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Coastal wetland management as a contribution to the US National Greenhouse Gas Inventory

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Supplementary Information for “Coastal wetland management as a contribution to the US National Greenhouse Gas Inventory”

OVERVIEW OF UNFCCC PROCESS AND GHG INVENTORY GUIDANCE

Under the UNFCCC, all Parties (countries) have agreed to report anthropogenic emissions by sources and removals by sinks, including from the land use, land-use change and forestry sector. Reporting is accomplished through the submission of national reports (National Communications and National GHG Inventories, biennial reports or biennial update reports), with different requirements for Annex I and non-Annex I countries (Iverson et al., 2014). The United States EPA prepares the official U.S. Inventory of Greenhouse Gas Emissions and Sinks to comply with existing commitments under the United Nations Framework Convention on Climate Change (UNFCCC).

In 2014, the IPCC released the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (herein “Wetlands Supplement”*;* IPCC 2014). The Wetlands Supplement “extends the content of the 2006 IPCC Guidelines by filling gaps in coverage and providing updated information reflecting scientific advances, including updating emission factors for human activities on wetlands.

Chapter 4 of the Wetlands Supplement provides guidance on estimating emission and removals of greenhouse gases (CO_2, CH_4 and N_2O) associated with specific activities on managed coastal wetlands, which may or may not result in a land use change (Wetlands Supplement, Overview Chapter, p. O-8). Regardless of whether a land-use change occurs or not, it is *good practice* to quantify and report significant emissions and removals (Table 4.1 of the Coastal Wetland Chapter) resulting from management activities on coastal wetlands in line with their country-specific definition (Wetlands Supplement, Chapter 4, p. 4-6).

The Wetlands Supplement provides methodological guidance on managed coastal wetlands so that countries can, at a minimum, produce Tier 1 estimates of GHG emissions and removals for specific management activities that had been shown at the time of writing to be among the most significant anthropogenic activities in coastal wetlands globally (IPCC 2014). Each country’s national circumstances will determine what anthropogenic activities are significant at a national scale, and countries will have different levels of resources and data to report on their GHG emissions and removals. As a result, the emphasis of the Wetlands Supplement and the guidelines that precede it, is on enabling countries to meet the conditions set by their national circumstances and good practice in national GHG inventory compilation.

National circumstances and Application of the Wetlands Supplement for Managed Coastal Wetlands in the US

A key question is on which wetlands should GHG emissions and removals be tracked. This is defined by whether those wetlands are considered “managed.” In many sectors of the economy the distinction between anthropogenic and natural emissions is clear. The AFOLU sector can be more complicated. Estimating all carbon stock change in LULUCF/AFOLU, fluxes of methane and nitrous oxide would capture the impact of management, all disturbance, indirect anthropogenic effects and natural processes, and IPCC guidelines provide appropriate details on estimation of these stock changes. However, while the effect of particular drivers may be estimated, the effect of multiple interactions is not always clear. For this reason, the IPCC guidelines recommend recognizing all emissions and removals from managed land as a proxy for anthropogenic emissions and removals (IPCC, 2006, IPCC, 2010). This is known as the *Managed Land Proxy"*. Within the conterminous United States over 95% of the land area is considered managed lands due to ownership, proximity to development and infrastructure. The U.S. Clean Water Act regulates discharges of pollutants into the waters of the United States, which includes many wetlands, in order to ensure that U.S. freshwater resources are protected. The U.S. also has the "No Net Loss" policy which was first adopted as a national goal in 1988. This policy uses multiple policy tools, including the Clean Water Act, the Coastal Zone Management Act, and conservation easements to stem the loss of wetlands in the U.S. by working to offset impacts to wetlands with created or restored wetlands that serve a similar function.

Further, this "wall-to-wall" approach was applied to ensure that there are no over- or under-estimates and that uncertainties could be reduced as far as practicable (IPCC GPG 2003), avoids "cherry-picking" and averts the intensive research and attribution needed to identify where management activities are occurring over the US land base.

Prior to the 2017 report Wetlands were not differentiated between managed and unmanaged. The Coastal Wetlands Carbon Work Group (CWCWG) recognized the continental U.S. (CONUS) coastal wetlands to be managed lands, given the proximity of human populations (coastal counties host 39% of the conterminous U.S. population), high degree of regulatory and management oversight and levels of access and disturbance,

The CWCWG expanded on the specified management activities identified in the Wetlands Supplement to ascribe major anthropogenic GHG sources and sinks to U.S. managed coastal wetlands: 1) Excavation of wetland soils; 2) drainage of wetland soils; 3) human-induced subsidence and erosion (e.g. wetland erosion due to activities such as sediment diversion, aquifer extraction); 4) CH_4 emissions associated with impaired tidal drainage; 5) forestry activities on tidally influenced forests; 6) aquaculture and 7) rewetting and revegetation (wetland restoration). GHG emissions and removals associated with these activities are consistent with methodologies developed in Wetlands Supplement guidance on managed coastal wetlands. These fell into the following sub-categories: Coastal Wetlands Remaining Coastal Wetlands and Land Converted to Coastal Wetlands with emissions estimated for the 3 primary GHGs – CO_2, CH_4, and N_2O. These estimates were derived from the crosswalk of specific human activities (e.g., extraction, aquaculture) and coastal wetland land use and land-use change since 1990 and used as the basis for methodologies applied.

Given absence of sufficient data not all these activities of interest were included in the inventory at this time. Inclusion of seagrasses was challenged primarily because of lack of national scale quantification of areal extent and changes to that extent through time. Secondarily, being subtidal seagrass areas fall beyond the defined extent of the US Land Representation, though this could be modified should seagrasses warrant inclusion in the inventory.. Palustrine forested wetlands and former coastal wetlands that fell into other Land Use, Land-Use Change, and Forestry (LULUCF) land-use categories (i.e. drained or developed coastal wetlands under Forest Land, Cropland, Grassland, Settlements and Other Lands) were also not included in these estimates since the inventory approach intends for these GHG emissions and removals to be included under other sections of the inventory. However, it should be noted that annual carbon accumulation in tidally influenced forests soils is not accounted for under the Forest Lands category. While forestry activities on coastal wetlands is common practice there are no data to inform the impacts on soil carbon stocks. And the current state of knowledge on both the distribution of impounded waters and methane emissions from those waters precluded inclusion of this land use, at this time. Also, following the existing U.S. inventory, GHG emissions and removals for managed coastal wetlands do not include Alaska, Hawaii or U.S. territories and are another area of planned improvement.

Table S1. Values are geometric means.

			Rates (t C ha^{-1} yr^{-1})	**95% CI**	**Range**	**n**	**Refs**
Tidal freshwater	Marsh	Temperate, Cold	1.01	0.17	-	2	*Koster et al. 2007; Crooks et al. 2014.*
		Temperate, Warm	1.65	0.47	0.95 – 3.96	14	*Campana unpublished data; Merrill unpublished data; Orson et al. 1990; Khan & Brush 1994; Neubauer et al. 2002; Church et al. 2006; Craft, 2007; Loomis & Craft, 2010.*
		Subtropical	1.57	0.59	0.21 – 3.11	7	*Smith et al. 1983; DeLaune et al. 1986; Nyman et al. 2006; Craft 2007; Villa & Mitsch 2015.*
Salt/Brackish	Marsh	Temperate, Warm	1.06	0.26	0.20 – 4.00	40	*Anisfeld unpublished data; McCaffrey & Thomson 1980; Cahoon & Stevenson 1986; Kearney & Stevenson 1991; Blum 1993; Roman et al. 1997; Orson et al. 1998; Anisfeld et al. 1999; Cebrian et al. 2000; Chmura et al. 2003; Chmura & Hung 2004; Hussein et al. 2004; Craft 2007; Johnson et al. 2007; PWA & SAIC 2009; Mudd et al. 2009; Loomis & Craft, 2010.*
		Mediterranean	0.98	0.21	0.085 – 1.19	3	*Miller et al. 2008; Callaway et al. 2012*
		Subtropical	1.26	0.58	0.18 – 17.13	73	*Cahoon unpublished data; Cahoon & Lynch unpublished data; Teal 1962; Day et al. 1973; de la Cruz et al. 1974; Hopkinson et al. 1978; White et al. 1978; Hatton et al. 1981,1983; Cahoon*

							& Turner 1989; Patrick & DeLaune 1990; Nyman et al. 1990; Craft et al. 1993; Cahoon 1994; Callaway et al. 1997; Bryant & Chabrek 1998; Craft& Richardson 1998; Markewich et al. 1998; Cebrian et al. 2000; Craft et al. 2002; Chmura et al. 2003; Craft et al. 2003; Brevik & Homburg 2004; Choi & Wang 2001.
	Forest	Subtropical	0.97	0.39	0.03 – 3.81	26	*Cahoon & Lynch unpublished data; Golley et al. 1962; Twilley et al. 1986; Lynch et al. 1989; Cahoon & Lynch 1997; Callaway et al. 1997; Cebrian et al. 2000; Chmura et al. 2003; Perry & Mendelssohn 2009, Bianchi et al. 2013; Marchio et al. 2016.*

Table S2. Values are geometric means.

			Stocks (t C ha^{-1})	**95% CI**	**Range**	**N**	**Refs**
Tidal freshwater	Marsh	Temperate, Warm	236.18	216.55	68.73 – 789.00	6	*EPA's NWCA 2011; Weston et al. 2014.*
		Subtropical	133.67	93.00	24.27 – 681.00	12	*Hatton et al. 1983; Nyman et al. 1990; Wieski et al. 2010; EPA's NWCA 2011; Nagy et al. 2014; Schmidt et al. 2014; Ricker & Lockaby 2015.*
	Scrub/ Forest	Subtropical	133.67	93.00	24.27 – 681.00	12	*Yu et al. 2008; Krauss & Whitbeck 2012, Noe et al. 2016.*
Salt/Brackish	Marsh	Temperate, Cold	329.15	53.45	102.26 – 601.30	30	*McCaffrey & Thomson 1980; French & Spencer 1993; Roman et al. 1997; Anisfeld et al. 1999; EPA's NWCA 2011.*
		Temperate, Warm	196.34	27.00	22.91 – 788.92	145	*Anisfeld unpublished data; Chmura*

							unpublished data; Craft et al. 1988; Kearney & Stevenson 1991; Callaway et al. 1997; Roman et al. 1997; Anisfeld et al. 1999; Connor et al. 2001; Chmura et al. 2003; Hussein et al. 2004; Craft 2007; Loomis & Craft 2010; EPA's NWCA 2011; Weston et al. 2014.
		Mediterranean	274.91	37.36	46.09 – 479.95	26	*Patrick & DeLaune 1990; Orson et al. 1998; Miller et al. 2008; EPA's NWCA 2011; Callaway et al. 2012.*
		Subtropical	218.16	80.45	9.27 – 1,899.90	85	*Cahoon unpublished data; Cahoon & Lynch unpublished data; Chmura unpublished data; Hatton 1981; Callaway et al. 1997; Cahoon & Turner 1989; Cahoon et al. 1996; Bryant & Chabrek 1998; Markewich et al. 1998; Choi & Wang 2001; Chmura & Hung 2004; Hussein et al. 2004; Perry & Mendelssohn 2009; EPA's NWCA 2011; Henry & Twilley 2013.*
	Forest	Subtropical	346	76	58.55 – 670.09	45	*Cahoon & Lynch unpublished data; Lynch et al. 1989; Callaway et al. 1997; Chen & Twilley 1999; McKee & Faulkner 2000; Ross et al. 2001; Chmura et al. 2003; Perry & Mendelssohn 2009; Castaneda-Moya et al. 2013; Henry & Twilley 2013; Doughty et al. 2015; Marchio et al. 2016.*

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