

A synthesis of freshwater forested wetland soil organic carbon storage

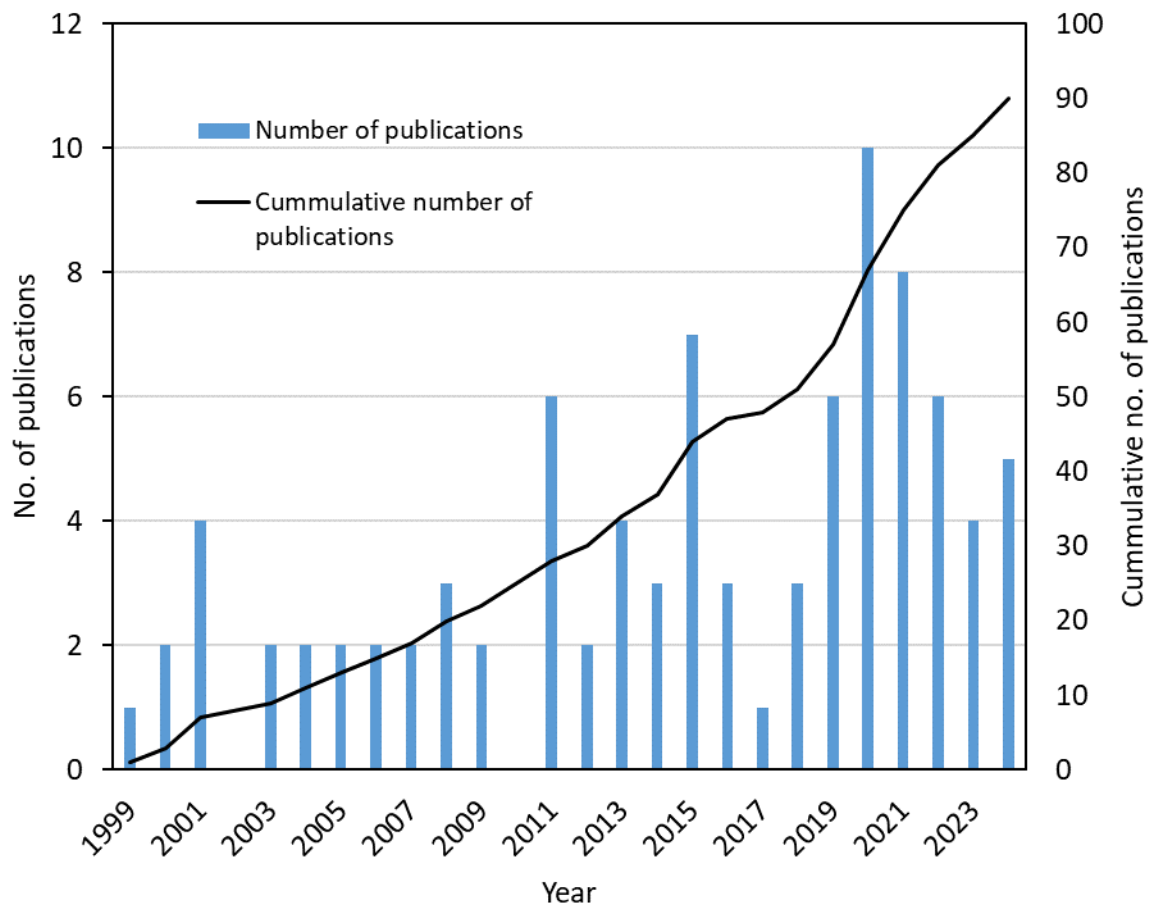
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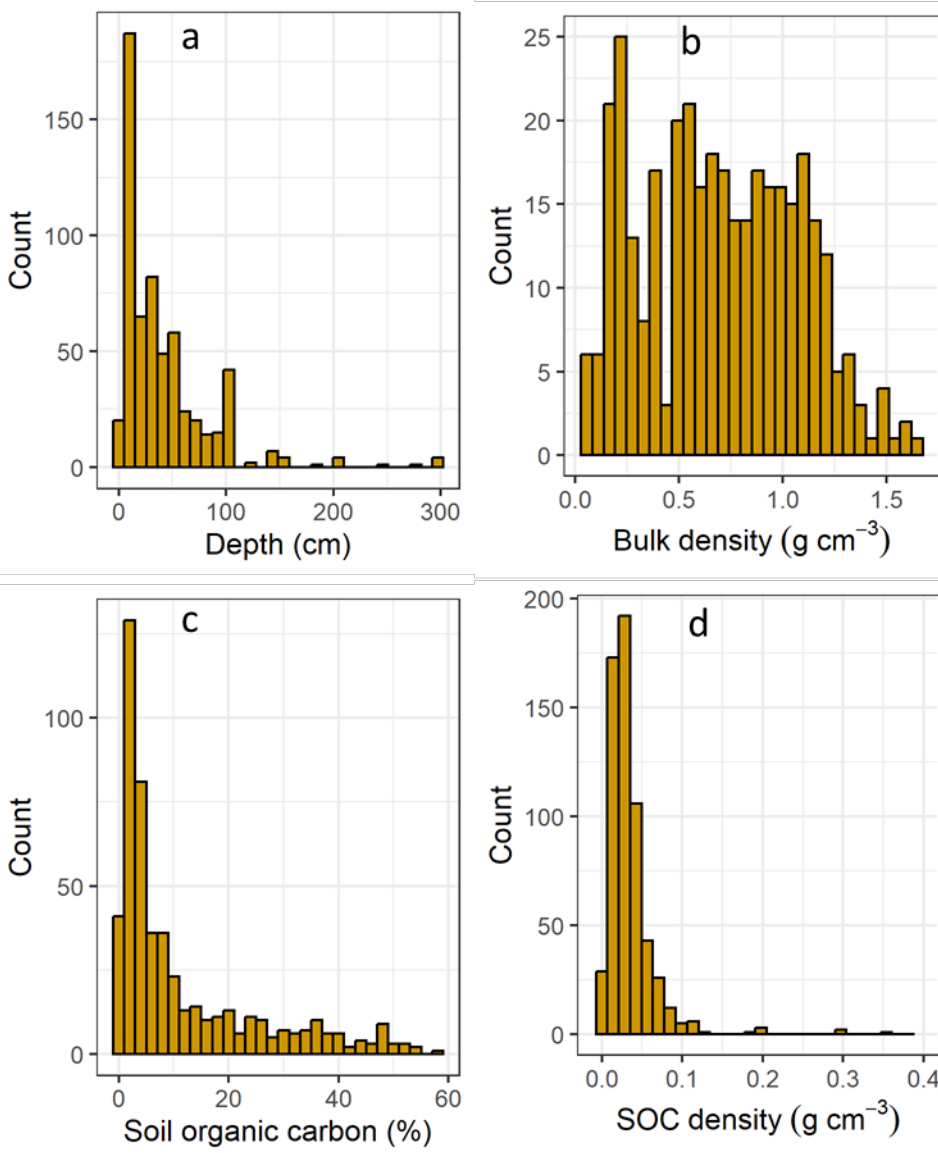
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Supplemental Materials:



Supplemental Figure 1: Annual (left y-axis) and cumulative (right y-axis) distribution of studies included in the freshwater forested wetland soil carbon dataset.



Supplemental Figure 2: Distribution of freshwater forested wetland carbon characteristics synthesized from the dataset, including a) maximum soil profile sampling depth with carbon concentration data (n = 600), b) bulk density (n=350), c) percent soil organic carbon (SOC) (n = 329), and d) SOC density across all depths (n = 600).

Supplemental Table 1: List of studies included in the freshwater forested wetland soil organic carbon (SOC) stock dataset including the study area, geomorphic and ecological setting, and dominant forest species. NA= Not available

Study	Study area	Geomorphic/ecological setting	Dominant forest species
Adame and Reef 2020	Queensland, Australia	Floodplain	<i>Melaleuca spp.</i>
Aguilos et al. 2020	NC, USA	Non-tidal swamp	<i>Nyssa spp.</i> , <i>Taxodium spp.</i> , <i>Acer spp.</i> , <i>Pinus spp.</i>
Anderson and Lockaby 2011	FL, USA	Tidal	<i>Nyssa spp.</i> , <i>Taxodium spp.</i> , <i>Sabal spp.</i> , <i>Laurus spp.</i> , <i>Quercus spp.</i> , <i>Fraxinus spp.</i>
Batson et al. 2015	VA, USA	Floodplain	NA, Forest type group from USFS
Bernal and Mistch 2008	OH, USA & Costa Rica	Floodplain, Non-tidal swamp	<i>Acer spp.</i> , <i>Quercus spp.</i> <i>Broad leaved trees</i>
Bernal and Mitsch 2011	OH, USA	Non-tidal swamp	<i>Quercus spp.</i>
Bukatta et al. 2015	FL, USA	Non-tidal swamp	<i>Nyssa sylvatica</i>
Campos et al. 2011	Veracruz, Mexico	Floodplain	<i>Pachira aquatica</i> , <i>Ficus insipida</i>
Carlo et al. 2019	Ontario, Canada	Floodplain	<i>Alnus spp.</i> , <i>Populus spp.</i> , <i>Acer saccharinum</i> , <i>Acer saccharum</i> , <i>Liquidambar styraciflua</i> , <i>Tilia americana</i> , <i>Carya spp.</i>
Cawson et al. 2001	GA, USA	Floodplain	<i>Acer rubrum</i> , <i>Liquidambar styraciflua</i> , <i>Quercus spp.</i>
Cejudo et al. 2022	Alto Lucero, Alvarado, Jamapa, Tecolutia, Tuxpan, Vega de Alatorre, Mexico	Floodplain, Non-tidal swamp, Tidal	<i>Ficus spp.</i> , <i>Pachira aquatica</i> , <i>Diospyros digyna</i>
Chuvochina et al. 2021	Queensland, Australia	Floodplain	<i>Melaleuca spp.</i>
Clement et al. 2002	Brittany, France	Floodplain	<i>Quercus spp.</i> , <i>Salix alba</i>
Comer-Warner et al. 2023	Vietnam	Floodplain	<i>Melaleuca cajuputi</i>
Cormier et al. 2013	GA, SC, USA	Tidal	<i>Taxodium distichum</i> , <i>Nyssa spp.</i> , <i>Fraxinus spp.</i> , <i>Acer rubrum</i>
Craft and Casey 2000	GA, USA	Floodplain, Non-tidal swamp	<i>Taxodium spp.</i> , <i>Nyssa spp.</i>
D'Angelo et al. 2005	KY, USA	Floodplain	<i>Quercus spp.</i> , <i>Carya spp.</i> , <i>Liquidambar styraciflua</i>

Study	Study area	Geomorphic/ecologic al setting	Dominant forest species
Davidson et al. 2022	Alberta, Ontario, Canada	Non-tidal swamp	<i>Broad-leaved, Needle-leaved, and Mixed trees</i>
Daze et al. 2022	Ontario, Canada	Non-tidal swamp	<i>Acer saccharinum, Ulmus americana, Betula alleghaniensis, Acer rubrum, Thuja occidentalis</i>
Ehrenfeld and Yu 2012	NJ, USA	Non-tidal swamp	<i>Pinus rigida, Acer rubrum, Nyssa sylvatica, Magnolia virginiana, Chamaecyparis thyoides</i>
Ensign et al. 2015	MD, USA	Floodplain, Tidal	<i>NA, Forest type group from USFS</i>
Entry 1999	FL, USA	Floodplain	<i>Taxodium spp., Nyssa spp., Quercus spp., Gordonia spp.</i>
Fellman and D'Amore 2007	AK, USA	Floodplain	<i>Tsuga heterophylla, Picea spp., Abies spp.</i>
Fellman et al. 2017	AK, USA	Rainforest	<i>Pinus resinosa, Alnus spp., Fraxinus nigra</i>
Fissore et al. 2009	CO, MN, SC, USA	Non-tidal swamp	<i>Picea spp., Abies spp., Pinus resinosa, Alnus spp., Fraxinus nigra</i>
Francl et al. 2004	MD, WV, USA	Bog	<i>NA, Forest type group from USFS</i>
Golovatskaya et al. 2024	Siberia	Bog	<i>Acer rubrum, Fraxinus pennsylvanica, Ulmus americana, Prioria copaifera</i>
Goyette et al. 2024	Quebec, Canada	Floodplain, Non-tidal swamp	<i>Raphia taedigera</i>
Groffman and Crawford 2003	MD, USA	Floodplain	<i>Nyssa sylvatica, Acer rubrum</i>
Groffman et al. 2001	Gandoca, Costa Rica	Floodplain	<i>Betula fruticosa, Alnus sibirica</i>
Gunderson et al. 2021	NC, USA	Non-tidal swamp, Tidal	<i>Betula platyphylla, Larix gmelina</i>
Han et al. 2023	Daxing, Xiaoxing, China	Bog, Non-tidal swamp	<i>Larix gmelina, Betula fruticosa, Alnus sibirica, Pinus spp., Taxodium spp, Nyssa spp., Quercus spp.</i>
Hansen and Nestlerode 2014	Northern Gulf of Mexico, USA	Floodplain, Non-tidal swamp	<i>Taxodium spp., Nyssa spp., Quercus spp.</i>
Herve et al. 2020	France	Bog	<i>Taxodium spp., Nyssa spp., Quercus spp., Acer saccharinum, Quercus alba, Platanus occidentalis, Populus deltoides</i>
Hogan et al. 2004	MD, USA	Non-tidal swamp	<i>Acer saccharinum, Quercus alba, Platanus occidentalis, Populus deltoides</i>
Hurst et al. 2016	LA, USA	Floodplain	<i>Taxodium spp., Quercus spp., Nyssa spp.</i>
Jacinthe 2015	IN, USA	Floodplain	<i>Acer saccharinum, Quercus alba, Platanus occidentalis, Populus deltoides</i>
Jicha et al. 2014	MN, USA	Floodplain	<i>Acer saccharinum</i>

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Kauffman et al. 2020	OR, WA, USA	Tidal	<i>Picea sitchensis</i>
Kendall et al. 2020	Nova Scotia, Canada	Non-tidal swamp	<i>Tsuga canadensis</i> , <i>Abies balsamea</i> , <i>Acer rubrum</i>
Korol and Noe 2020	VA, USA	Floodplain, Non-tidal swamp	<i>NA</i> , <i>Forest type group from USFS</i>
Korol et al. 2018	MD, PA, VA, WV, GA, SC, USA	Floodplain	<i>NA</i> , <i>Forest type group from USFS</i>
Krauss et al. 2018	GA, SC, USA	Tidal	<i>Taxodium distichum</i> , <i>Nyssa spp</i> , <i>Fraxinus spp</i> , <i>Acer rubrum</i>
Kurkowski et al. 2023	Great lake region (WI, MI, MN), USA	Bog	<i>NA</i> , <i>Forest type group from USFS</i>
Lane et al. 2015	FL, USA	Non-tidal swamp	<i>NA</i> , <i>Forest type group from USFS</i>
Lane et al. 2017	LA, USA	Non-tidal swamp	<i>Taxodium distichum</i> , <i>Nyssa spp.</i>
Leford et al. 2022	VA, USA	Floodplain	<i>Juglans spp</i> , <i>Quercus spp.</i> , <i>Carya spp.</i>
Li et al. 2023	Anhui, China	Non-tidal swamp	<i>Populus spp.</i> , <i>Taxodium spp.</i>
Liu et al. 2017	Chongxi, China	Non-tidal swamp	<i>Alnus trabeculosa</i> , <i>Taxodium distichum</i>
Lu et al., 2022	Heilongjian g, China	Non-tidal swamp	<i>Larix gmelinii</i> <i>Pinus spp</i> , <i>Acer rubrum</i> , <i>Taxodium distichum</i> , <i>Nyssa aquatica</i> , <i>Morella cerifera</i>
Martinez and Ardon 2021	NC, USA	Tidal	
Mazurezyk and Brooks 2018	PA, USA	Floodplain, Non-tidal swamp	<i>NA</i> , <i>Forest type group from USFS</i>
McKee et al. 2013	AL, USA	Floodplain	<i>Nyssa aquatica</i> , <i>Taxodium distichum</i> <i>Acer rubrum</i> , <i>Alnus incana</i> , <i>Chamaedaphne calyculata.</i> , <i>Picea mariana</i> , <i>Larix laricina</i> , <i>Pinus banksiana</i>
McLaughlin et al. 2011	MI, USA	Floodplain	
McNicol et al. 2019	WA, USA; BC, CA	Rainforest	<i>Needle-leaved forest</i>
Middleton and Anaemaet 2019	AR, IL, KY, LA, MS, TN USA	Non-tidal swamp	<i>Taxodium distichum</i>
Minick et al. 2019a	NC, USA	Non-tidal swamp	<i>Nyssa spp.</i> , <i>Taxodium distichum</i> , <i>Pinus taeda</i>
Minick et al. 2019b	NC, USA	Non-tidal swamp	<i>Nyssa spp.</i> , <i>Taxodium distichum</i>

Study	Study area	Geomorphic/ecologic al setting	Dominant forest species
Minick et al. 2019c	NC, USA	Non-tidal swamp	<i>Nyssa spp.</i> , <i>Taxodium distichum</i>
Minick et al. 2021	NC, USA	Non-tidal swamp	<i>Nyssa spp.</i> , <i>Taxodium distichum</i> <i>Quercus spp.</i> , <i>Nyssa spp.</i> , <i>Taxodium spp.</i> , <i>Picea mariana</i> , <i>Larix laricina</i>
Morse et al. 2012	NC, USA	Non-tidal swamp	
Mu et al. 2013	Heilongjian g, China	Non-tidal swamp	<i>Larix gmelinii</i> <i>Pinus elliottii</i> , <i>Pinus clausa</i> , <i>Quercus</i> <i>virginiana</i>
Nagy et al. 2013	FL, USA	Non-tidal swamp	
Nahlik and Fennessy 2016	CON USA		<i>Palustrine forested</i>
Ndondo et al. 2020	Nsimi, Cameroon	Rainforest	<i>Gilbertiodendron dewevrei</i> , <i>Raphia</i> <i>monbuttorum</i>
Noe et al. 2020	MD, USA	Floodplain	<i>NA</i> , <i>Forest type group from USFS</i>
Obregon et al. 2023	Ontario, Canada	Floodplain	<i>Alnus spp.</i> , <i>Fagus grandifolia</i> , <i>Acer</i> <i>saccharum</i> , <i>Thuja occidentalis</i>
Orr et al. 2007	WI, USA	Floodplain	<i>Broad leaved trees</i>
Phillips et al. 2001	TN, USA	Floodplain	<i>Acer rubrum</i> , <i>Liquidambar styraciflua</i> , <i>Fraxinus spp</i> <i>Celtis laevigata</i> , <i>Liquidambar styraciflua</i> , <i>Quercus spp.</i> , <i>Nyssa spp.</i> , <i>Taxodium</i> <i>distichum</i>
Ricker and Lockaby 2015	SC, USA	Floodplain, Non-tidal swamp	
Ricker et al. 2014	NA, USA	Floodplain	<i>Acer rubrum</i> , <i>Nyssa sylvatica</i>
Schmidt and Ahn 2021	VA, USA	Floodplain	<i>Juglans spp.</i> , <i>Quercus spp.</i> , <i>Carya spp.</i>
Stewart et al. 2024	WA, USA	Rainforest	<i>Needle leaved forest</i> <i>Picea rubens</i> , <i>Acer rubrum</i> , <i>Betula</i> <i>alleghaniensis</i>
Stine et al. 2011	WV, USA	Bog	
Stoeckel and Miller-Goodman, 2001	SC, USA	Floodplain	<i>Nyssa aquatica</i> , <i>Taxodium distichum</i> , <i>Liquidambar styraciflua</i> , <i>Quercus spp.</i> , <i>Acer rubum</i>
Treby et al. 2024	New South Wales, Australia	Floodplain	<i>Eucalyptus camaldulensis</i> <i>Pinus banksiana</i> , <i>Picea mariana</i> , <i>Larix</i> <i>laricina</i>
Trettin et al 2011	MI, USA	Floodplain	
Ullah and Faulkner 2006a	MS, USA	Floodplain	<i>Ulmus americana</i> , <i>Quercus nigra</i> , <i>Quercus</i> <i>laurifolia</i> , <i>Acer rubrum</i>
Ullah and Faulkner 2006b	MS, USA	Floodplain	<i>Quercus spp.</i> , <i>Fraxinus pennsylvanica</i> , <i>Ulmus americana</i> <i>Ulmus americana</i> , <i>Quercus spp.</i> , <i>Acer</i> <i>rubrum</i> , <i>Fraxinus pennsylvanica</i>
Ullah et al. 2005	MS, USA	Floodplain	
Vitharana, et al. 2024	Ontario, Canada	Floodplain	<i>Pinus spp.</i>

Study	Study area	Geomorphic/ecologic al setting	Dominant forest species
Wang et al. 2021	Yichun, China	Bog, Non-tidal swamp	<i>Alnus hirsuta</i> , <i>Betula platyphylla</i> , <i>Larix gmelini</i>
Webster et al. 2008a	Great Lake, Canada	Non-tidal swamp	<i>Fraxinus nigra</i> , <i>Thuja occidentalis</i> , <i>Acer rubrum</i> , <i>Abies balsamea</i>
Webster et al. 2008b	Great Lake, Canada	Non-tidal swamp	<i>Fraxinus nigra</i> , <i>Thuja occidentalis</i> , <i>Acer rubrum</i> , <i>Abies balsamea</i>
Weingarten et al. 2023	AL, USA	Tidal	<i>Taxodium distichum</i> , <i>Nyssa spp</i> <i>Acer rubrum</i> , <i>Salix nigra</i> , <i>Morella cerifera</i> , <i>Alnus serrulata</i> , <i>Taxodium distichum</i> , <i>Nyssa spp.</i>
Wigginton et al. 2000	GA, USA	Floodplain	
Xiong et al. 2015	Shaanxi, China	Floodplain	<i>Taxodium distichum</i> , <i>Nyssa spp</i>
Yo et al. 2021	Queensland, Australia	Tidal	<i>Melaleuca quinquenervia</i>
Yu and Ehrenfeld 2009	NJ, USA	Non-tidal swamp	<i>Chamaecyparis thyoides</i> , <i>Pinus rigida</i> , <i>Acer rubrum</i> , <i>Nyssa sylvatica</i>
Zamora et al. 2020	Mexico	Non-tidal swamp	NA

Supplemental Table 2: p-values derived from multiple comparisons (Dunn's test) of carbon densities at different geomorphic and ecological settings. Bonferroni correction have been applied to control family-wise error rate (FWER).

	Floodplain forested wetlands	Non-tidal swamp	Tidal freshwater forested wetlands	Rainforest
Non-tidal swamp	1			
Tidal freshwater forested wetlands	0.002	0.0091		
Rainforest	1	1	1	
Bog	<0.0001	0.0004	1	1

Supplemental Table 3: Median ($\pm$ median absolute deviation) SOC density and SOC stock at different depth intervals for forest types based on leaf shape

Depth (cm)	Median SOC density (kg m^{-3})		
	Broad-leaved	Needle-leaved	Mixed
0-15	31.2 $\pm$ 11.4	36.5 $\pm$ 15.6	38.8 $\pm$ 19
15-30	23.6 $\pm$ 16.6	26.1 $\pm$ 11	37.6 $\pm$ 31.9
30-50	16 $\pm$ 7.9	19.7 $\pm$ 7.5	25.5 $\pm$ 16.6
50-100	16 $\pm$ 7.9	18.5 $\pm$ 9.5	29.6 $\pm$ 12
Median SOC stock (Mg ha^{-1})			
0-30	82.2 $\pm$ 42	94 $\pm$ 39.8	114.6 $\pm$ 76.3
0-100	193.9 $\pm$ 170.5	226.1 $\pm$ 102.5	313.5 $\pm$ 169.4

Supplemental Table 4: p-values derived from multiple comparisons (Dunn's test) of carbon densities at different CONUS forest type groups. Bonferroni correction have been applied to control family-wise error rate (FWER).

	<i>Pinus</i>					
	<i>Tsuga/</i> <i>Picea</i>	<i>strobis/resinosa</i> <i>/banksiana</i>	<i>Picea/</i> <i>Abies</i>	<i>Ulmus/Fraxinus</i> <i>/Populus</i>	<i>Quercus</i> <i>/Pinus</i>	<i>Quercus</i> <i>/Carya</i>
<i>Pinus strobis/resinosa/</i> <i>banksiana</i>	0.0001					
<i>Picea/Abies</i>	1	<0.0001				
<i>Ulmus/Fraxinus/</i> <i>Populus</i>	0.7093	0.0702	0.1662			
<i>Quercus/Pinus</i>	1	<0.0001	1	0.24		
<i>Quercus/Carya</i>	0.2841	0.0192	0.0474	1	0.0485	
<i>Quercus/Liquidambar/</i> <i>Taxodium</i>	0.1747	0.0053	0.0238	1	0.0135	1

Supplemental Table 5: Median ($\pm$ median absolute deviation) SOC density and SOC stock at different depth intervals for natural and restored forested wetlands

<u>SOC density (kg m⁻³)</u>					<u>SOC stock (Mg ha⁻¹)</u>				
Depth (cm)	Natural site		Restored site		Depth (cm)	Natural site		Restored site	
	N	Value	N	Value		N	Value	N	Value
0-15	240	35.2 $\pm$ 15	49	25.6 $\pm$ 20	0-30	303	86 $\pm$ 44.9	73	60.6 $\pm$ 56.6
15-30	63	22.1 $\pm$ 15	24	14.8 $\pm$ 17.8	30-100	150	150.1 $\pm$ 85	22	87.1 $\pm$ 43.9
30-50	42	20.5 $\pm$ 9.6	15	14.5 $\pm$ 4.4	0-100	453	236.1 $\pm$ 129.9	95	147.6 $\pm$ 100.6
50-100	108	21.8 $\pm$ 13.2	7	11.6 $\pm$ 7					

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