preparation of future extraction. It is argued that the indirect impact of drainage for domestic extraction is much larger. Therefore this multiplier factor may be revisited when more specific findings emerge.

Commercial companies have a number of after-use options, including conversion to other land use (forestry, agriculture), abandonment, rewetting and restoration. Much land managed by the state company is approaching the end of commercial extraction, and therefore the company is carefully considering after-use options. The company has engaged in a number of studies including managed rewetting and restoration pilot studies. These studies, combined with earlier habitat and ecosystem studies, allow to make a coarse estimate of biomass recovery in restored areas and to estimate the timescale for recovery. A small area of cutaway peatland has already been put to “after-use”, and is included in the data submission provided by the company. It is assumed that the private commercial sector behaves in a similar manner regarding after use, but there is very limited data to support that. It is perhaps more likely that private extraction areas are abandoned and that the drainage channels gradually close and rewet the drained areas. This would lead to longer recovery periods.

For domestically cut peatlands, it is assumed that the peat is extracted down to the water table. In that case rewetting is immediate, and revegetation and recovery takes place over the same timescale as restoration of commercially exploited peatland.

In the inventory analysis, no distinction is made between rewetted and restored peatland. It is likely that restored peatland maintain a higher biomass and have a larger resilience to change compared to rewetted peatlands. The inventory analysis assumed recovery to a peatland state typical of the formerly existing peatland.

EMISSION FACTORS

There are no default emission factors available to estimate emissions and removals for rewetted and restored wetlands. Country specific factors have been estimated based on a limited number of pilot studies and on existing previous regional, national and local surveys of peatland.

Biomass recovers to a carbon density of 3tC ha^{-1} over a period of 5 years.

Rewetting of peat is assumed to stop the emission of CO_2 and N_2O to the atmosphere from peat oxidation. With the recovery of the vegetation, the normal process of growth and decay is likely to result in CH_4 emissions. In the national inventory examined here, it has been assumed that this CH_4emission is offset in the longer term by the gradual accumulation of new dead organic material (new peat formation). Therefore neither CH_4 emissions nor sequestration of carbon in peat are reported.

REPORTING OF GHG EMISSIONS AND REMOVALS OF MANAGED WETLANDS WITH COMPLETENESS AND WITHOUT DOUBLE-COUNTING

This *Wetlands Supplement* provides a supplementary guidance to the inventory compilers for estimating and reporting the GHG emissions and removal from managed wetlands and emissions from water-borne carbon and fire from drained organic lands. Extended reporting approaches should be adopted when the compilers prepare their inventory as below:

1) For estimating and reporting, emissions and removals from rewetted and restored wetlands, managed coastal wetlands, managed inland mineral soil wetlands and constructed wetlands should be included. Emissions from the drained organic soil, water-borne carbon and peat fire are taken into account when the national inventory is prepared.

2) For wetlands remaining wetlands, besides the emissions from wetlands remaining wetlands including peatland undergoing peat extraction and from flooded land remaining flooded land, the emissions and removals resulting from the human activities of rewetting and/or restoring after peat extraction, managements on coastal wetlands and inland mineral soil wetlands and from constructed wetlands should be included. It should also report the emissions from peat fire and water-borne carbon of drained wetlands and CH_4 emission from drainage ditches during the drainage of wetlands.

3) As wetlands converted to other lands, all greenhouse gases emissions and removals due to the conversion with biomass changes, and the changes of soil organic matter in term of carbon and nitrogen should be counted and reported.

The extension of the reporting categories of *2006 IPCC Guidelines* is provided in Table 1.5.

TABLE 1.5
EXTENSION OF REPORTING CATEGORIES IN 2006 IPCC GUIDELINES

2006 IPCC Guidelines			*Wetlands Supplement*
3.B.4	Wetlands	Emissions from 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. The category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.	Emissions and removals from rewetted and restored wetlands, managed coastal wetlands, managed inland mineral soil wetlands and constructed wetlands are included. Emissions from the drained organic soil, peat fire and water-borne carbon are taken into account when the national inventory is prepared.
3.B.4.a	Wetlands Remaining Wetlands	Emissions from peatland undergoing peat extraction and from flooded land remaining flooded land.	Besides emissions from wetlands remaining wetlands including peatland undergoing peat extraction and from flooded land remaining flooded land, the emissions and removals resulting from the of rewetting and restoring after peat extraction, managements on coastal wetlands and inland mineral soil wetlands and from constructed wetlands should be included. It should also report the emissions from peat fire and water-borne carbon of drained wetlands and CH_4 emission from drainage ditches during the wetlands are drained.
3.B.4.a.i	Peatlands Remaining peatlands	Includes (1) on-site emissions from peat deposits during the extraction phase and (2) off-site emissions from horticultural use of peat. The off-site emissions from the energy use of peat are reported in the Energy Sector and are therefore not included in this category.	Emissions and removals from rewetting and restoring after peat soil drainage and/or extraction, and other management activities on the peatlands remaining peatlands.
3.B.4.a.ii	Flooded Land remaining Flooded Land	Emissions from flooded land remaining flooded land. Flooded lands are defined as water bodies where human activities have caused changes in the amount of surface area covered by water, typically through water level regulation. Examples of flooded lands include reservoirs for the production of hydroelectricity, irrigation, navigation, etc. Regulated lakes and rivers that have not experienced substantial changes in water area in comparison with the pre-flooded ecosystem are not considered as flooded lands. Some rice paddies are cultivated through flooding of land, but because of the unique characteristics of rice cultivation, rice paddies are addressed in 3C7.	Emissions from Flooded Land Remaining Flooded Land

3.B.4.a.iii	Other Wetlands remaining wetlands	*This category is not included in the 2006 IPCC Guidelines.*	Emissions from wetlands remaining wetlands not included in 3.B.4.a.i or 3.B.4.a.ii, which are the drained peatlands or organic lands, coastal wetlands, inland mineral soil wetlands and constructed wetlands remaining corresponding wetlands. The inventory compilers should determine the emission factors in correspondence to management activities to report the emissions and removals from other wetlands remaining wetlands.
3.B.4.b	Land Converted to Wetlands	Emissions from land being converted for peat extraction from land converted to wetland.	
3.B.4.b.i	Land Converted for Peat Extraction	Emissions from land being converted for peat extraction	
3.B.4.b.ii	Land Converted to Flooded Land	Emissions from land converted to flooded land	
3.B.4.b.iii	Land Converted to Other Wetlands	Emissions from land converted to other wetlands than flooded land and land for peat extraction	Emissions from land converted to other wetlands than flooded land and land for peat extraction excluding constructed wetlands used for wastewater treatment which are reported under 4D

1.8 AVAILABILITY OF RELEVANT DATA FOR WETLANDS AND ORGANIC SOILS WORLDWIDE

Inventory compilers will need to gather activity data or determine appropriate proxy data to generate estimates of wetland emissions and removals. Variables include wetland type, size, water table depth, vegetation composition, precipitation, temperature, and management practices. Guidance on data collection is provided in Volume 1, Chapter 2 of the *2006 IPCC Guidelines*. *Good practice* focuses these efforts on collecting data needed to improve estimates of key categories, which will vary by country depending on what are the largest emission sources, have the largest potential to change, or have the greatest uncertainty (*2006 IPCC Guidelines*). Inclusion of emission and removal estimates as specified in this *Wetlands Supplement* will require that inventory compilers access new data sources, engage new data suppliers, and involve them in activities such as reviewing initial estimates, and establishing an agreement for future information sharing (IPCC 2006). The activity data sections within Chapters 2-6 provide specific guidance on where and how to obtain activity data for the relevant emission estimates. Additionally, Chapter 7 provides guidance on general good practice issues related to the quality and quantity of data.

After determining which Wetlands 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 a national database of wetland and soil data does not exist, data on individual lands of interest may be available from individual land managers, organizations, or interest groups. Data on wetland restoration or rewetting, in particular, are likely to be available through conservation organizations. Depending on the conservation landscape in a particular country, wetland managers or interest groups could be individually targeted 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 wetlands and organic soils, or if in-country data are not readily available, inventory compilers may be able to use internationally available data. Although availability of highly specific

data needed to accurately estimate emissions and removals is limited, there are certain meta-databases that may prove useful to inventory compilers. The most notable wetlands dataset is the Ramsar Wetland Data Gateway. For all 'wetlands of international importance,' the Ramsar database provides wetland 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 data necessary to provide inputs to the methods in this *Wetlands Supplement*, but does not contain every wetland nor all organic soil 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 (drainage, restoration, etc.) 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 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 - https://secure.worldwildlife.org/science/data/item1877.html
  - 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 (cf. Joosten 2010) 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 stock 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

COUNTRY-SPECIFIC DATABASES

- U.S. National Wetlands Inventory, conducted by the U.S. Fish and Wildlife Service - http://www.fws.gov/wetlands/
- Australian Spatial Data Inventory - http://asdd.ga.gov.au/asdd/

OTHER POTENTIAL RESOURCES

- National Soil Surveys
- National Geological Surveys
- Land tax authorities
- Chambers of Agriculture
- National Forest Bureaus
- 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

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