Pocosins
North America's Forgotten Peatlands for Climate Mitigation and Sea Level Rise Protection

Duke
NICHOLAS SCHOOL
of the ENVIRONMENT

Professor Curtis J. Richardson

&

Dr. Neal Flanagan

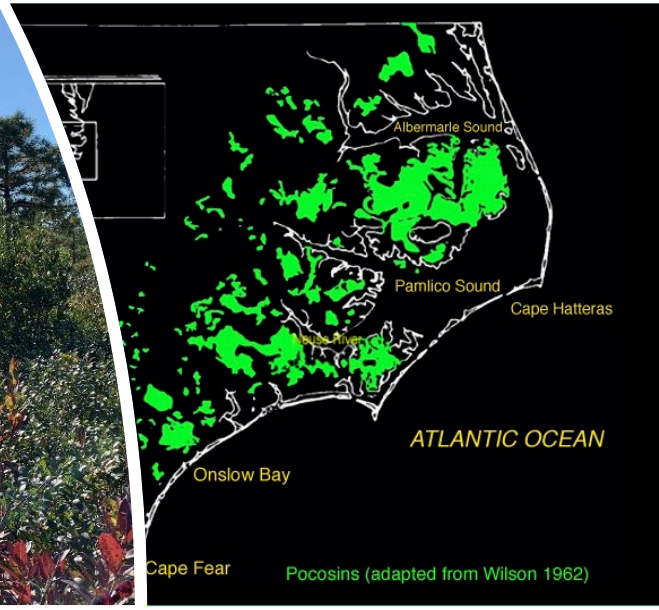
Duke University Wetland and Coasts Center

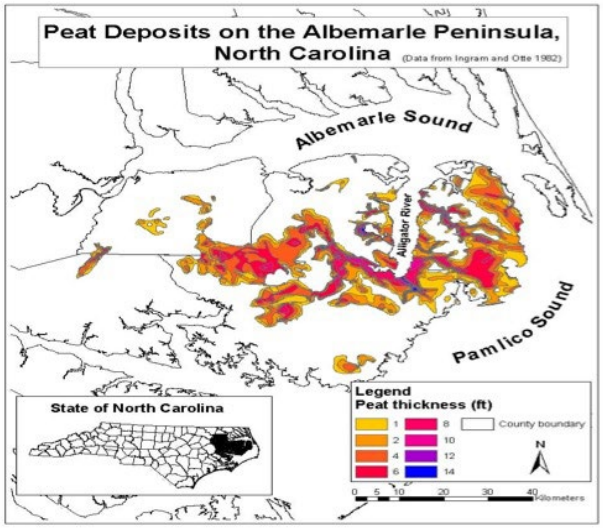
Nicholas School of the Environment

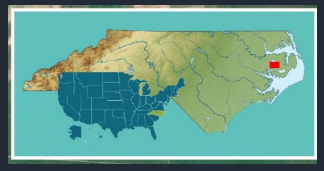
curtr@duke.edu

Introduction

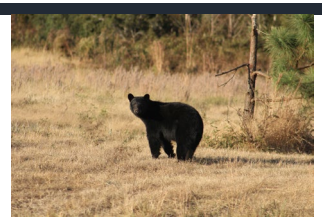
- **Overview of Pocosin peat bogs as NBs**
- **Pocosins are degraded by human activities? DRAINAGE (farming, forestry)**
- **DRAINED pocosins are restorable through rewetting**
- **Discuss the implications of rewetting for significant reductions in CO_2 emissions , soil C storage**
- **Assess their role in climate change**







Characteristics of Pocosins



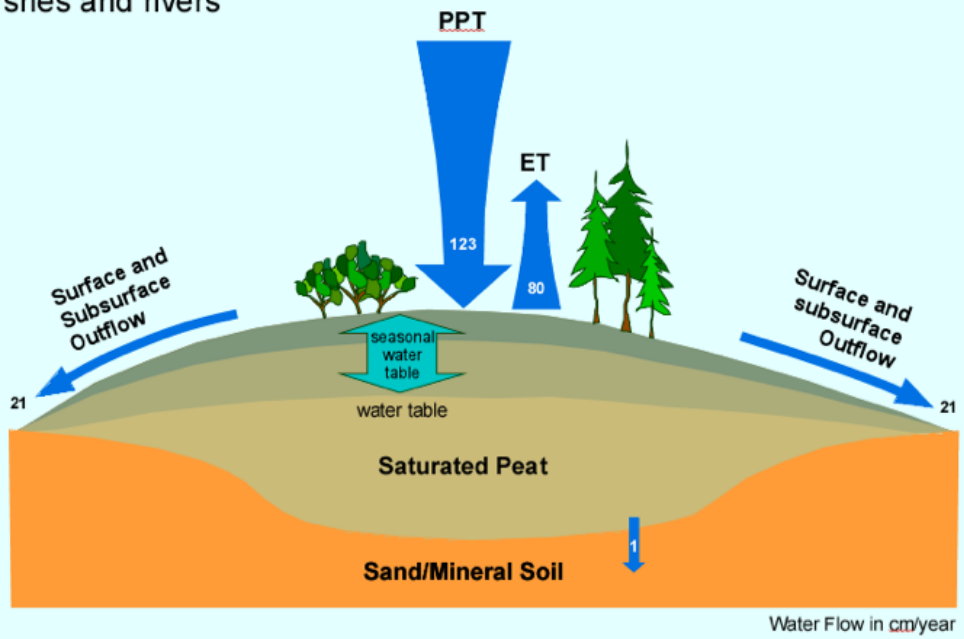
Evergreen shrub bogs

- **Occur across the southeastern coastal plain, VA to FLA, but primarily in NC**
- **4-10,000 YEARS OLD**
- **Typical peat depth 1- 3 m (up to 6m)**
- **High summer temperature (up to 40^{o}C) and Evapotranspiration**
  - **Summer water table often > 1.2 m**
- **Fire-adapted dominant plants**
  - **Pond Pine (*Pinus serotina*)**
  - **Ericaceous, *Ilex sp*. shrubs**
- **Fire Return Interval 6 -25YR**
- **Peat is formed from wood rather than mosses**
  - **Pocosins have characteristics between tropical and temperate peatlands: Sub-tropical**
  - **Complex peat C chemistry with high content of phenolic and aromatic compounds (slows decomposition)**
  - **NC has estimated 1.2 billion tons of CO_2-e stored in coastal peatlands**

Hydrologic Balance for Natural and Drained Pocosin

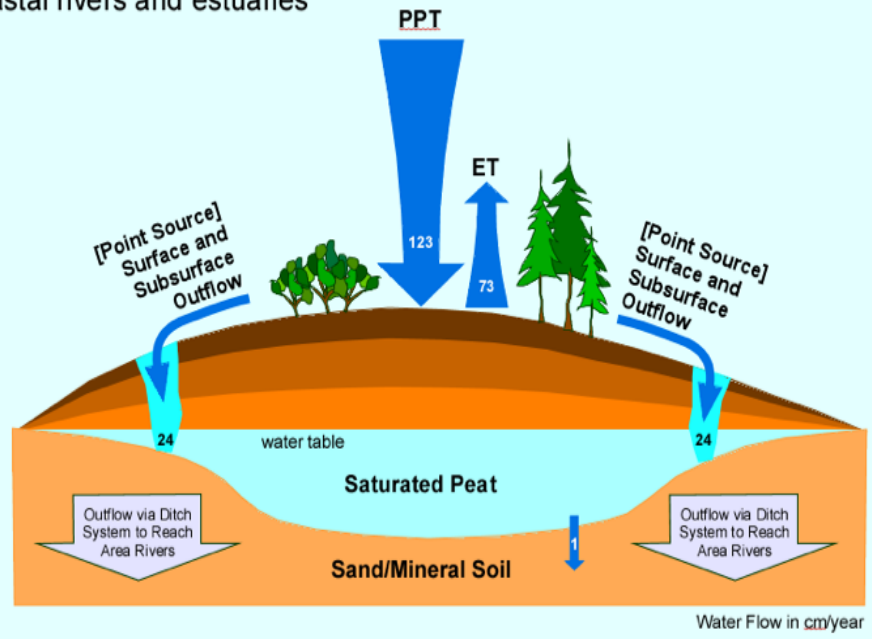
Natural Pocosin:

Water flows over the broad landscape to coastal marshes and rivers

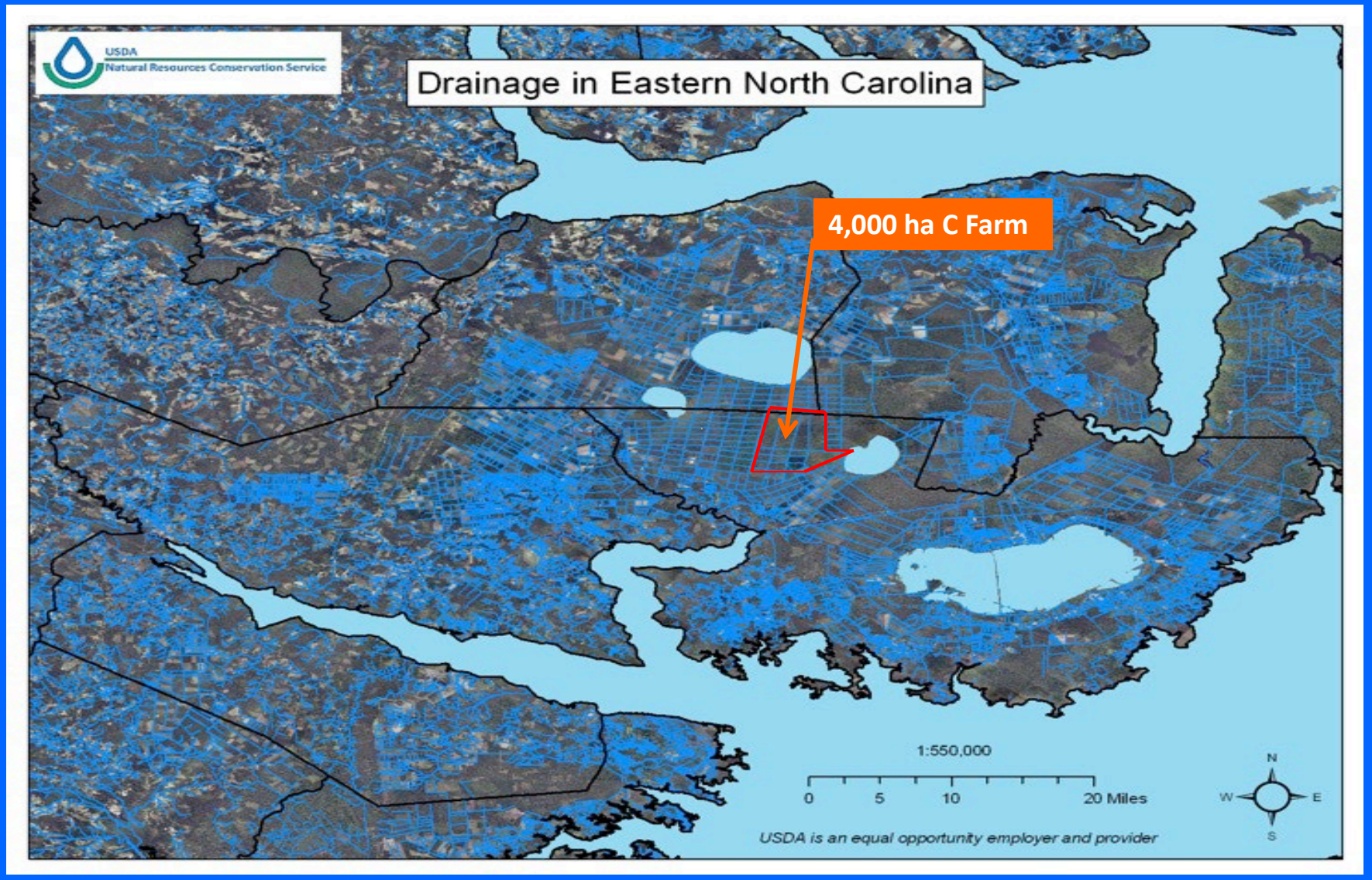


Drainage Alterations:

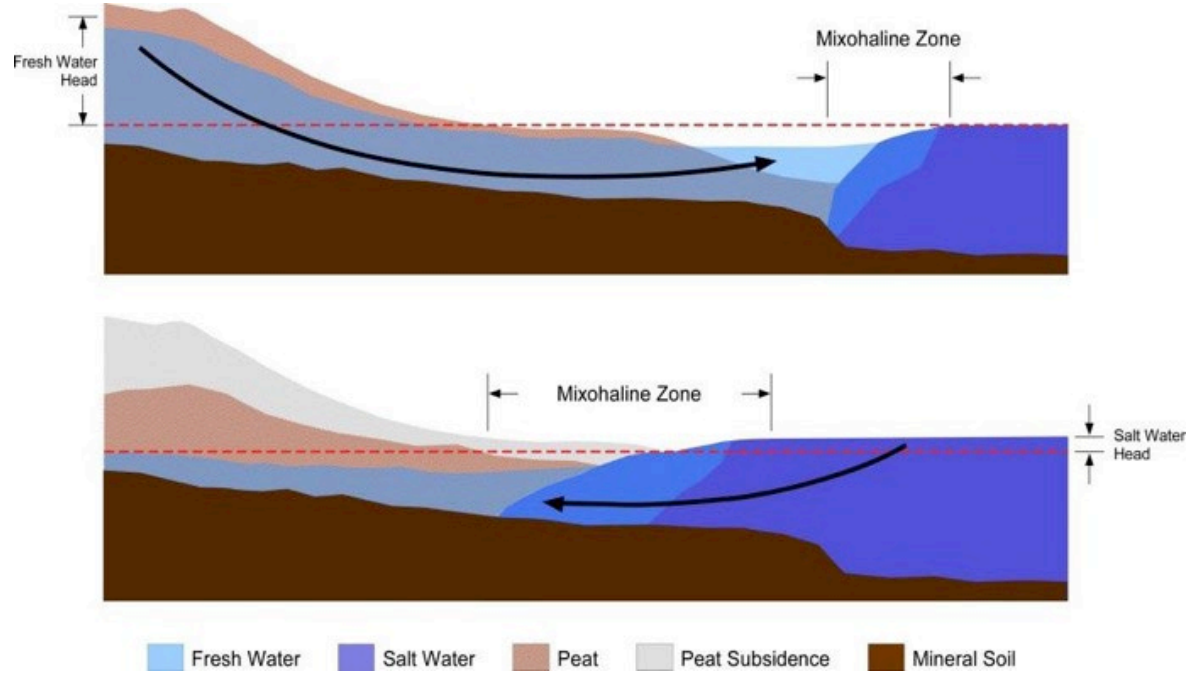
Point source water flow through ditches and canal systems to coastal rivers and estuaries

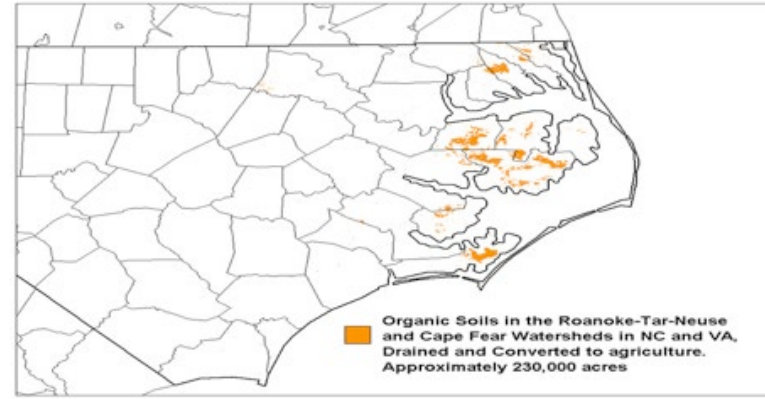


Richardson, C.J. and E.J. McCarthy. 1994. Effect of land development and forest management on hydrologic response in southeastern coastal wetlands: A review. *Wetlands* 14:56-71.


USDA
Natural Resources Conservation Service
Drainage in Eastern North Carolina
4,000 ha C Farm
1:550,000
0
5
10
20 Miles
N
W
E
S
USDA is an equal opportunity employer and provider

Coastal Freshwater Wetlands if not Drained can Protect Against Sea Level Rise & Salt Water Intrusion

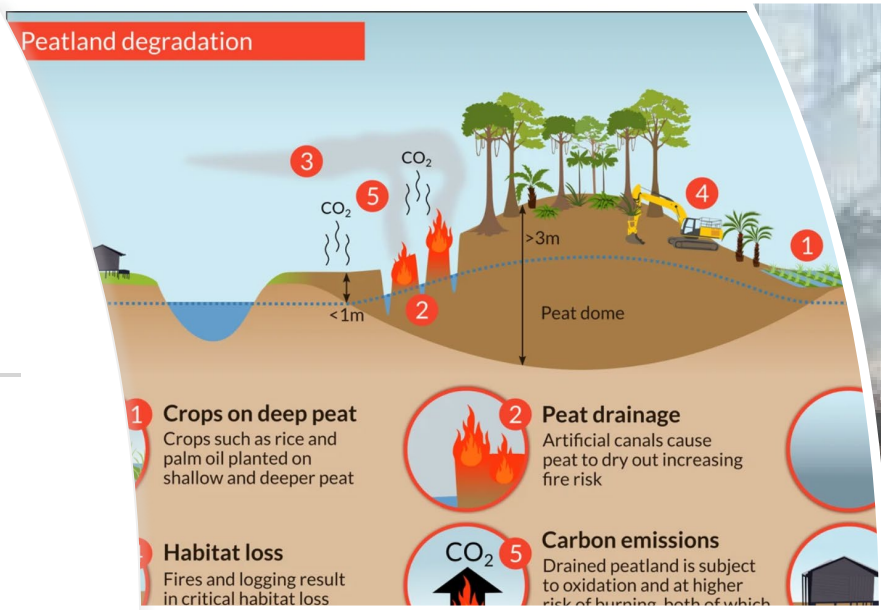




Threats to Pocosin Carbon Stores

- **Drainage for agriculture, tree farming and logging**
- **Resulting carbon losses**
  - **Microbial oxidation (decomposition)**
  - **Fire**

    -Especially deep smoldering fires in drained peatlands

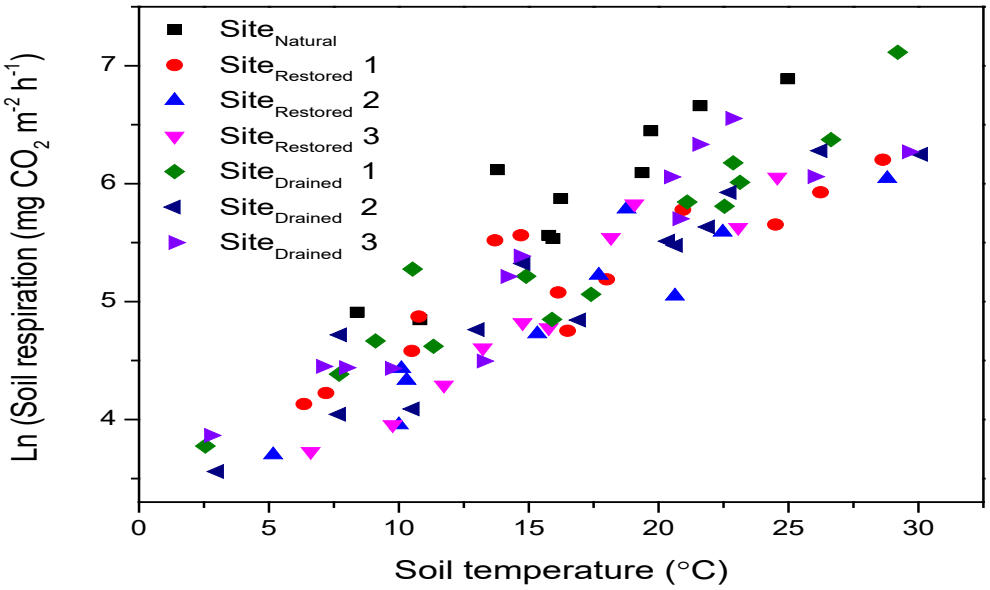


Panel 1: Fleming et al., 2021
https://www.nature.com/articles/s41599-021-00878-8/figures/1

Long-term Pocosin Questions

- How have Pocosins existed in the SE sub-tropical coastal Plains for the past 10,000 years during increased warming, droughts and fire?
- What accounts for reported low decomposition rates when Pocosins are Drained ?
- Are Natural Pocosins a C Sink or Source of GHGs on the landscape today ?
- What mechanisms control GHG fluxes in drained and natural Pocosins ?
- Can Pocosins function again as a long-term C sink if restored?

Well Know Relationships



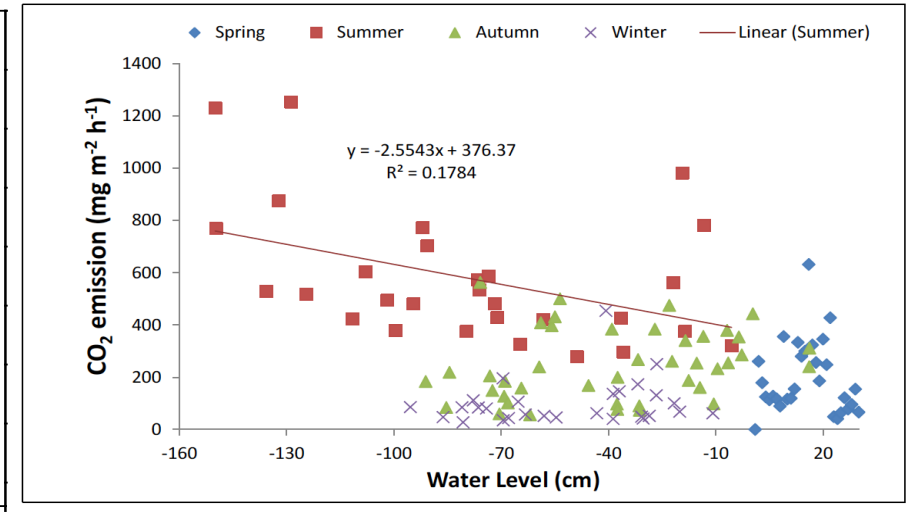
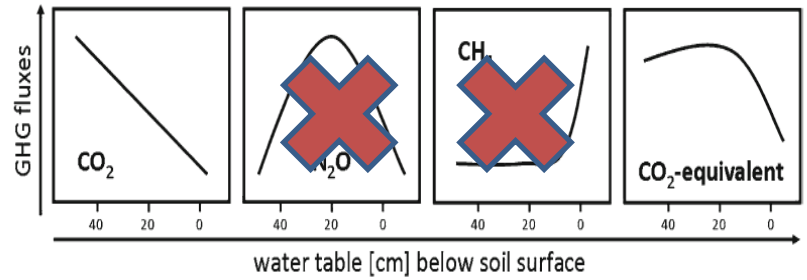
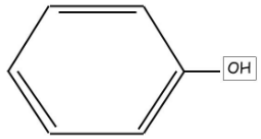


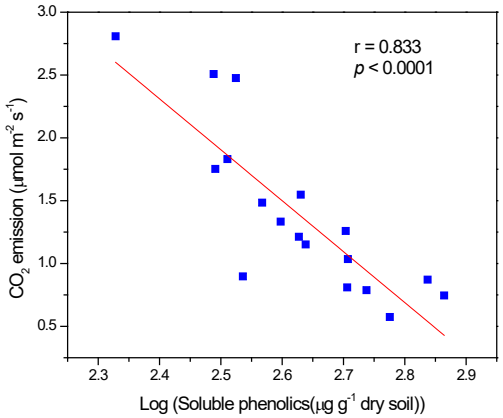
Fig.10. The relationship between CO_2 emissions and water table depth during each season at PLNWR in coastal NC. All treatment sites are included in this graph. The regression shown is significant for only the summer months.

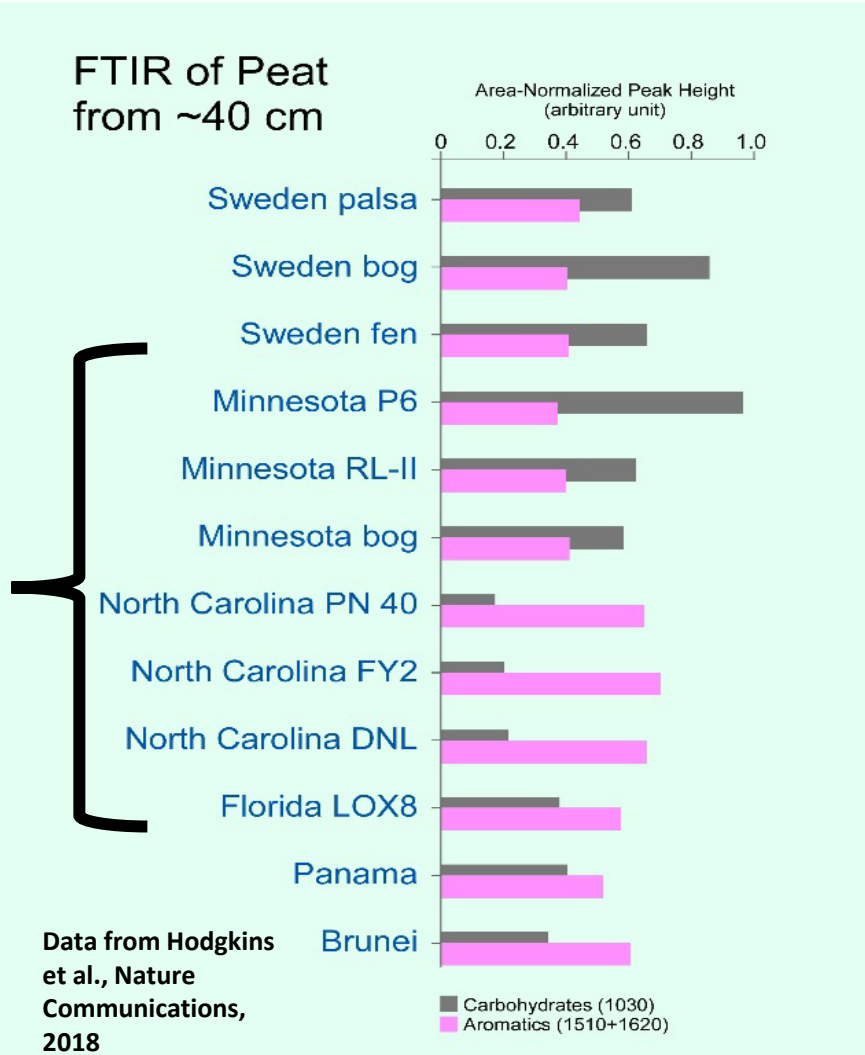


Phenolics/Aromatics Inhibit Soil Respiration in Bog Soil



Phenolics >= a phenol group-a hydroxyl functional group on an aromatic ring





Data from Hodgkins et al., Nature Communications, 2018

Boreal

N

Sub-Tropical

Tropical

S

High Aromatics make pocosins have a high potential for longterm C storage

Most Natural Wetland Fires (Light Surface Fires)

Wet burn in the Green Swamp, Brunswick County, NC. Photo: Gary Curcio, NC Division of Forest Resources.

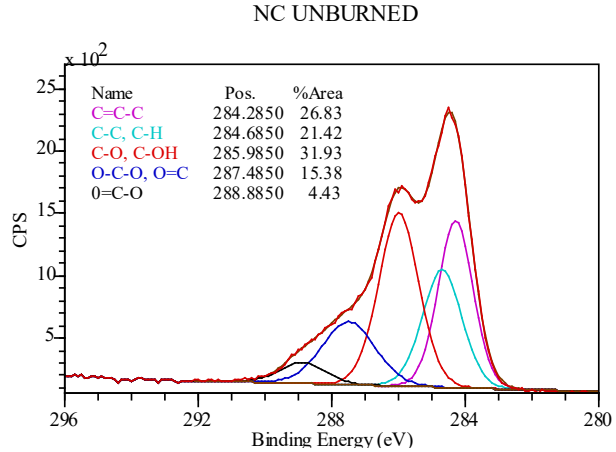
Reardon and Curcio, 2011

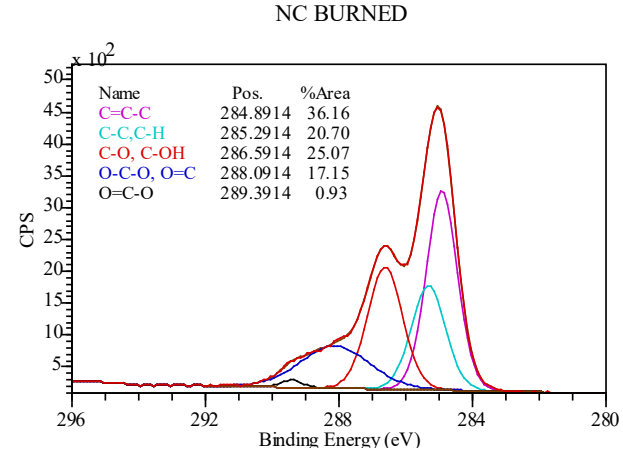
Photo by Caleb Spiegel, US FWS

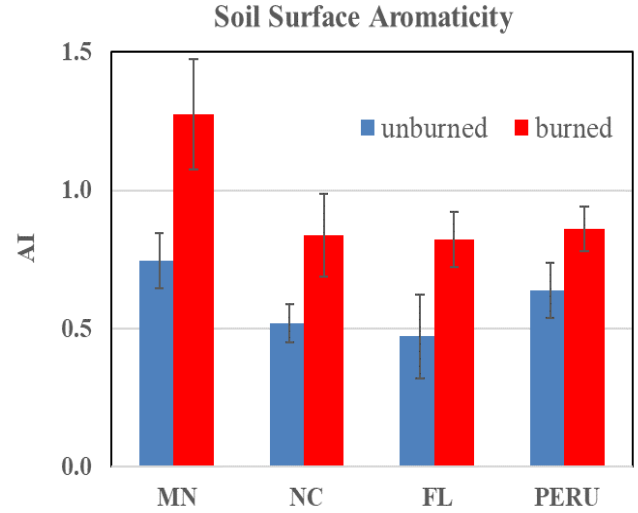
US FWS
https://www.flickr.com/photos/usfwssouth

Croatan NF, Spring 2017

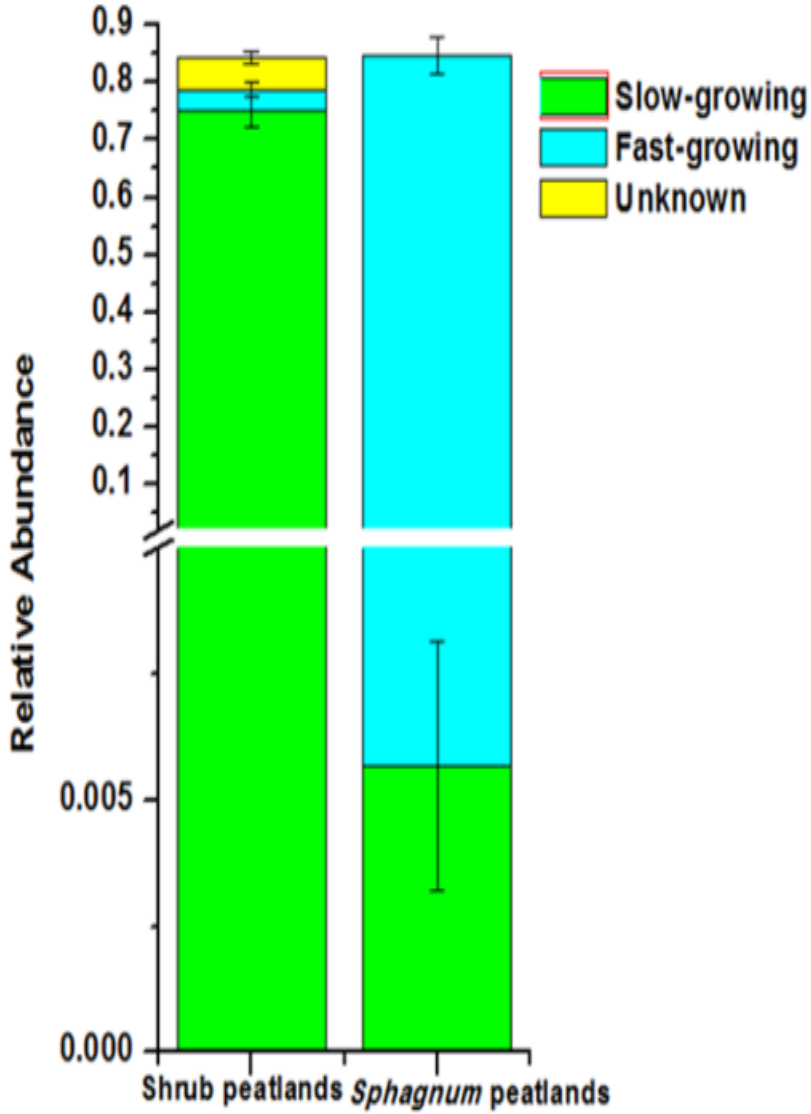
XPS spectra (x-ray photoelectron spectroscopy)



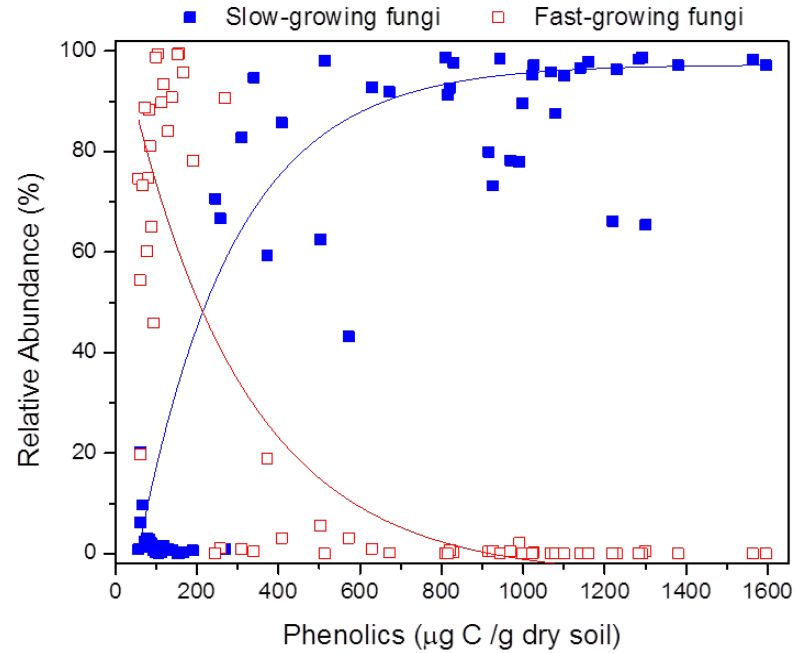


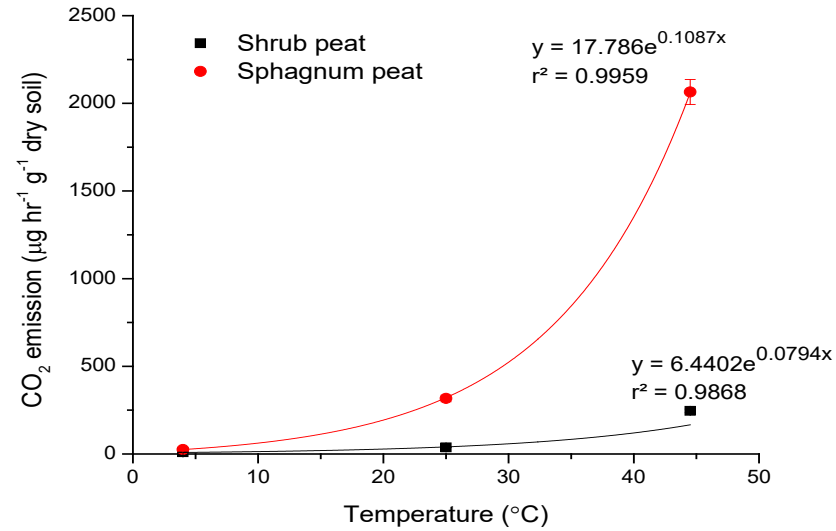


Flanagan, Wang, Winton, Richardson, 2020. Low-severity fire as a mechanism of organic matter protection in global peatlands: Thermal alteration slows decomposition. Global change Biology. 26: 3930-3946.



NC MN





Slow-growing Microbes with Low Carbon Turnover Rates Dominate in High-Phenolic Peats

Wang, *et al., Commun Earth Environ* **2,** 67 (2021).

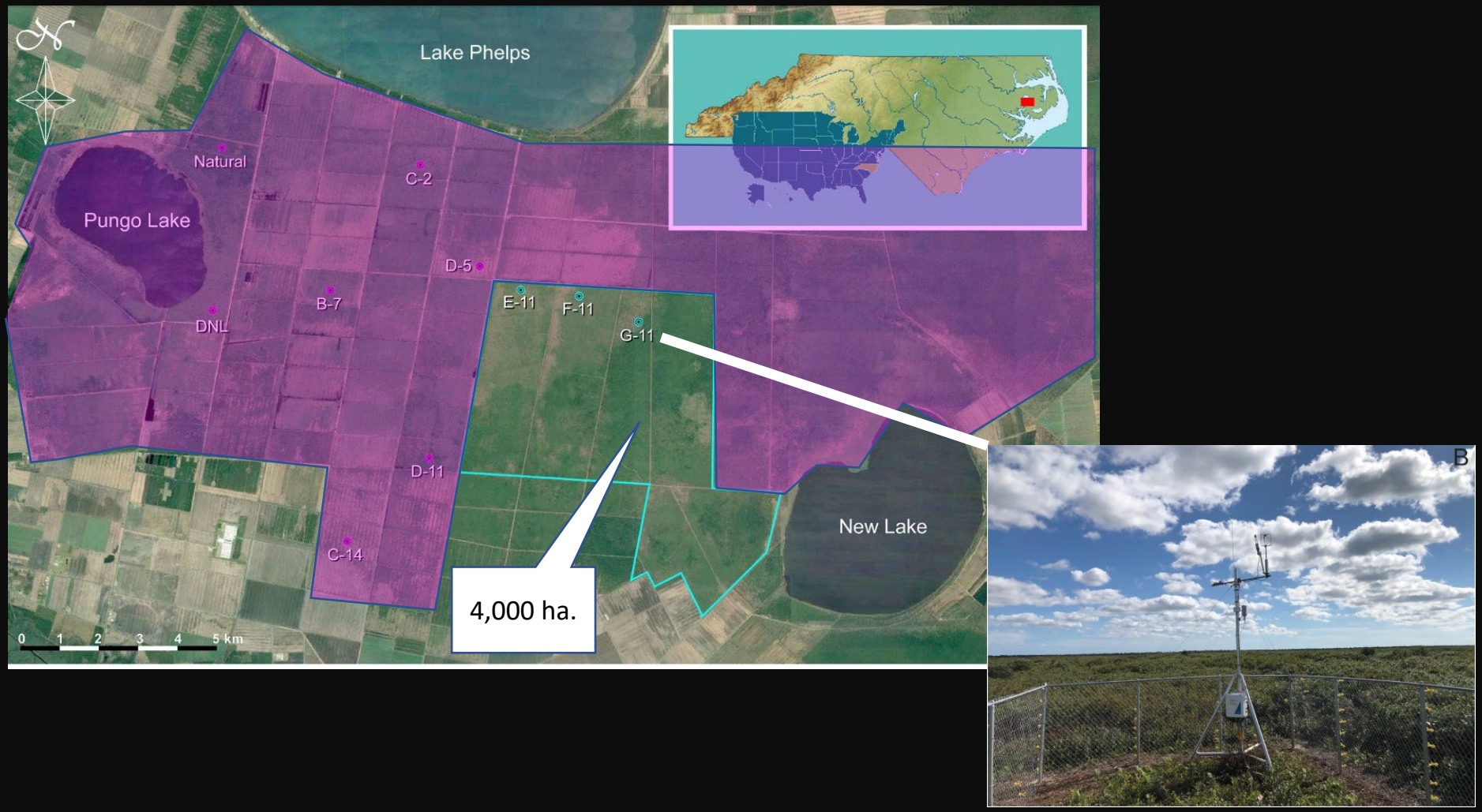
Secondary Factors Can Act as Key C Decomposition Controls in Lower Latitude wetlands ?

- **Low-latitude shrub peatland C decomposition is down regulated by higher production of phenolics and aromatic compounds than found in northern *Sphagnum/Carex* communities.**

- **Higher concentrations of phenolic/aromatic compounds = highly recalcitrant peat compounds, which inhibit microbial activity.**

- **Recurring low-intensity fires = higher aromatic C peat compounds, lower carbohydrates and decreased microbial respiration.**

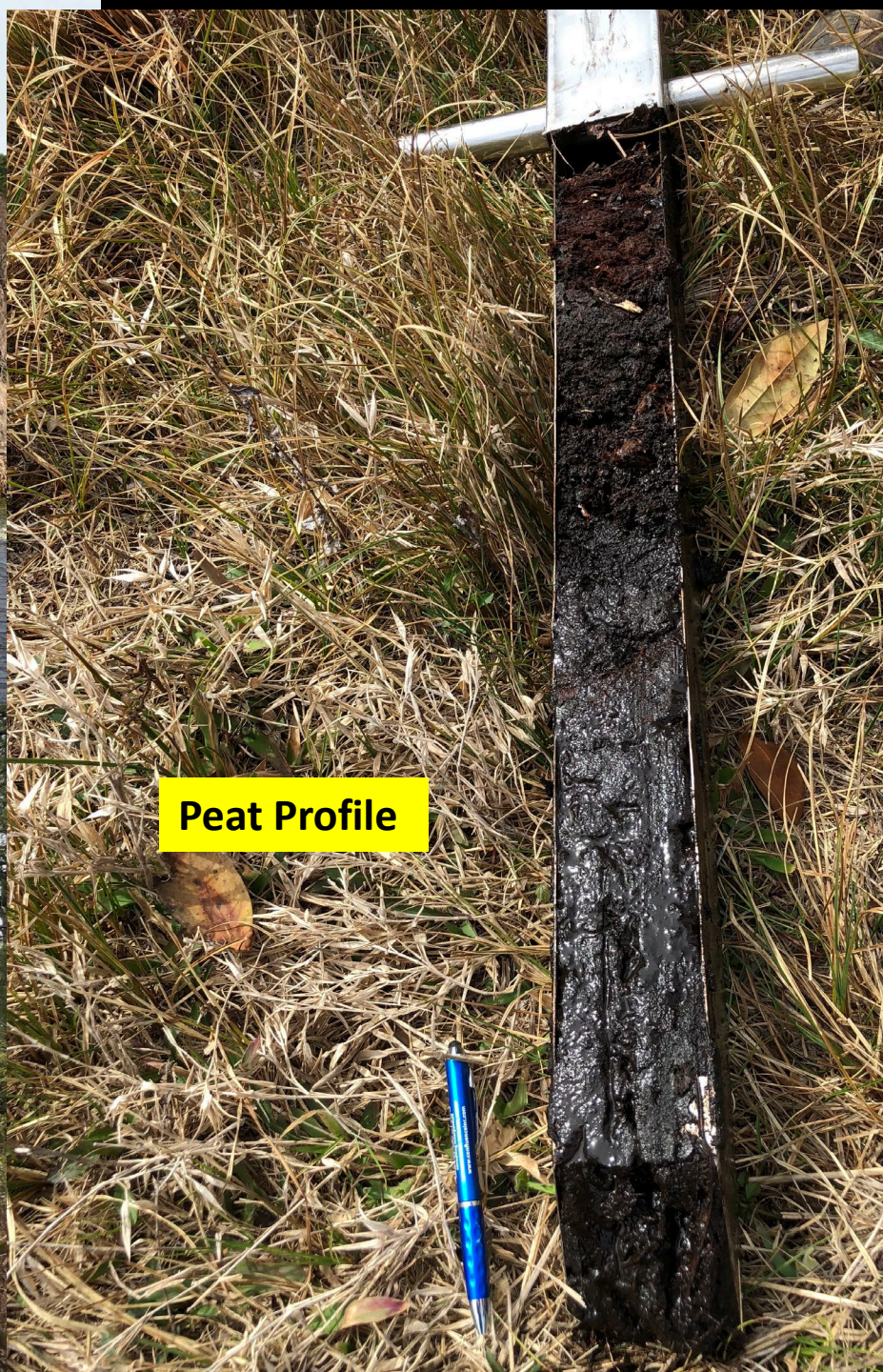
- **Slow growing microbes found with higher phenolics, lower Temp response for decomposition**


Lake Phelps
Natural
C-2
Pungo Lake
D-5
B-7
E-11
F-11
DNL
G-11
D-11
New Lake
C-14
4,000 ha.
0 1 2 3 4 5 km
B


Aerial View of Carolina Ranch a 4,000 ha Private Farm

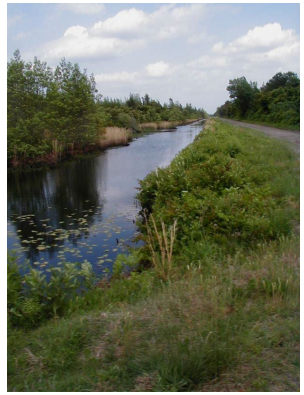

Drained Pocosin


Natural Pocosin


Peat Profile

ASSESSING RESTORATION IMPACT

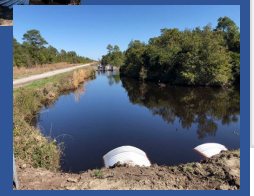
Reduction of Carbon Losses to atmospheric CO_2 Emissions through rewetting on 4,000 ha

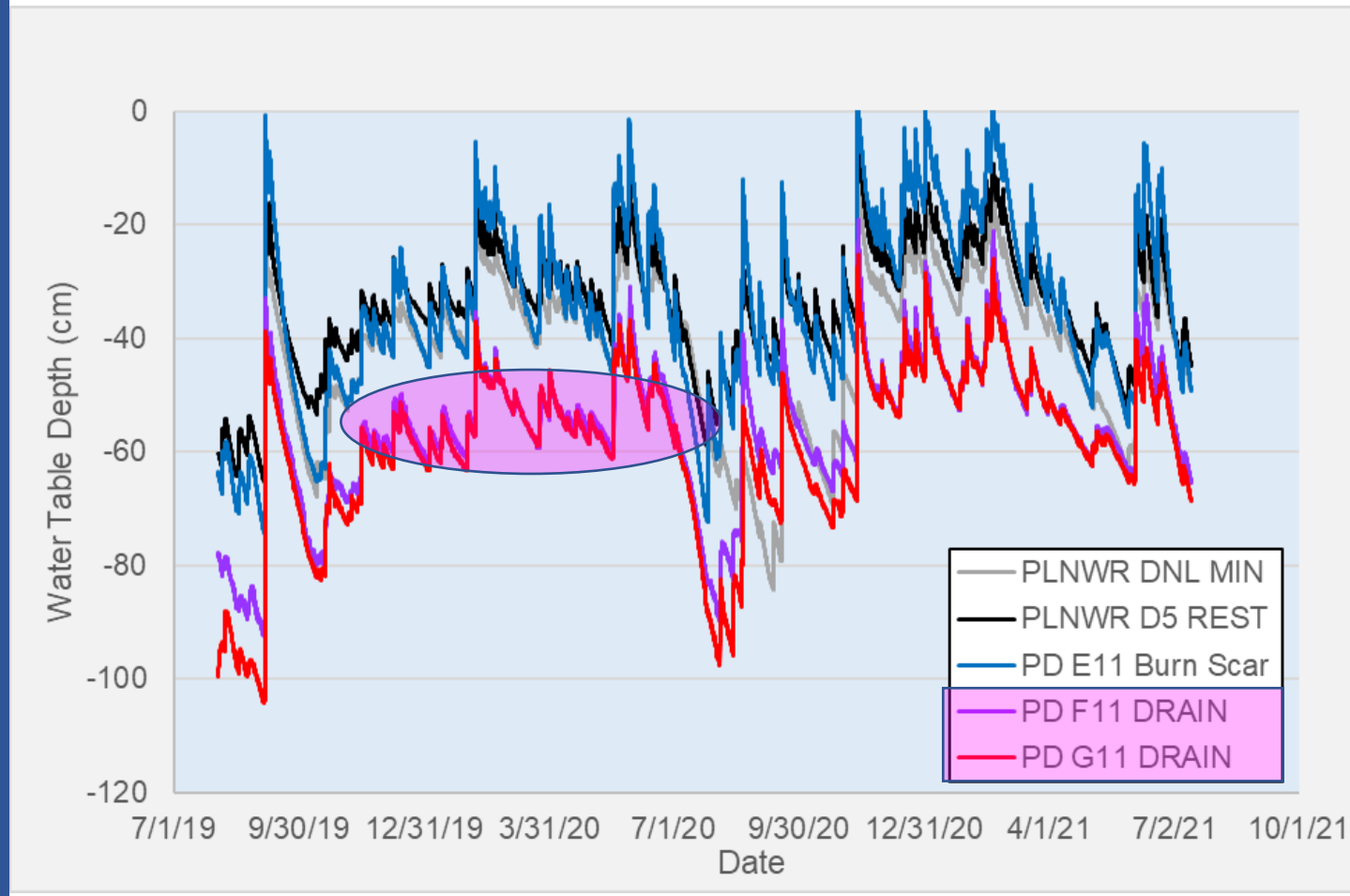


Quantify regional emission reductions:

- **Reduced microbial oxidation**
- **Reduced losses to fire**

Water Table Depths and Rewetting



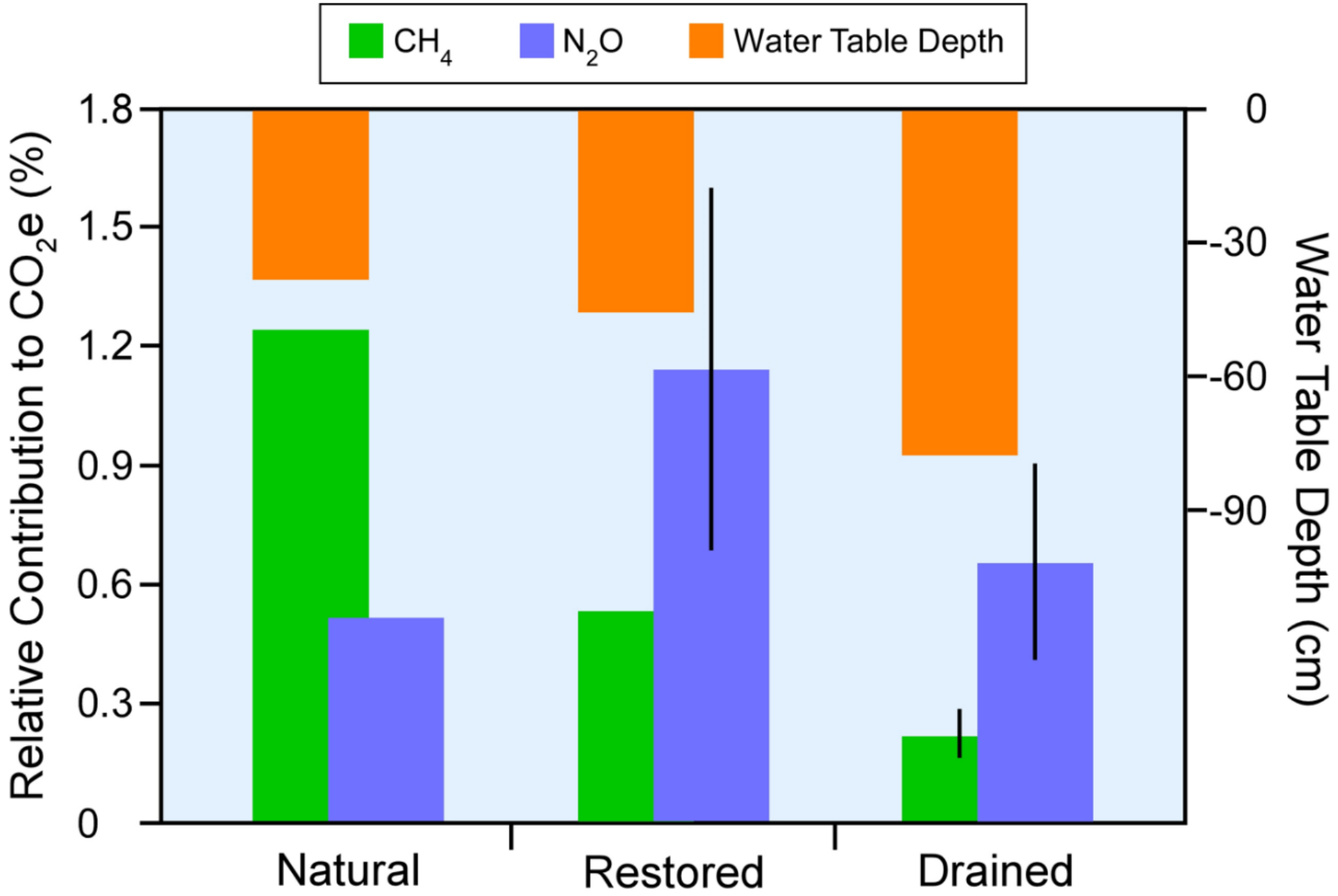


Richardson et al., In GCB, 2022

Eddy Covariance measurement of Net Ecosystem Exchange

Eddy-Flux Towers used to Measure Green House Gas Losses (CO_2) & Net Ecosystem Exchange (NEE) and C accretion

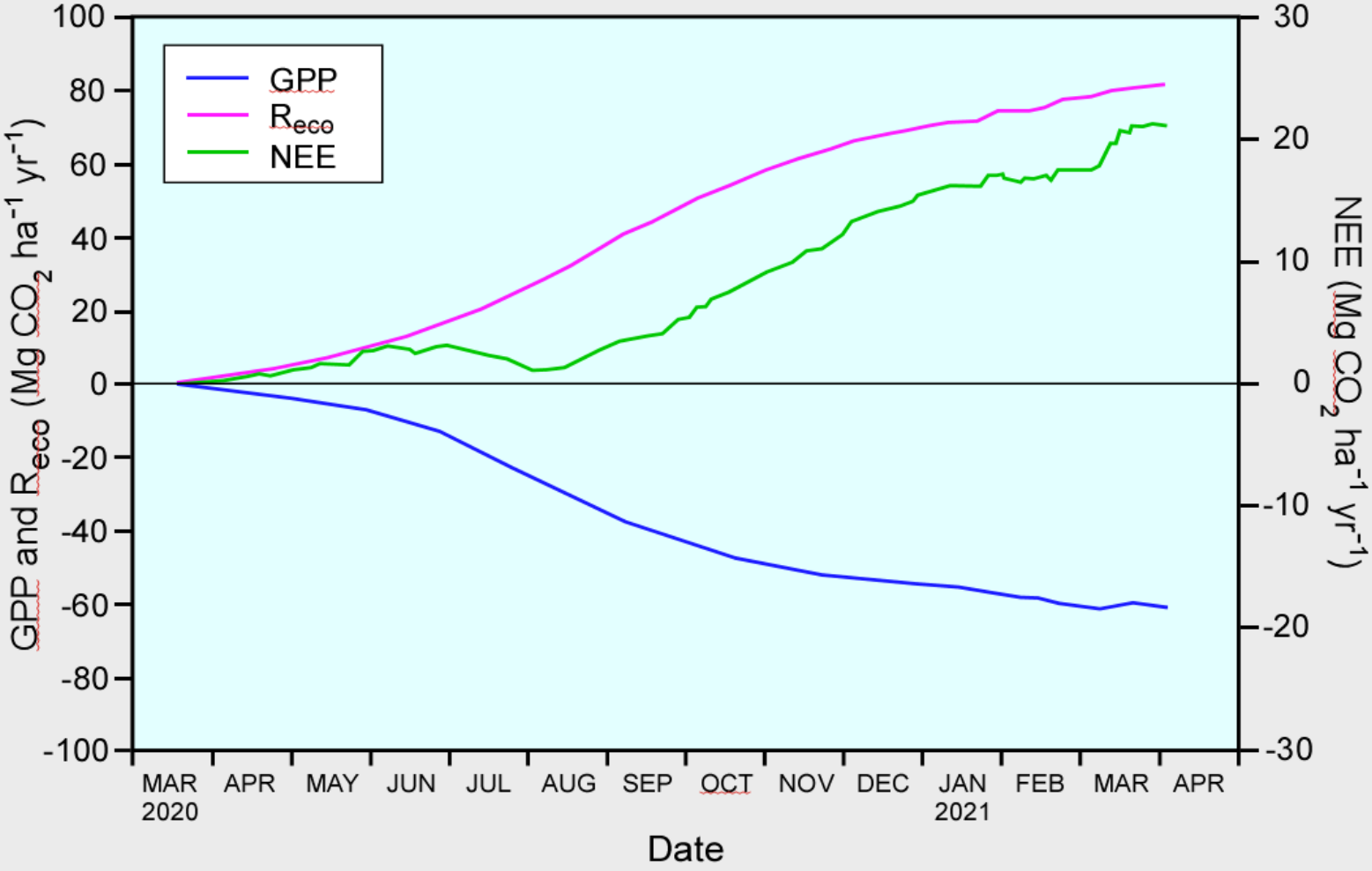
Smart Chamber



Richardson et al., Ecological Engineering, 2023

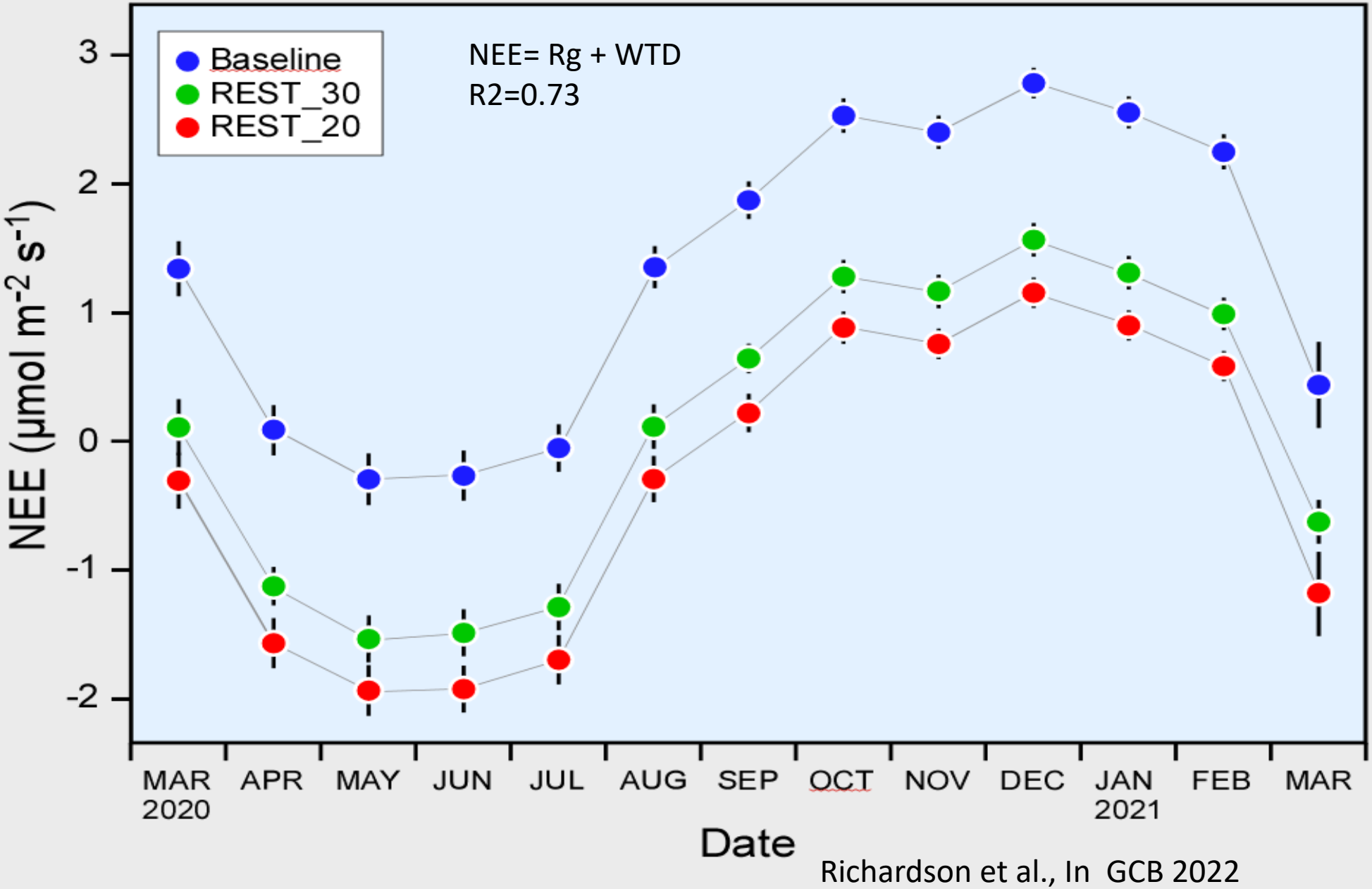
Cumulative NEE, GPP and R_{eco}

DRAINED SITE



Richardson et al., In GCB 2022

Proxy model NEE predictions with water table depths raised 20 or 30 cm vs 60 cm



Richardson et al., In GCB 2022

Linear Model Predictions

Modeling results comparing the CO_2 stored by raising water tables to within 30 or 20 cm of the surface compared to drained pocosin sites (baseline). Water table depths (WTD) refer to annual mean depth below soil surface.

Scenario	NEE		Delta*
	Mg CO_2 ha^{-1} yr^{-1}	t/acre	
Baseline (unrestored, WTD = 60 cm)	21.2.	8.6	—
Restored, annual Mean WTD = 30 cm	2.0	0.8	19.2
Restored, annual Mean WTD = 20 cm	−3.3	-1.3	24.5 10

*Delta is the differences between the restored scenarios and baseline (unrestored) scenario

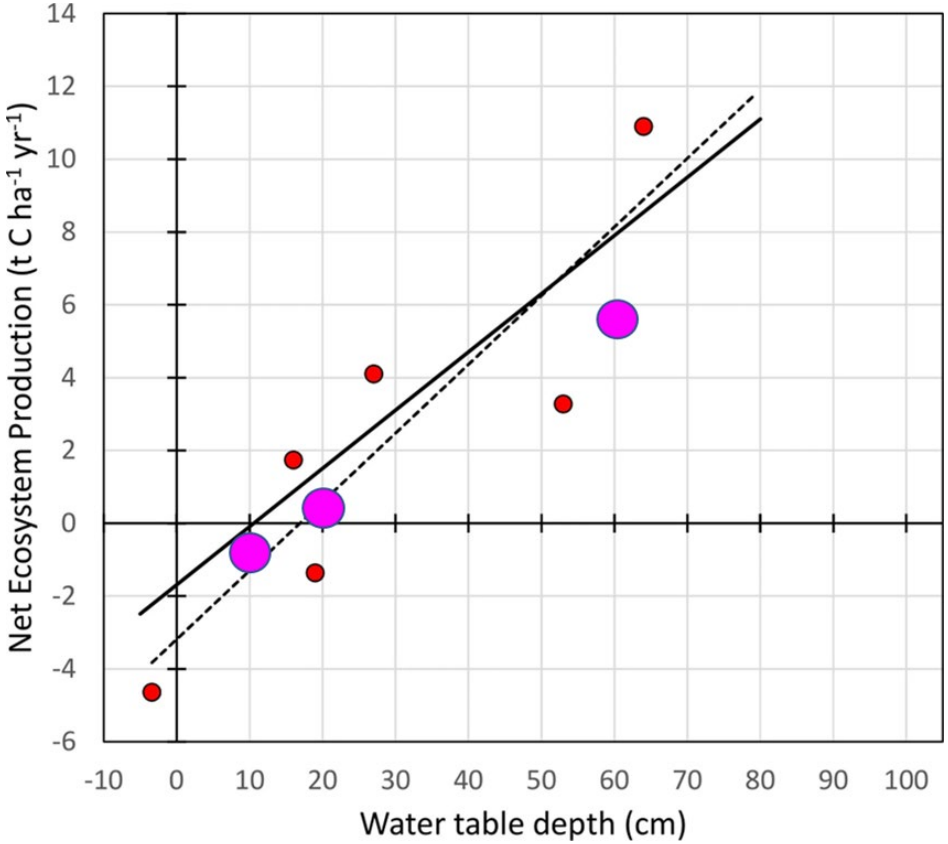
Linear Model

NEE = WTD + Rg R^2=0.73

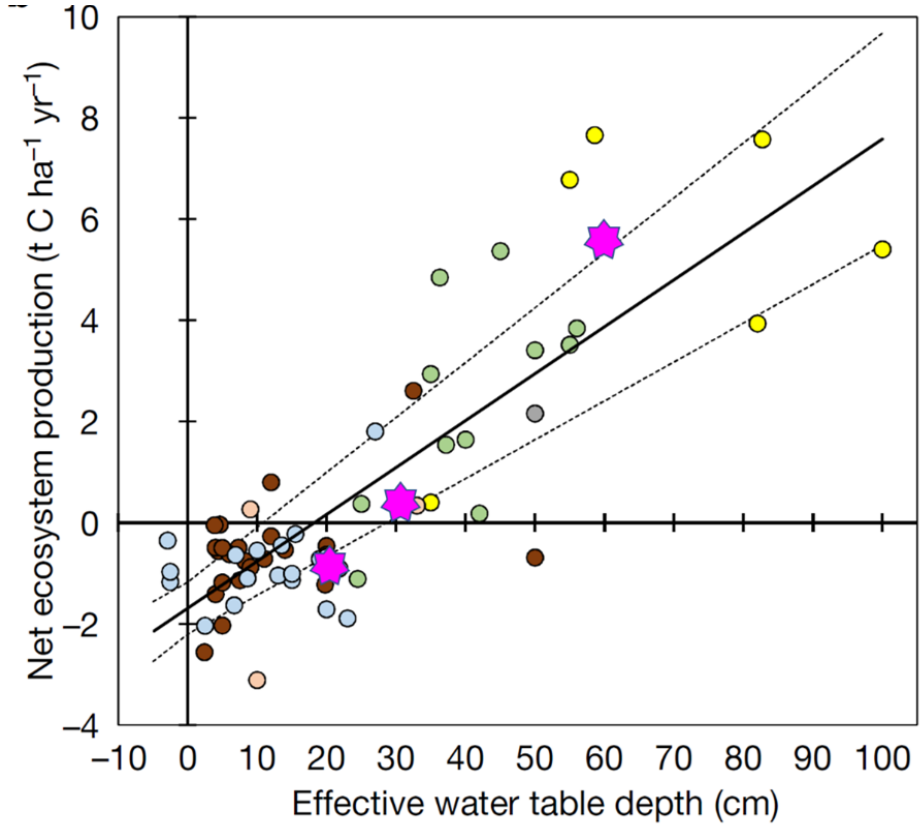
NEE =half-hour average values from Eddy Covariance
R_g = Global Radiation
WTD = Distance to Water Table below soil surface

Richardson et al., GCB 2022

Tropical Peatlands



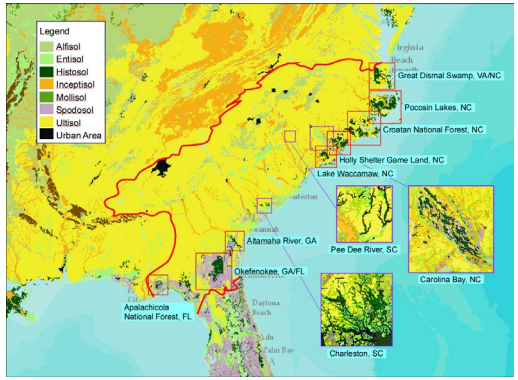
Temperate European Peatlands



Overlay of Richardson and Flanagan et al., 2022 data

EVANS ET AL., NATURE, 2021

SE Peatland Inventory



CO_2 Losses for Drained & Burned Peatlands

State	Histosol Area (ha)	Restorable Histosols on Cropland and Pasture (ha)	Restorable Histosols on Non-Wetland LUs (ha)	C Losses	
				Microb. Oxidation 21.2 Mg CO_2 ha^{-1} yr^{-1}	Fire 36.7 Mg CO_2 ha^{-1} yr^{-1}
NC	518,900	43,861	71,320	930,000–1,512,000	1,610,000–2,617,000
SC	46,726	1,185	3,104	25,000–66,000	43,000–114,000
GA	136,987	209	1,159	4,400–25,000	7,700–42,000
VA	55,379	186	1,154	3,900–24,000	6,800–42,000
Sum	757,992	45,441	76,737	963,000–1,627,000	1,668,000–2,816,000

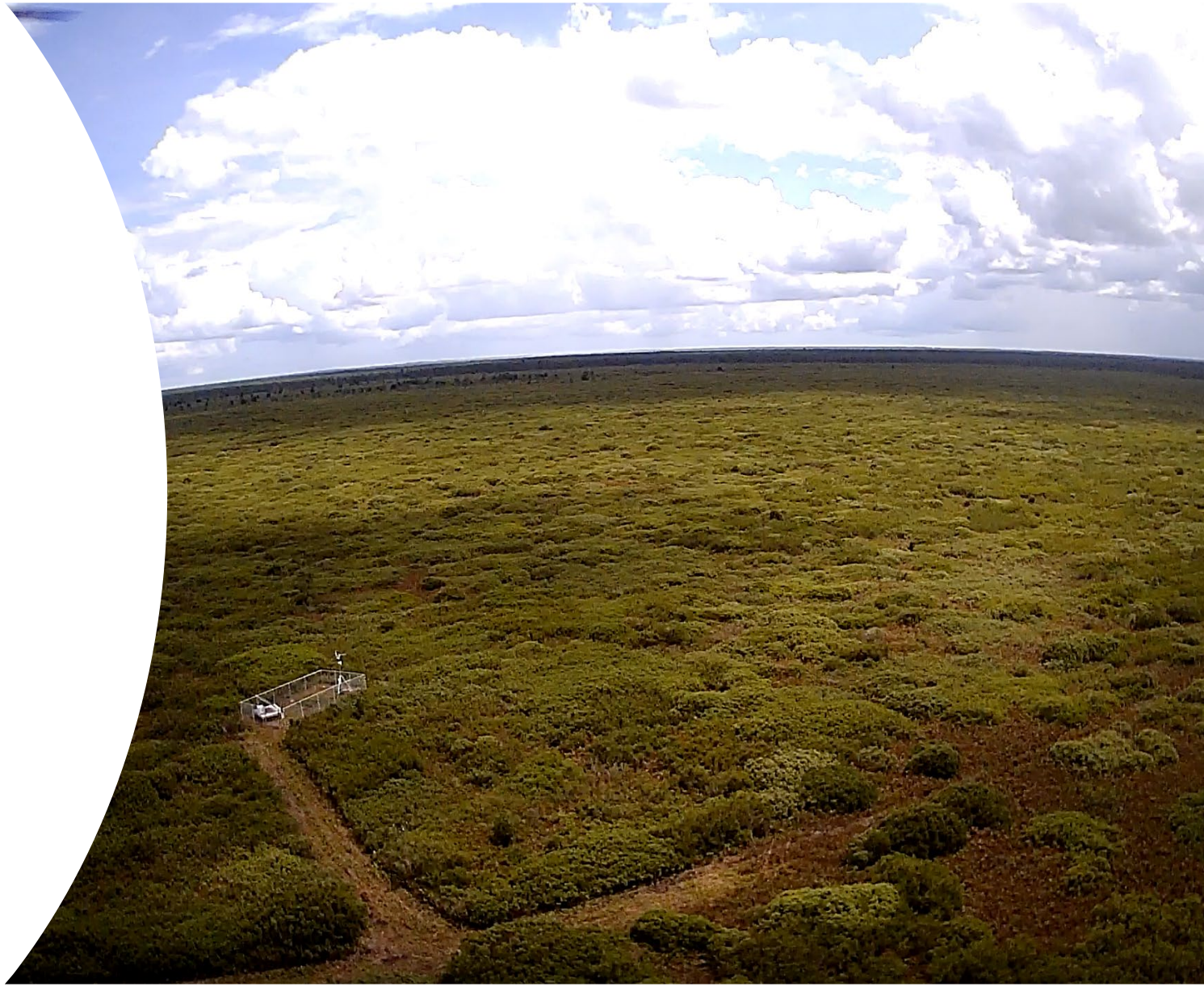
Total; 2,631,000 – 4,443,000

or 2.6 to 4.4 Tg CO_2 yr^{-1}

Richardson et al., GCB 2022: Note- 21.2 assumes net zero losses after rewetting

CONCLUSIONS

- **Rewetting of 45 and 77 hectares of pocosins could reduce annual GHG emission up to 4.4 Tg of total avoided loss of CO_2 per year across the region**
- **Despite covering <0.01% of continental USA land area, rewetting degraded pocosin can potentially provide 2.4% of the annual CO_2 nationwide USA reduction target of 180 Tg necessary to achieve net zero in 28 years (total reduction 5Gt)**



Acknowledge Long term Contributors

Dr. Curtis J. Richardson

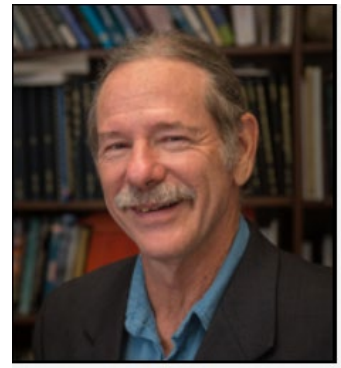
Dr. Hongjun Wang

Dr. Neal Flanagan

Dr. Suzanne Hodgkins

Dr. Rytas J. Vilgalys

Dr. Mengchi Ho



Dr. Jeff Chanton

Dr. Jianqing Tian

Acknowledgments

- **C** gradient Research is supported by the U.S. Department of Energy, Office of Science, Terrestrial Ecosystem Sciences, Climate and Environmental Sciences Division, Office of Biological and Environmental Research under grant award DE-SC0012272.
- Pocosin Funding: U.S. Fish and Wildlife Service, The Nature Conservancy, Grantham Foundation, & Duke Wetland Center Endowment
- Wes Willis and Belen de la Berra for Lab analysis & graduate students for field & lab work at the Duke Wetland Center.


Questions?
www.env.duke.edu/wetland