Stability Matters: A New Perspective on Wetland Soil Carbon

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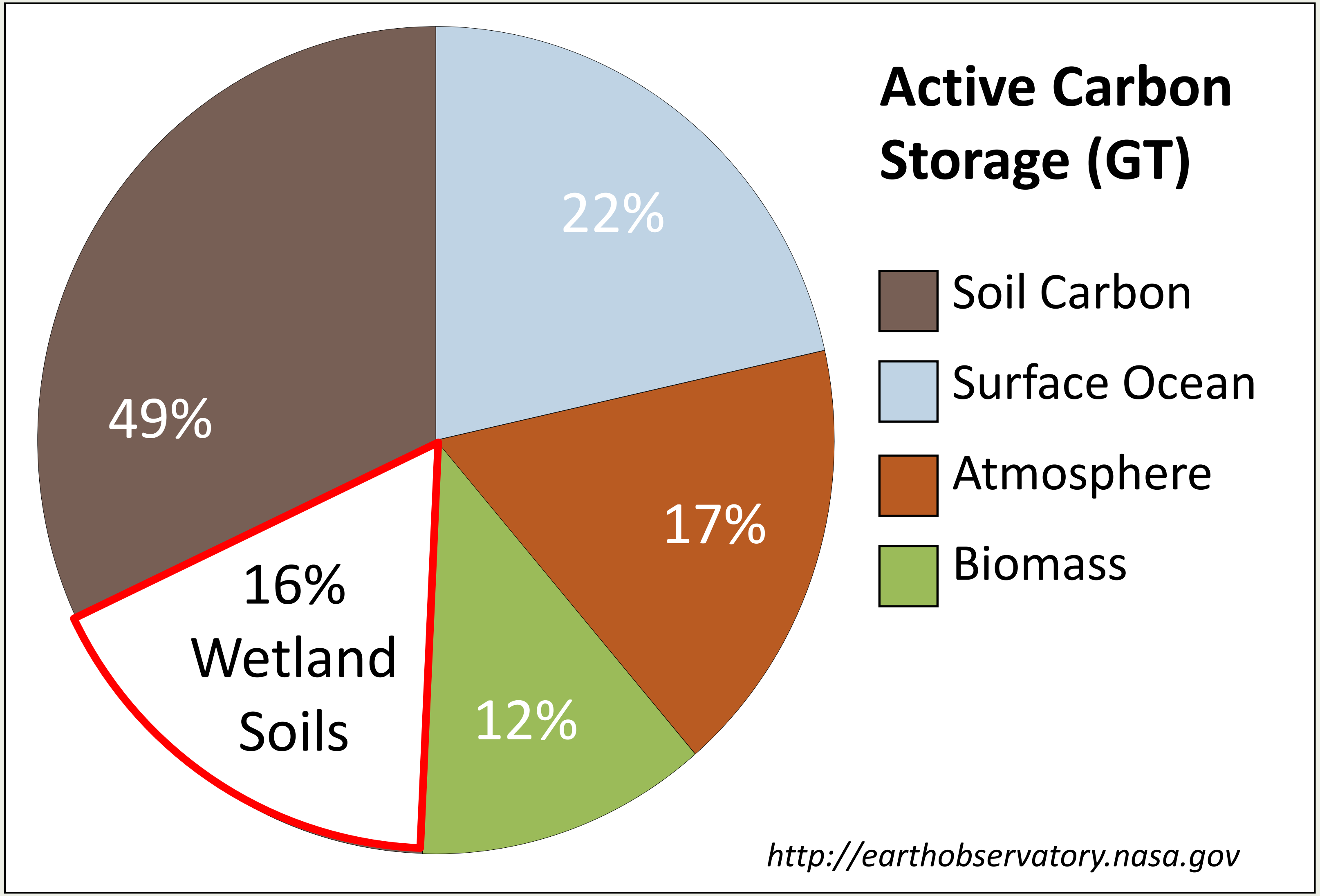
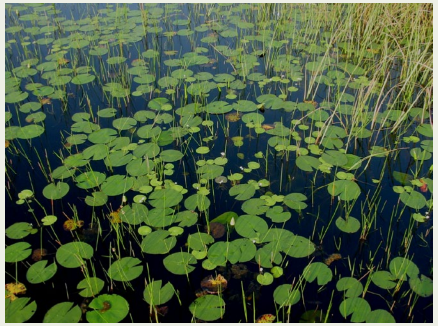
Aquatic Biogeochemistry Lab

Outline

1. Current understanding of soil C stability
2. What does it mean for wetlands
3. Research Applications
    1) Quantifying by habitat type
    2) Maximizing C stability
    3) Minimizing C stability
    4) Documenting environmental change

Why study wetland soil carbon?





Nathaniel Spicer

Jennifer Bennett

my hand

Tasnim Mellouli

Wetland soil carbon inventories are now commonplace

(Radabaugh et al., 2023; Breithaupt et al., 2023; Bennett and Chambers, 2023; Hurst et al., 2022; Harttung et al., 2021; Steinmuller et al. 2020a, 2020b; Ho and Chambers, 2020; Chambers et al., 2018; etc.)

Wetland can store a ton of carbon…

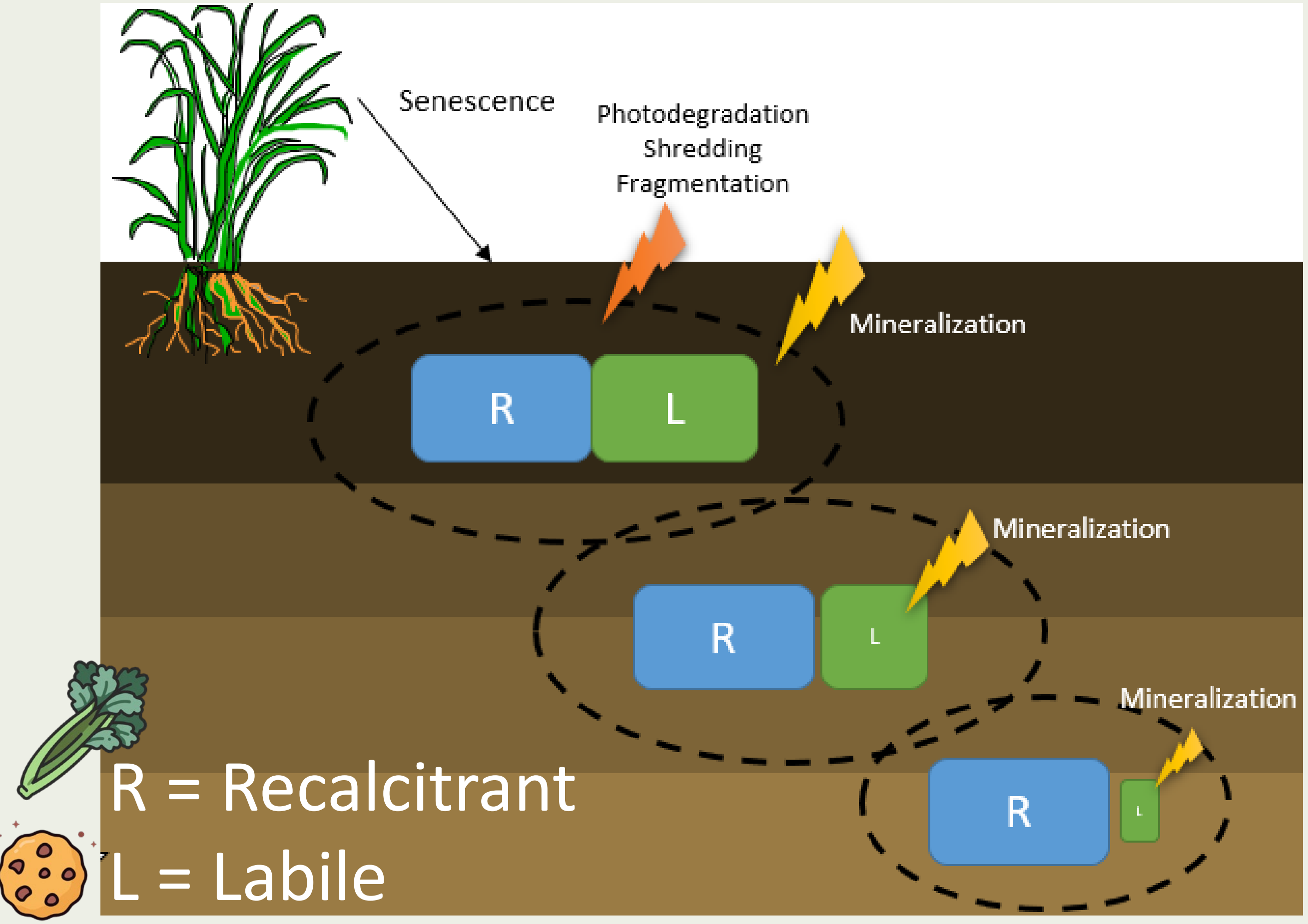
…but it's highly vulnerable.

What controls which C stays in the soil, and which C is lost?

Two theories have dominated wetland science:

Selective Preservation

(intrinsic properties; molecular biochemistry; decay continuum)



(Steinmuller and Chambers, 2019)

Anaerobic Redox Chemistry

Alternative Electron Acceptor Cascade

O_2

NO_3^-

Mn^{4+}

Fe^{3+}

SO_4^{2-}

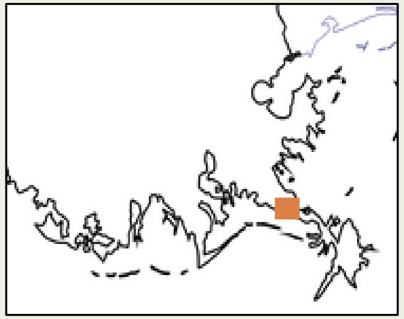
CO_2 / H_2

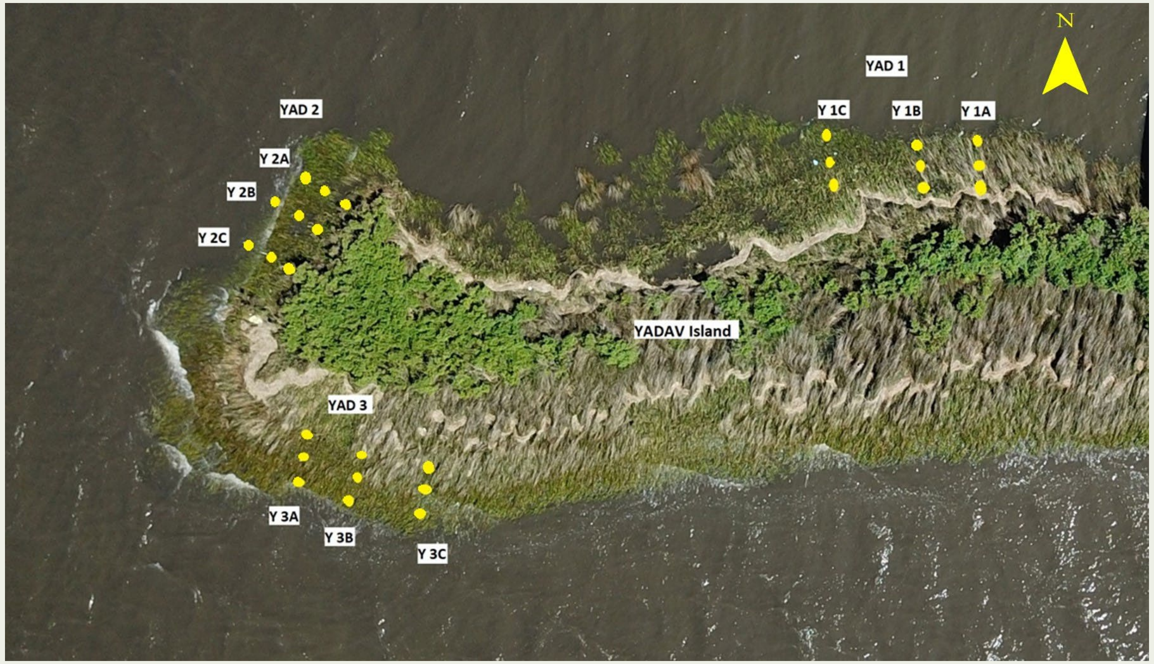
Decreasing energy yield

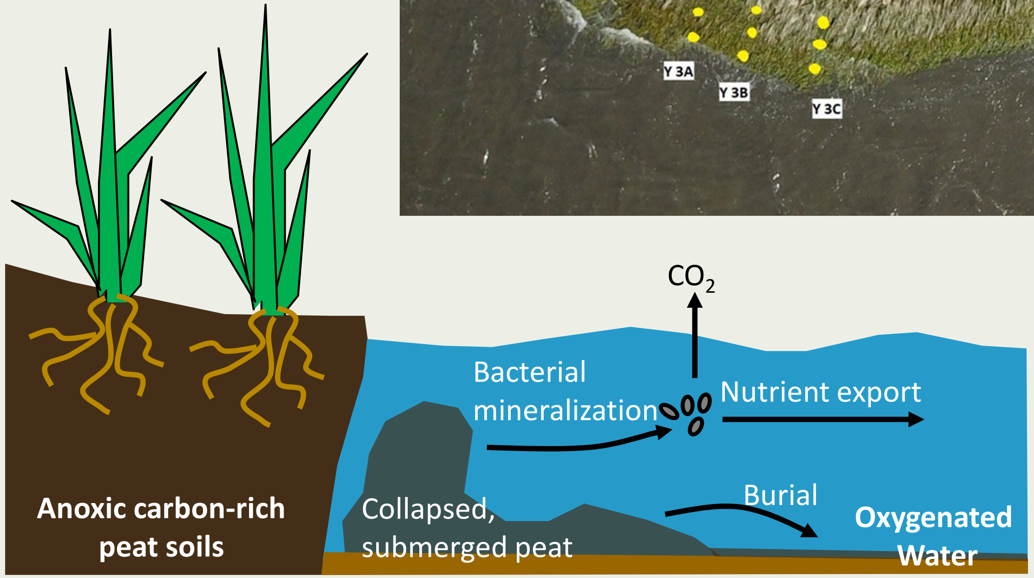
These theories led us to believe…

- If depth is a proxy for age, then C degradability decreases with depth
  - Biogeochemical studies can focus on top ~30 cm
  - C:N decreases with depth, but N is protected via “humification”
- Soil total C is an ecological significant measurement

These theories don't always fit the data…





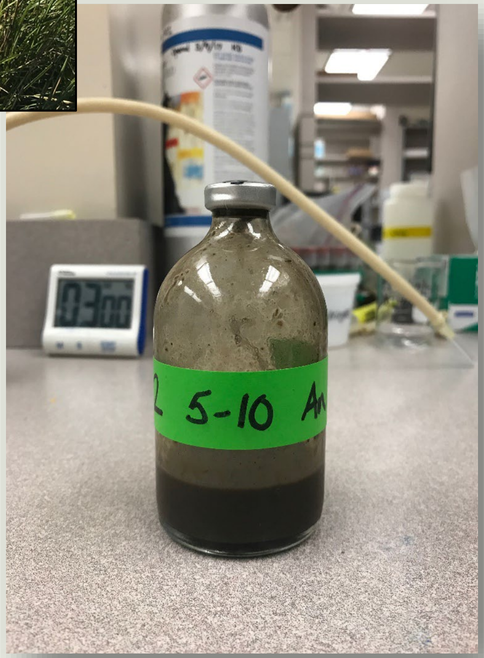


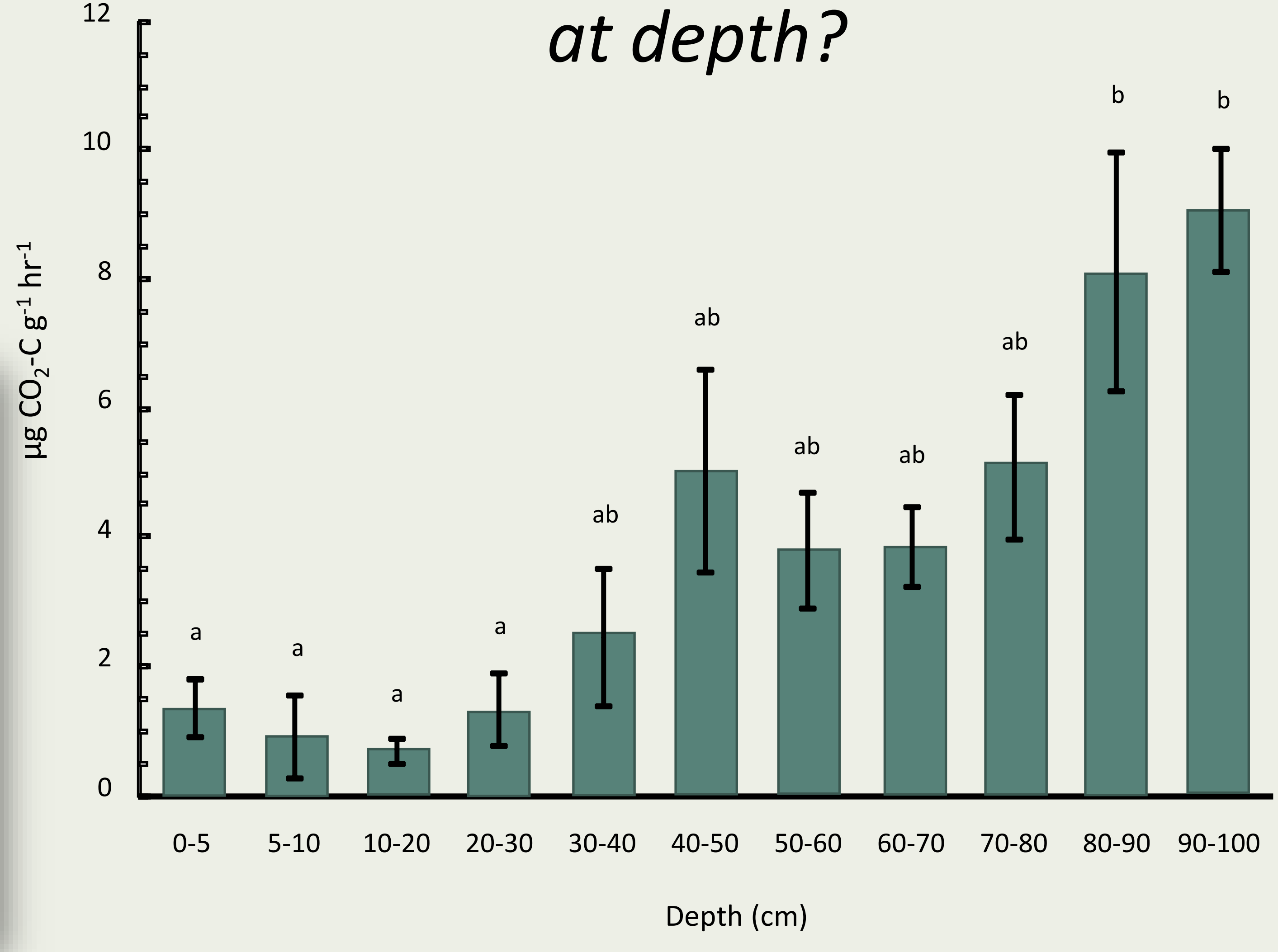
Collaborators: John White, Robert Cook, Zuo "George" Xue

Soil C is more labile at depth?

Havalend Steinmuller

LOUISIANA UNIVERSITIES MARINE CONSORTIUM
LUMCON

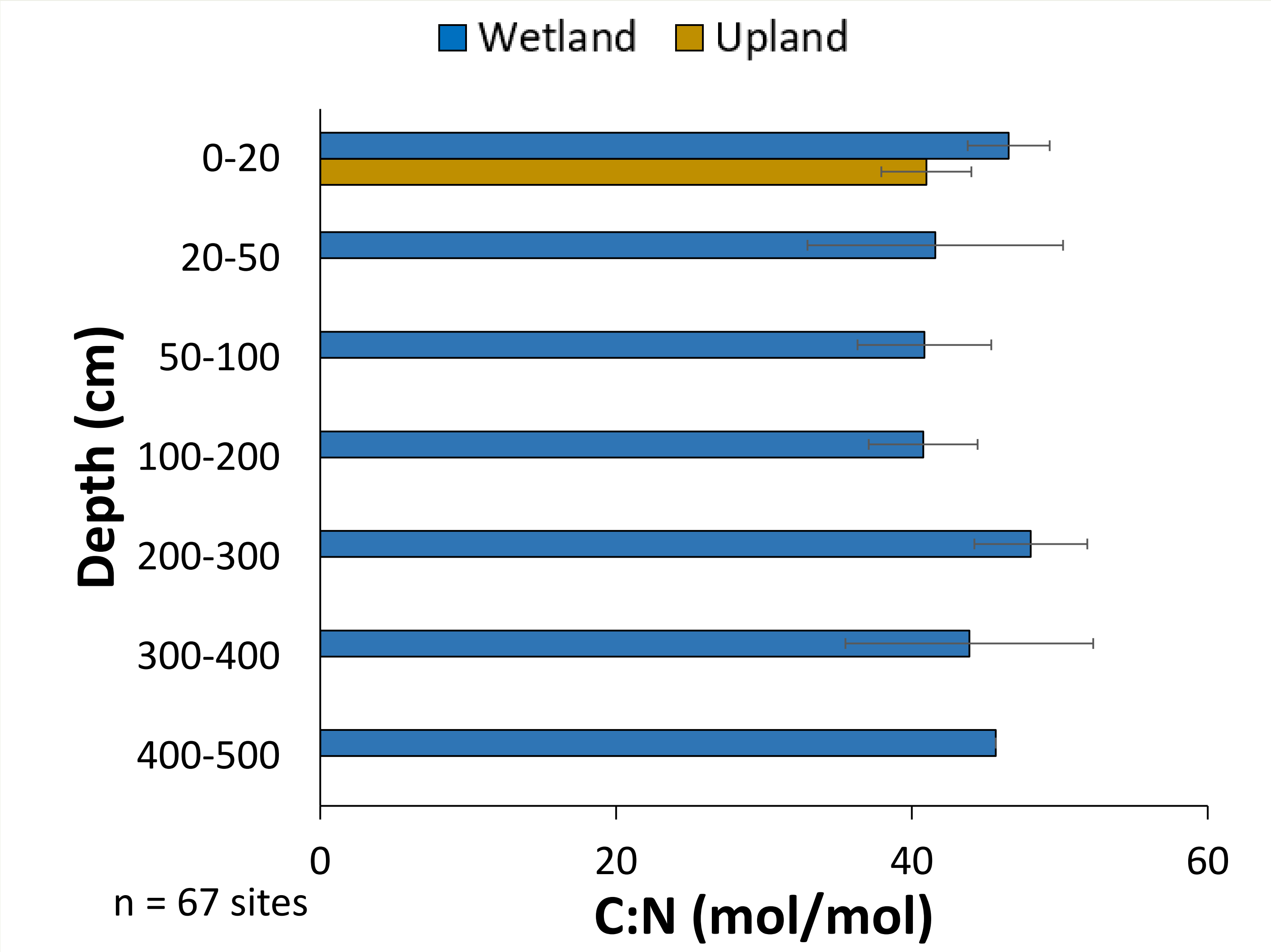




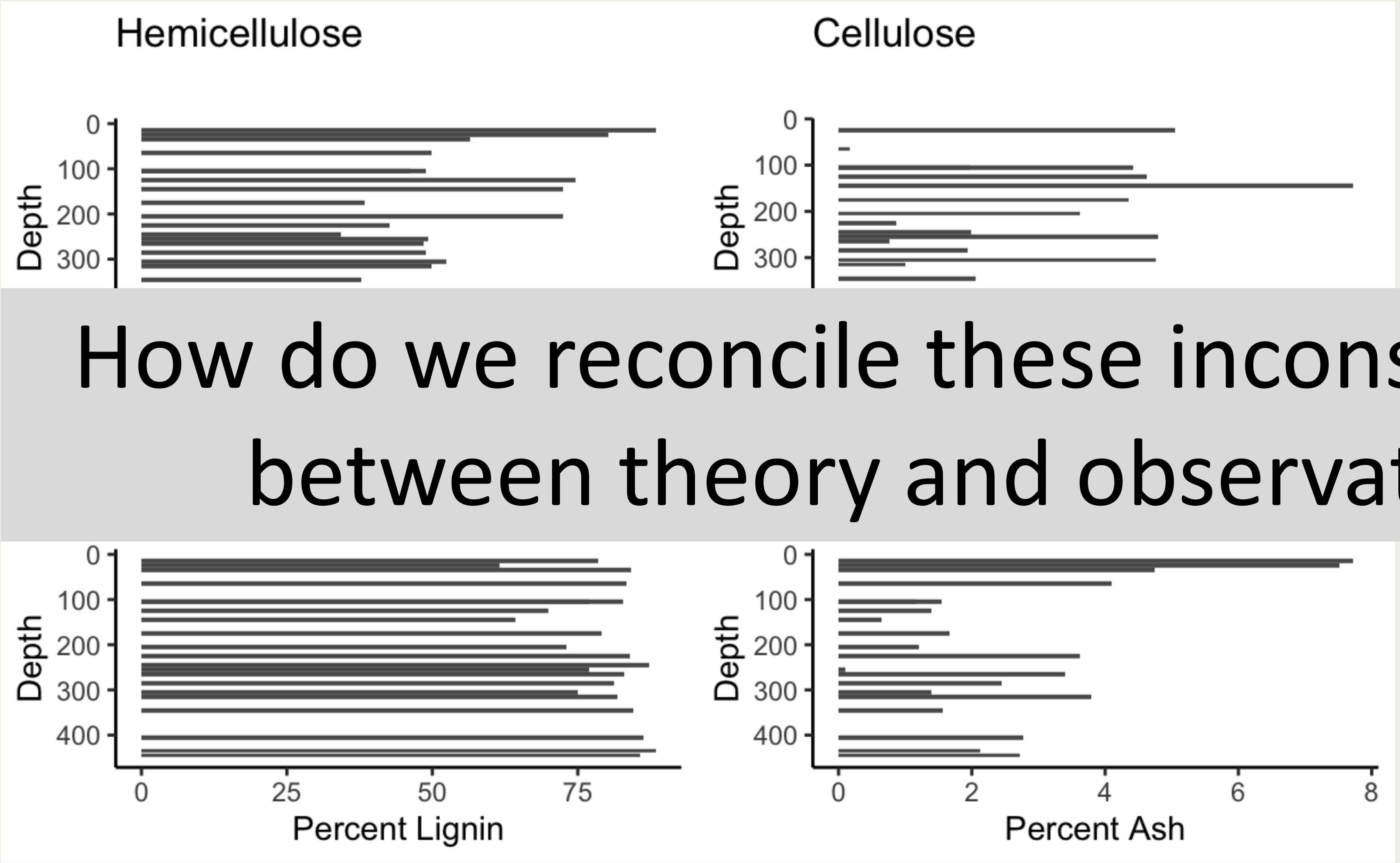
(Steinmuller et al., 2019; 2020; Chambers et al., 2019)

C:N doesn't change down to 5m deep?

(Bennett and Chambers, 2023)



No clear relationship between depth and biochemical properties?



How do we reconcile these inconsistencies between theory and observation?

My eureka moment!

PERSPECTIVE

doi:10.1038/nature10386

Persistence of soil organic matter as an ecosystem property

Michael W. I. Schmidt[1]*, Margaret S. Torn[2,3]*, Samuel Abiven[1], Thorsten Dittmar[4,5], Georg Guggenberger[6], Ivan A. Janssens[7], Markus Kleber[8], Ingrid Kögel-Knabner[9], Johannes Lehmann[10], David A. C. Manning[11], Paolo Nannipieri[12], Daniel P. Rasse[13], Steve Weiner[14] & Susan E. Trumbore[15]

LETTERS

PUBLISHED ONLINE: 7 SEPTEMBER 2015 | DOI: 10.1038/NGEO2520

nature geoscience

Formation of soil organic matter via biochemical and physical pathways of litter mass loss

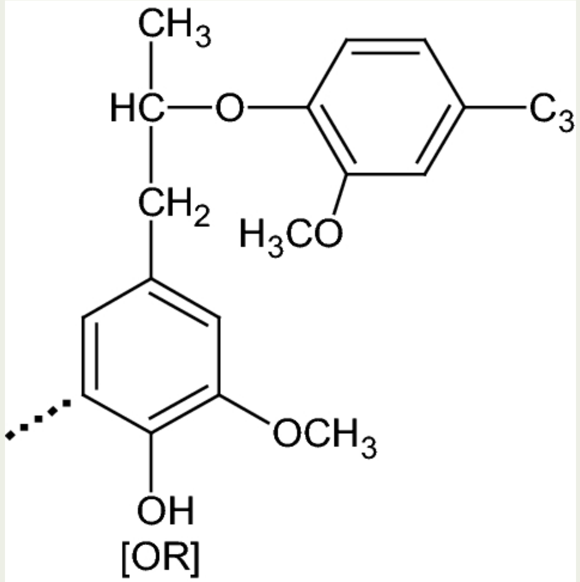
M. Francesca Cotrufo[1,2]*, Jennifer L. Soong[1], Andrew J. Horton[1], Eleanor E. Campbell[1], Michelle L. Haddix[1], Diana H. Wall[1,3] and William J. Parton[1]

- “Since pioneering work in the 1980s, new insights gathered across disciplines (ranging from soil science to marine science, microbiology, material science and archaeology) have **challenged several foundational principles of soil biogeochemistry** and ecosystem models; in particular, the perceived importance of the ‘recalcitrance’ of the input biomass (the idea that molecular structure alone can create stable organic matter) and of humic substances (biotic or abiotic condensation products).”

(Schmidt et al., 2011)

Upland Soil Science: 4 Mechanisms of Carbon Protection

1) Biochemical Protection



- Only "marginally important" in first phase of decomposition
- No support for humification
- Lignin continuously degrades

2) Environmental Protection

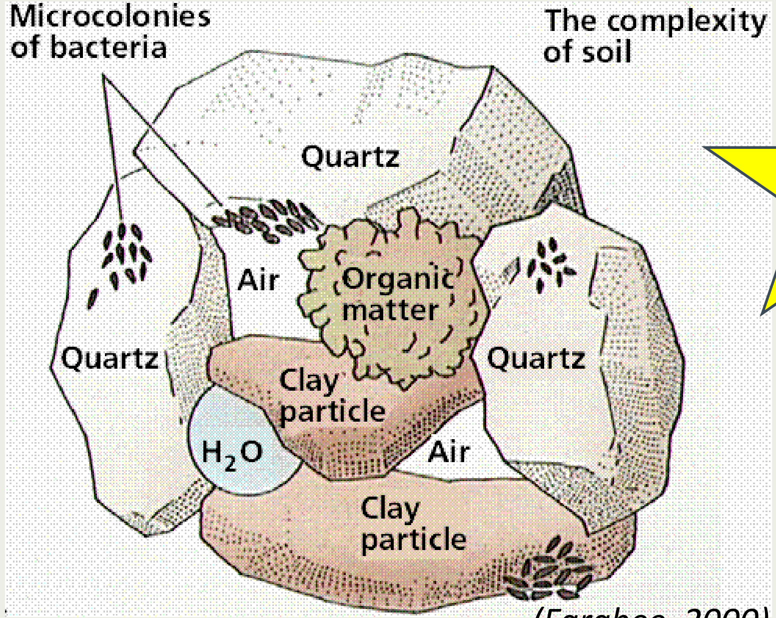
- Water-logging, low temps cause microbial physiological inhibition

Upland Soil Science: 4 Mechanisms of Carbon Protection

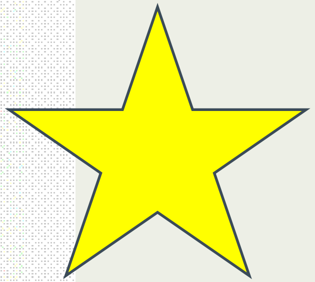
3) Physical Protection (Aggregates)

- primary mineral particles bound together by polysaccharides, bacteria, and plant debris
- Reduce microbial, enzyme, and fauna access

4) Chemical Protection (Mineral Associated Organic Matter)

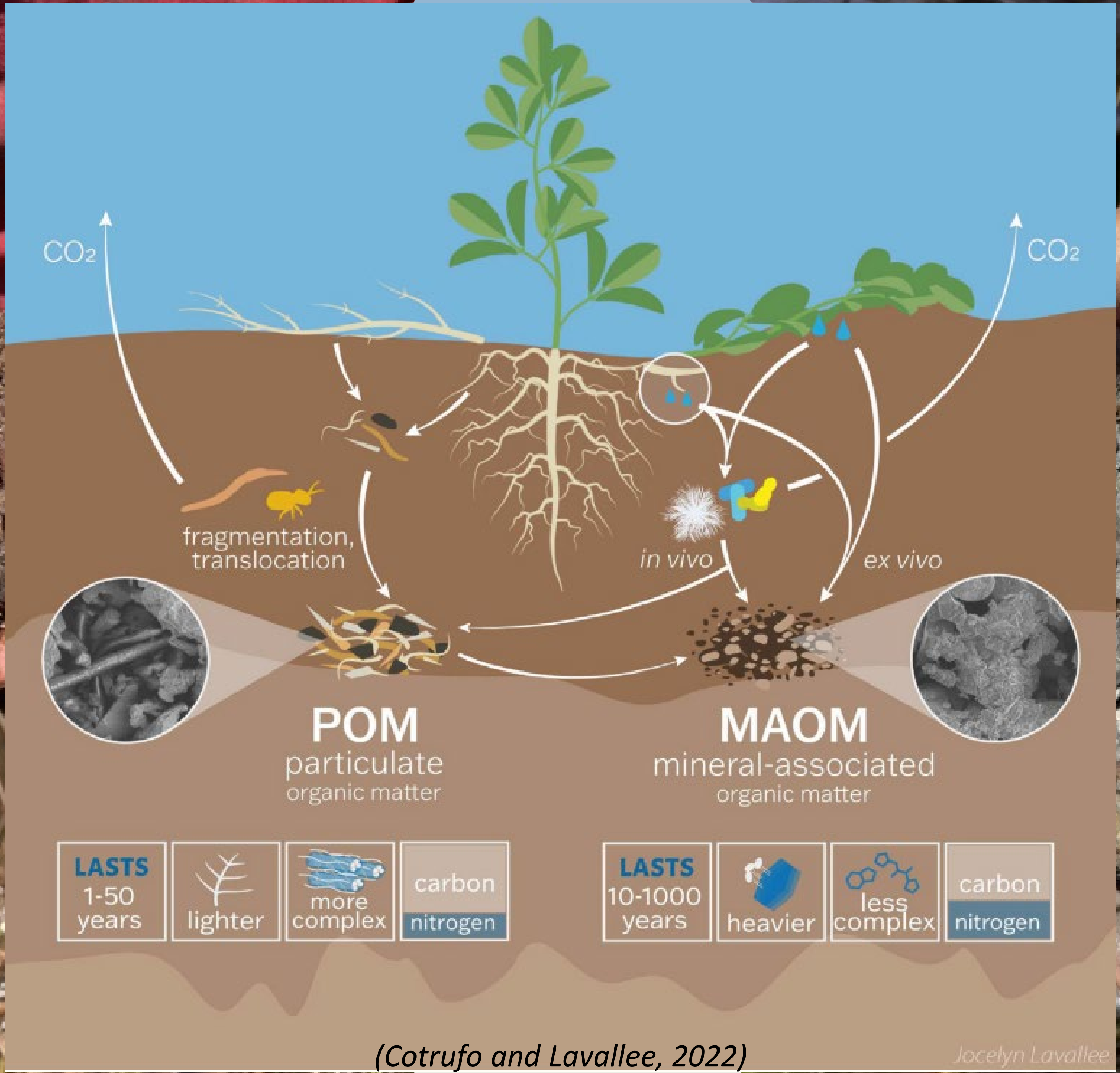


(Farabee, 2000)



- Physicochemical binding between fine minerals (<53µm) and organic matter

If fine mineral associations are so critical in uplands, *what about wetlands?*



(Cotrufo and Lavallee, 2022)

MAOM

<53 um

>1.85 g/cm3

(Cotrufo and Lavallee, 2022)

Measuring MAOM in wetland soil

Anthony Mirabito

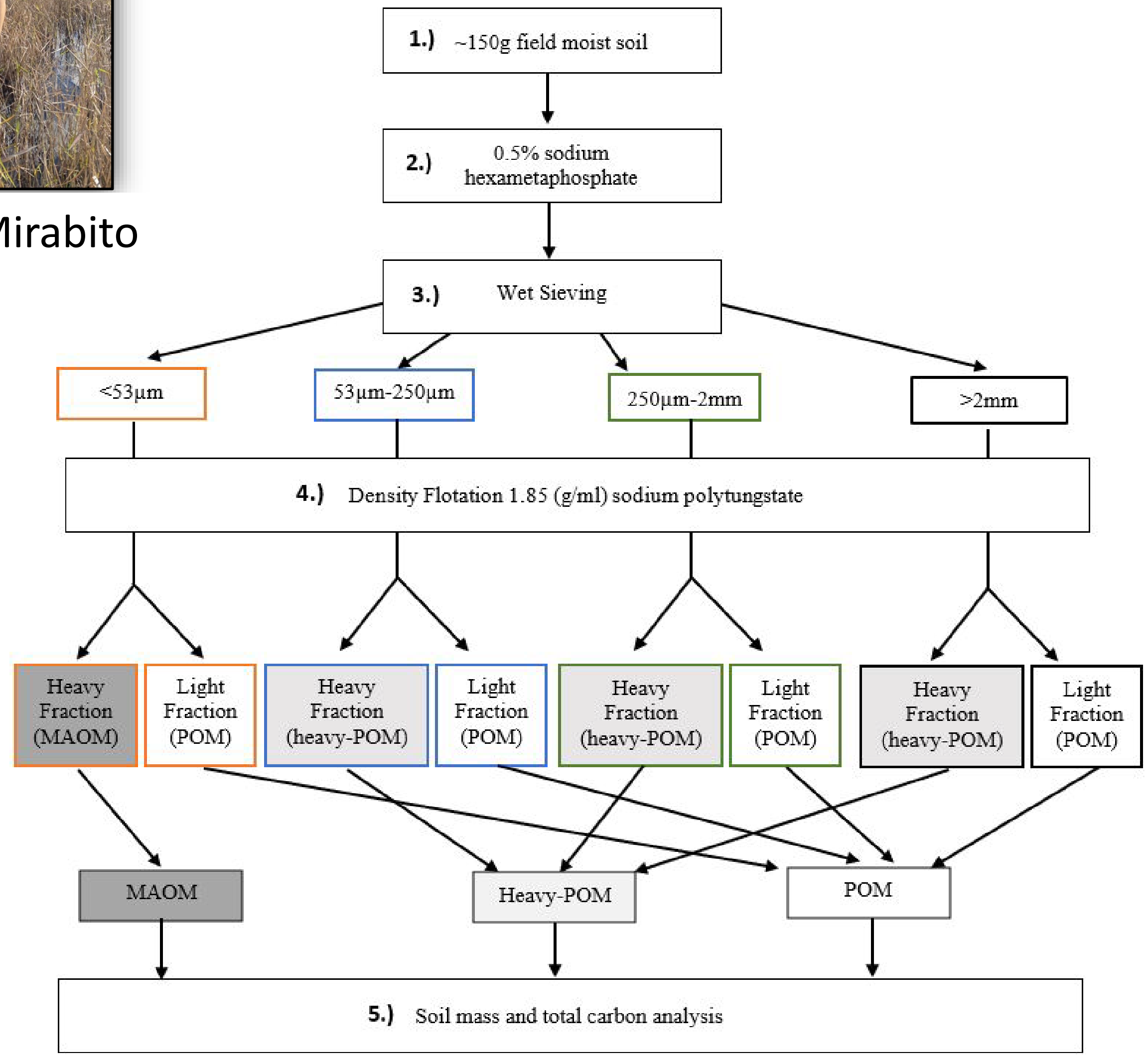


Fig. 4. Physical and density soil fractionation method adapted from Six et al., 1998 and Cotrufo et al., 2015 (Mirabito and Chambers, in prep).

Disperse and wet sieve into 4 size fraction

Density fractionate

Dry, weigh and analyze for total C and N

(Mirabito and Chambers, 2023)

How much MAOM is in wetland soils?

- Florida Inland Bayhead Swamp
- 85% soil organic matter
- Low mineral content

"High Organic"

- Florida Inland Cypress Dome
- 13% soil organic matter
- High sand content

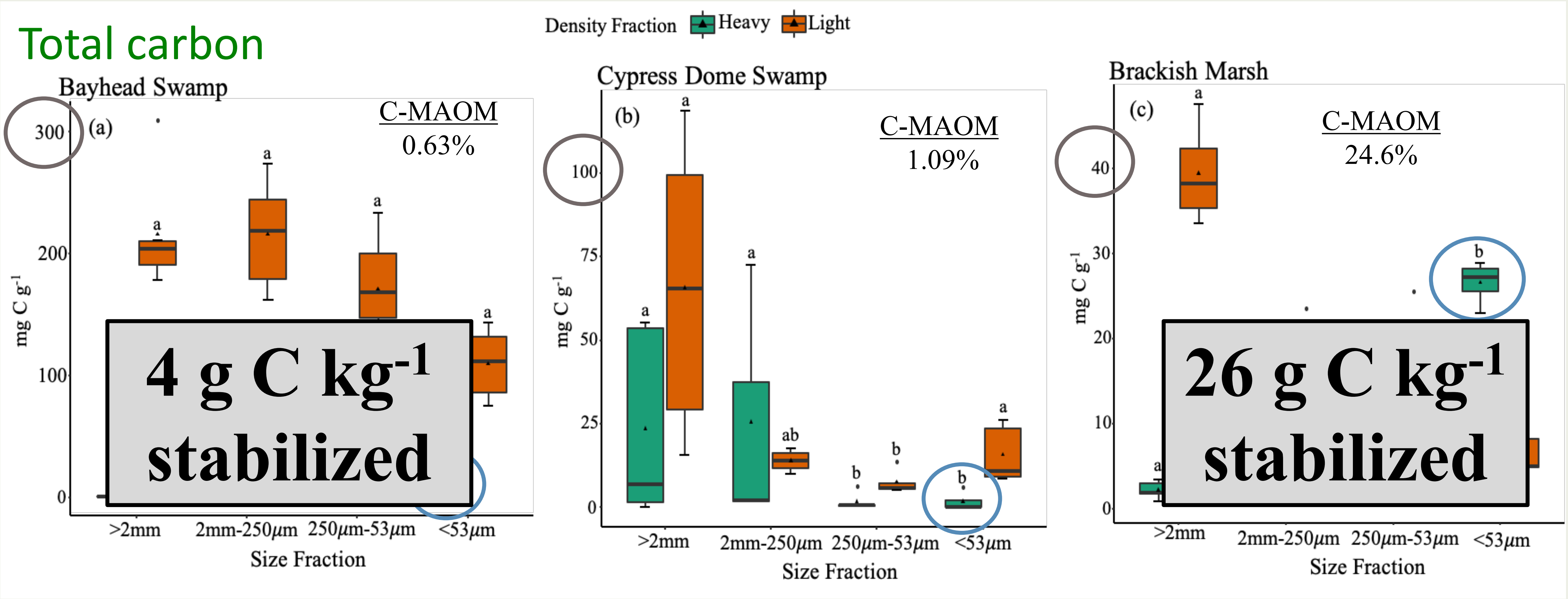
" High Sand"

- Coastal Louisiana Salt Marsh
- 20% soil organic matter
- High silt & clay content

" High Silt"

(Mirabito and Chambers, 2023)

Total carbon is inversely related to 'stable' carbon

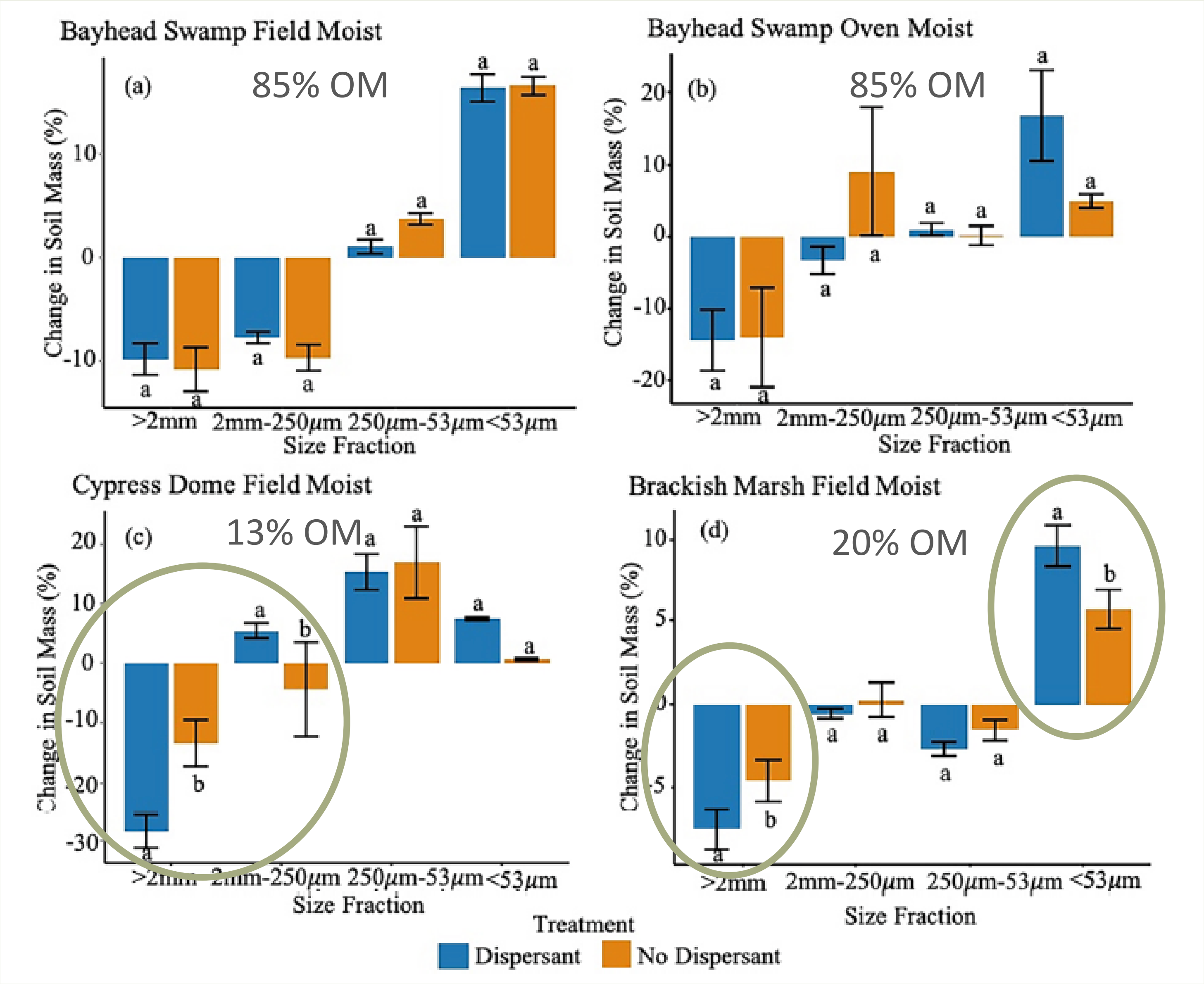


High Organic **High Sand** **High Silt**

(Mirabito and Chambers, 2023)

Aggregates can exist in wetlands, if minerals are present

- Method implications:
  - Dispersant needed
  - Fractionate field-wet to prevent artificial aggregate formation



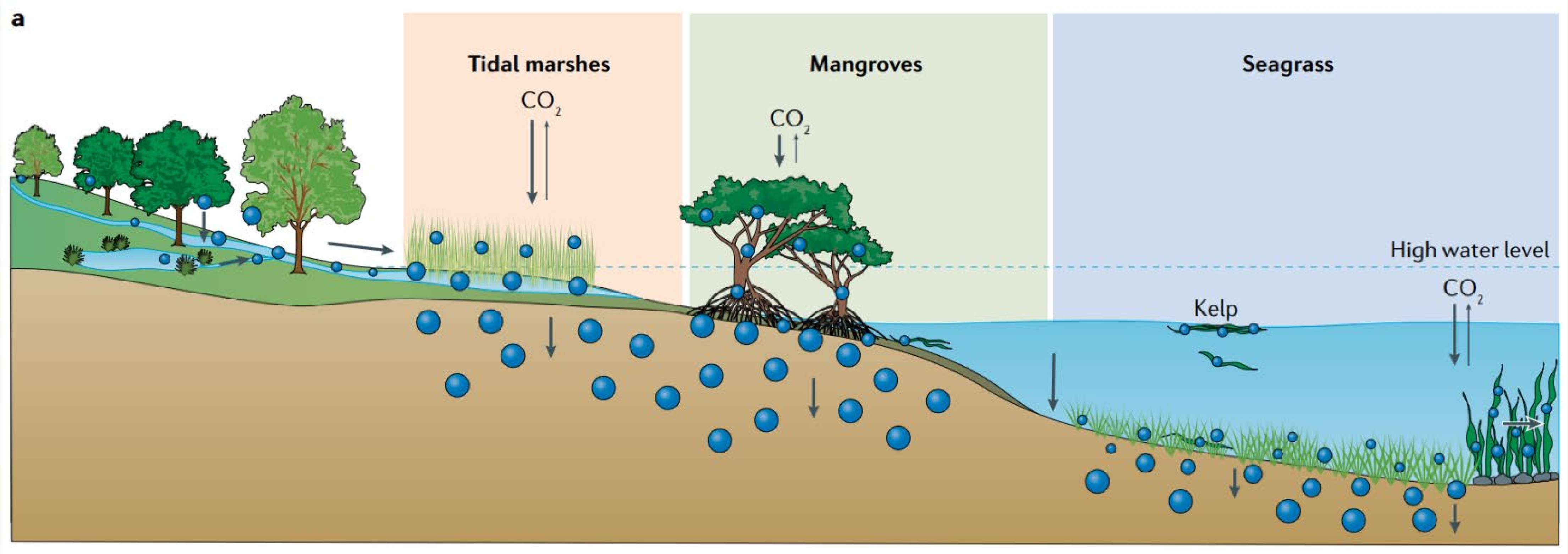
(Mirabito and Chambers, 2023)

Research Applications in Soil Carbon Stability:

1) Quantifying by habitat type
2) Maximizing C stability
3) Minimizing C stability
4) Documenting environmental change

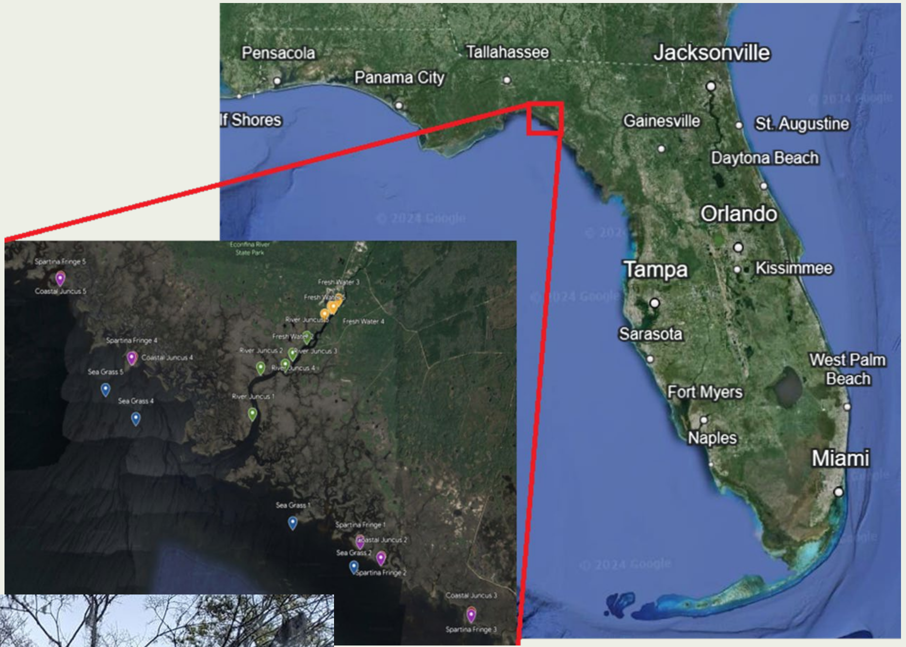


What does *stability* mean for "Blue Carbon"?



Blue Carbon: The carbon captured by living coastal and marine organisms and stored in coastal ecosystems, including salt marshes, mangroves, and seagrass beds.

Quantifying "Blue Carbon" habitats by stability



UCF | **College of Sciences**

Seed Grant (2023)

Collaborator: Melanie Beazley

Econfina River Field Station


Coastal Juncus
Coastal Spartina

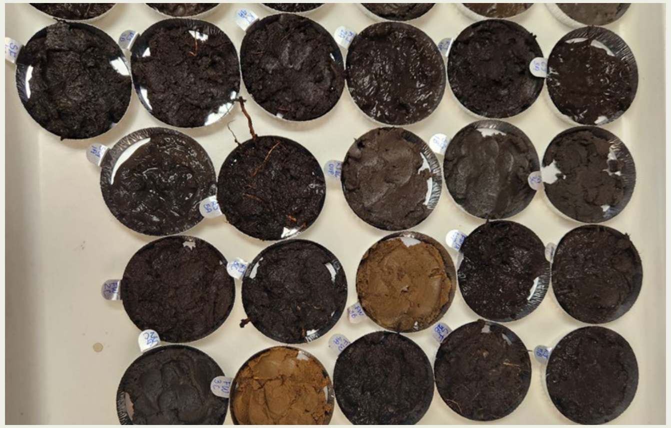

Seagrass Bed


Riverine Juncus


NELSON
10
Freshwater Tidal

Field Methods

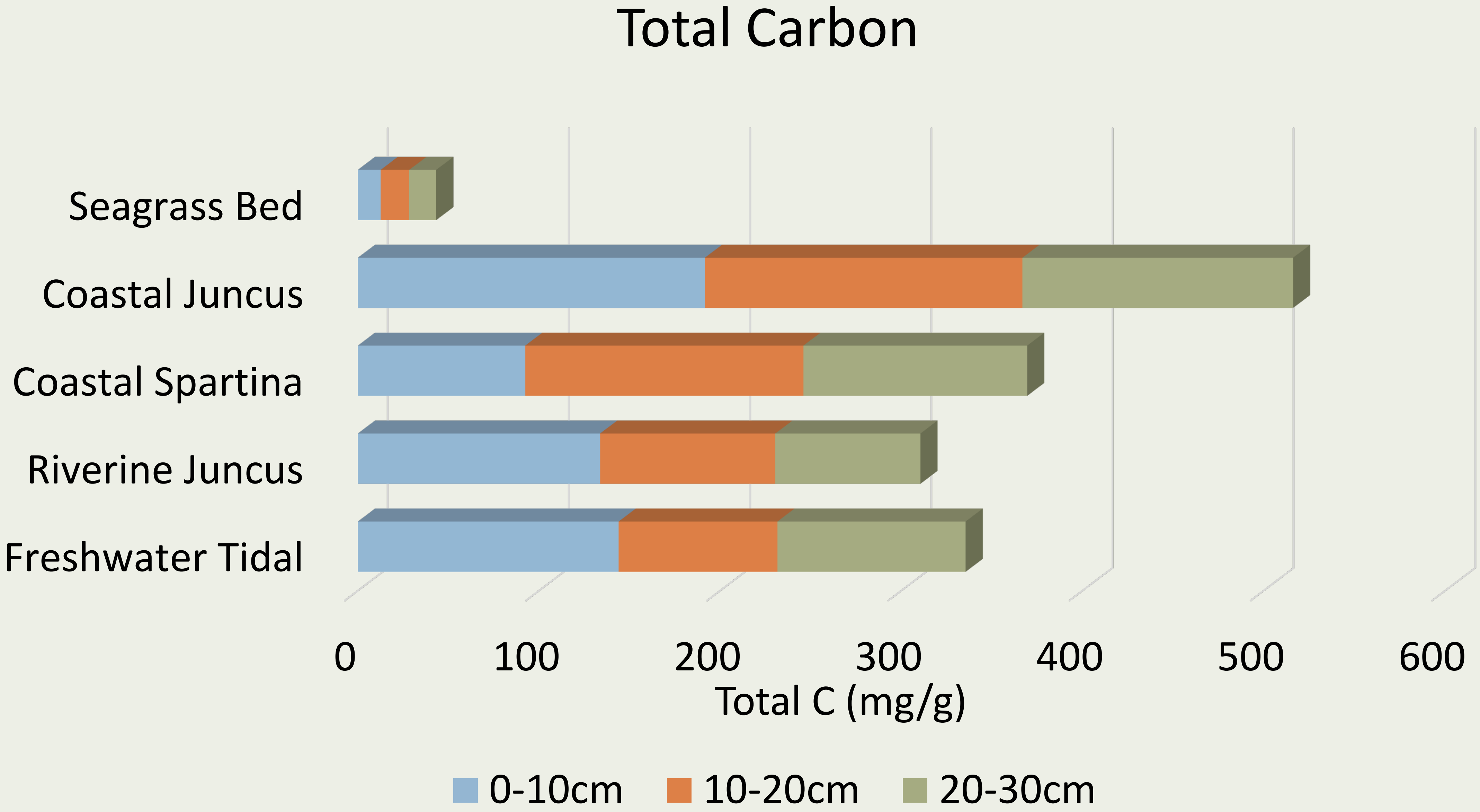
Five 0-30 cm soil cores from each of the 5 coastal habitats



Lab Methods

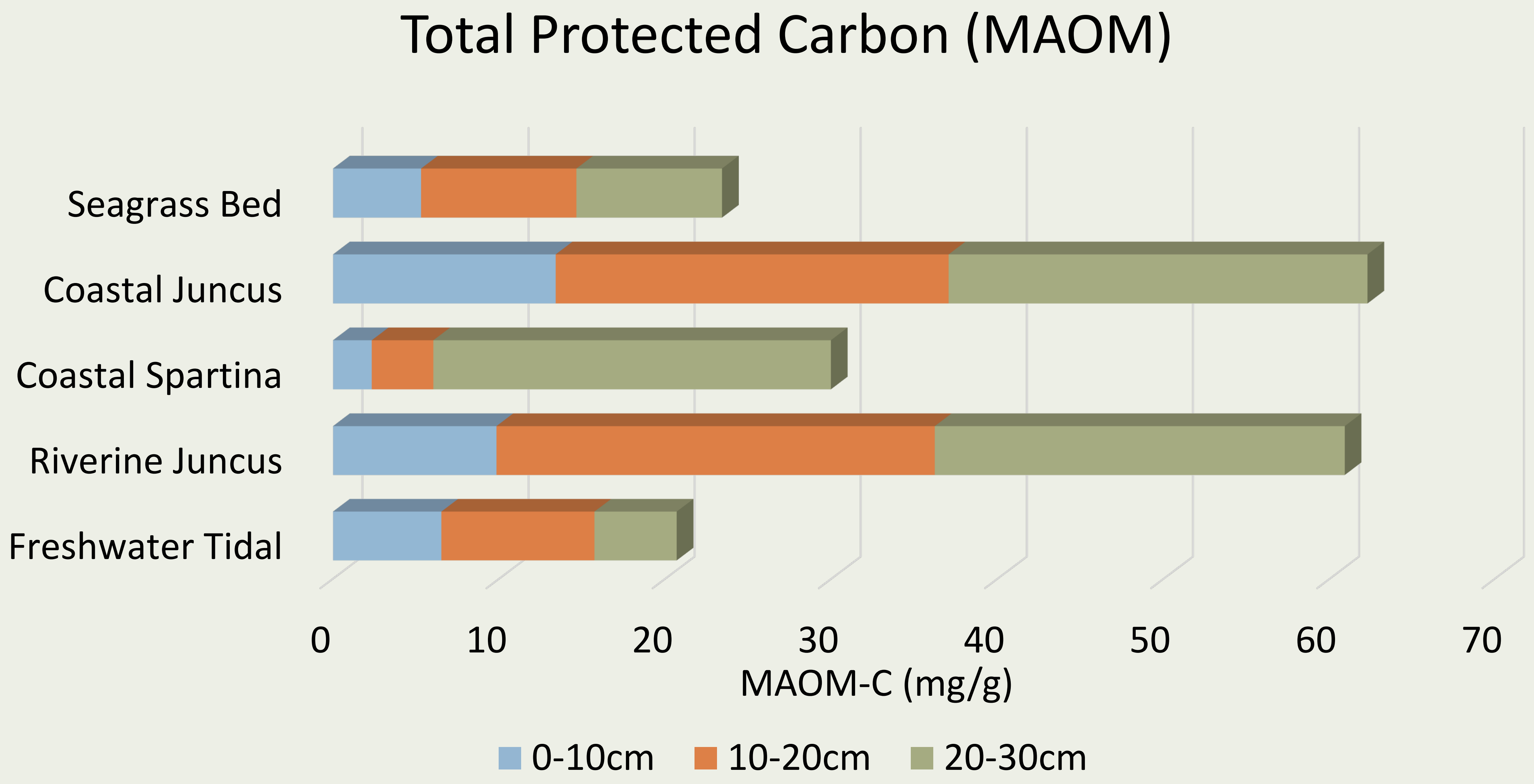
- **C quantity**: %OM and total C analysis
- **C stability**: physical and density fractionation into POM and MAOM
- General physicochemical soil properties
- Total and organic-bound metals (ICP-MS)

Results



(Chambers et al., in prep.)

Results



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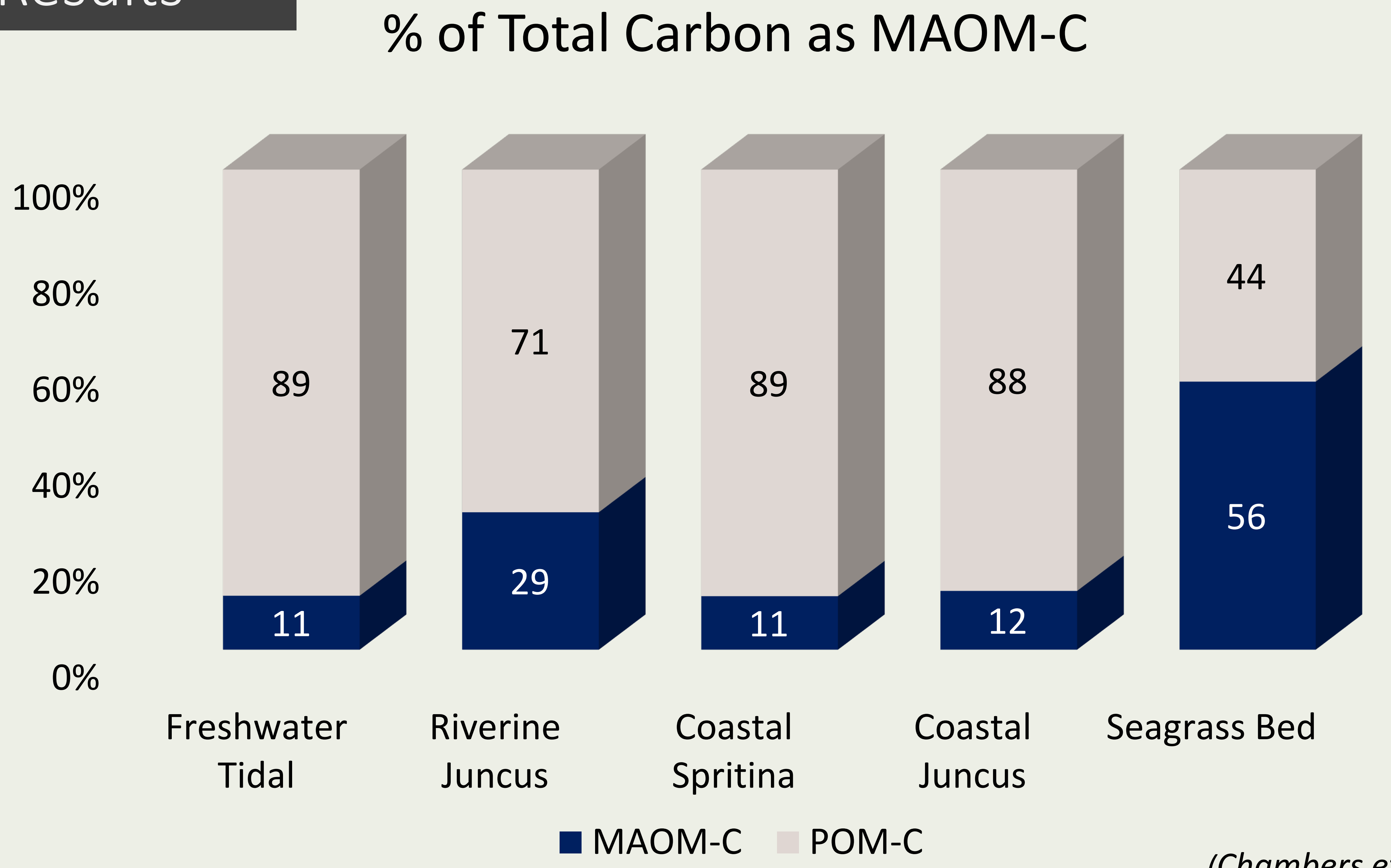
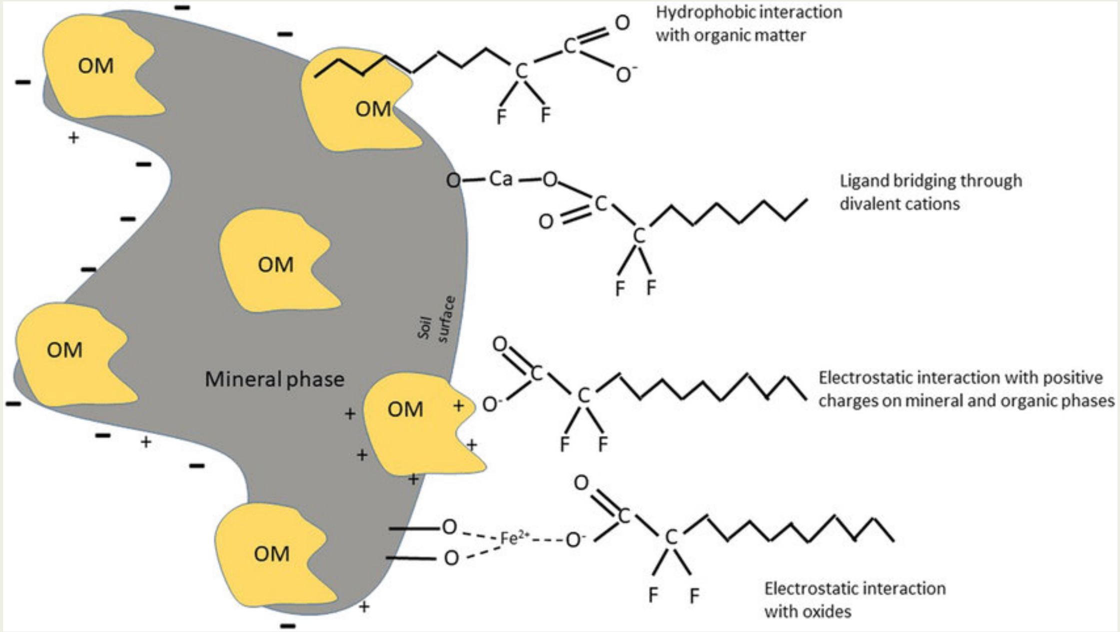
Results



(Chambers et al., in prep.)

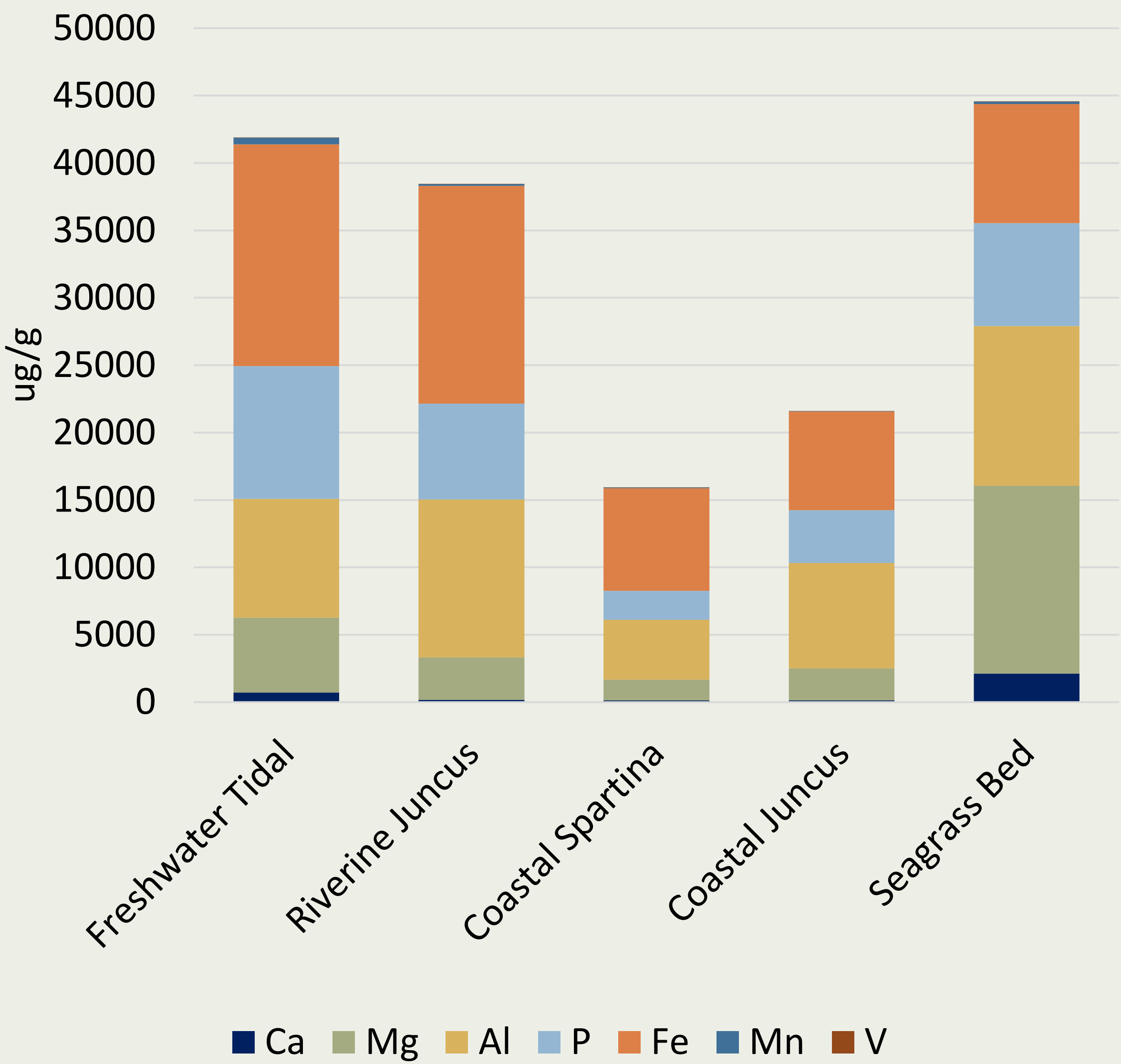
Results

- Understanding metal and mineral composition is the next step



(Li et al., 2018)

MAOM fraction: Average Total Metal (preliminary)



Coastal Restoration to Maximize C stability

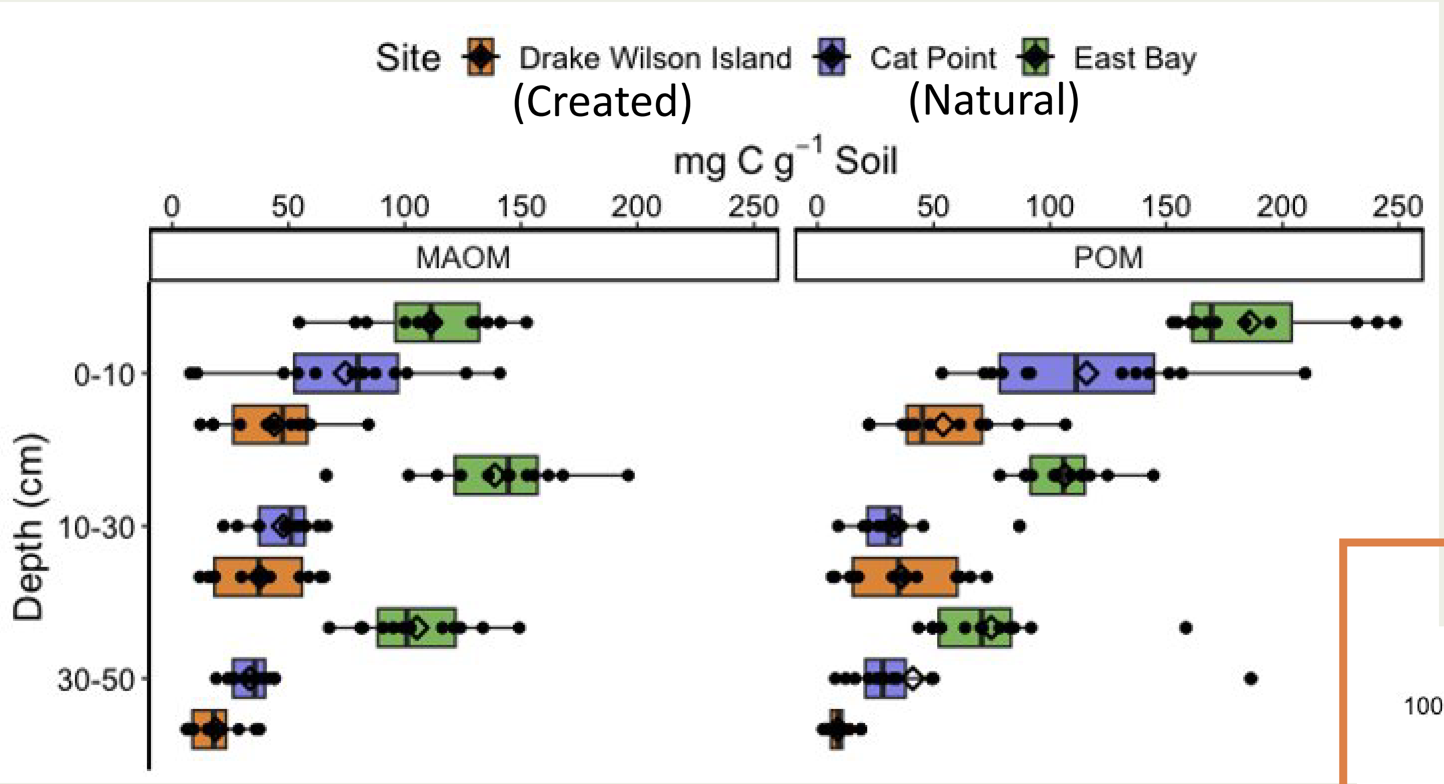
If minerals are limiting, could dredge sediment enhance carbon stability?

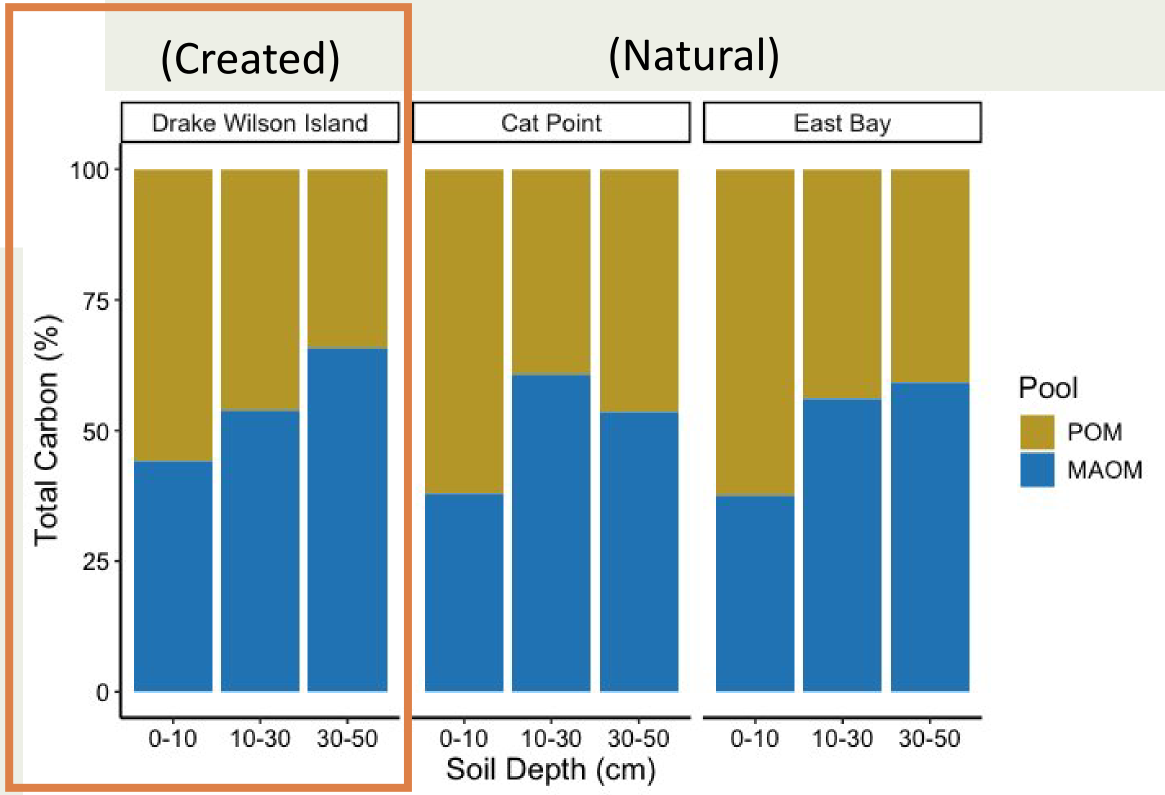
Engineering With Nature ®

Collaborators: Nia Hurst and Jacob Berkowitz

Apalachicola, FL

- Young, created wetlands have less total carbon.

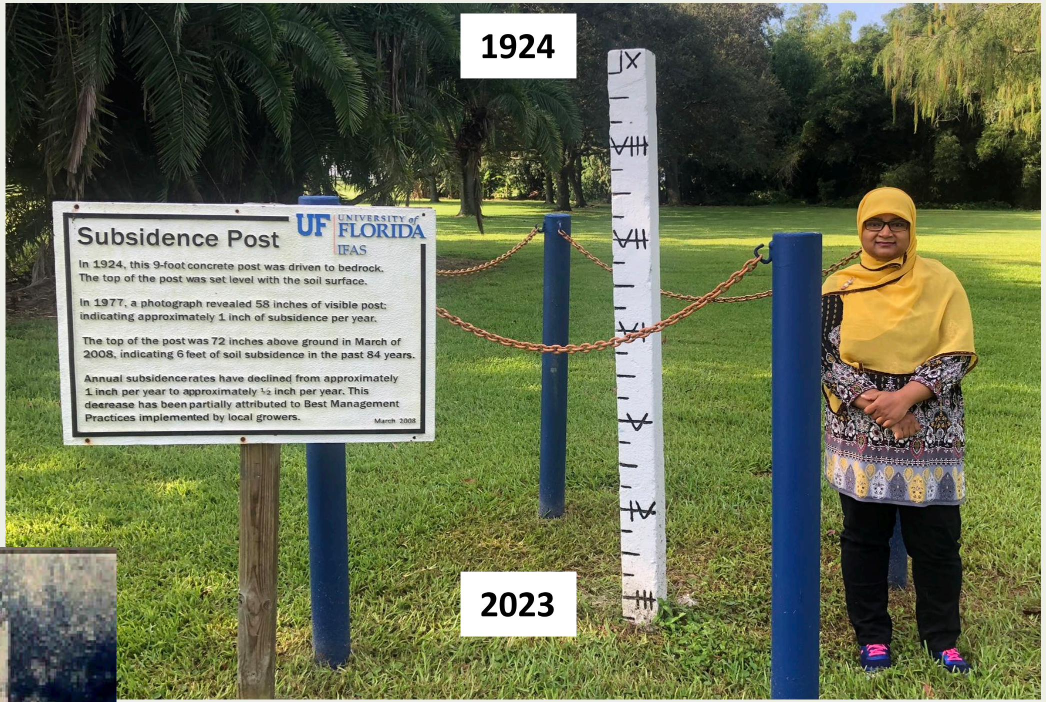


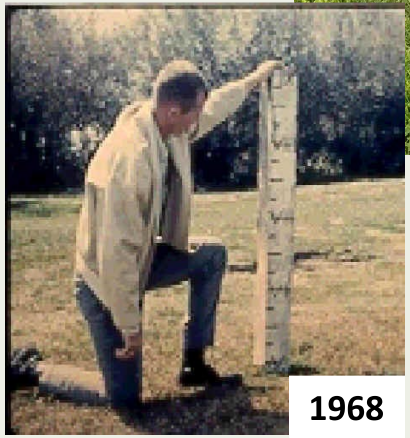


- But, as a larger percent of that carbon is stable (MAOM) in the dredge-created site, compared to the natural reference sites.

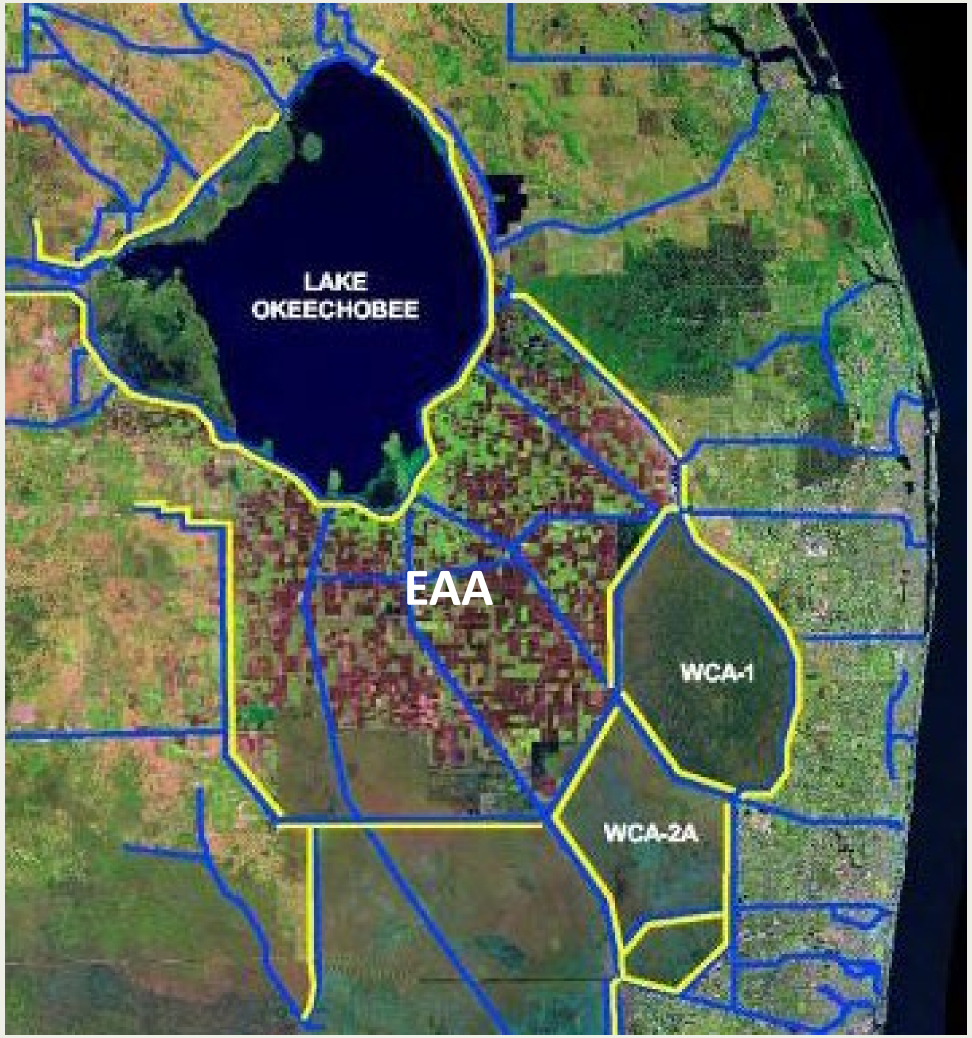
(Mirabito et al., in review)

Maximizing carbon stability in vulnerable soils: the Everglades Agricultural Area (EAA)

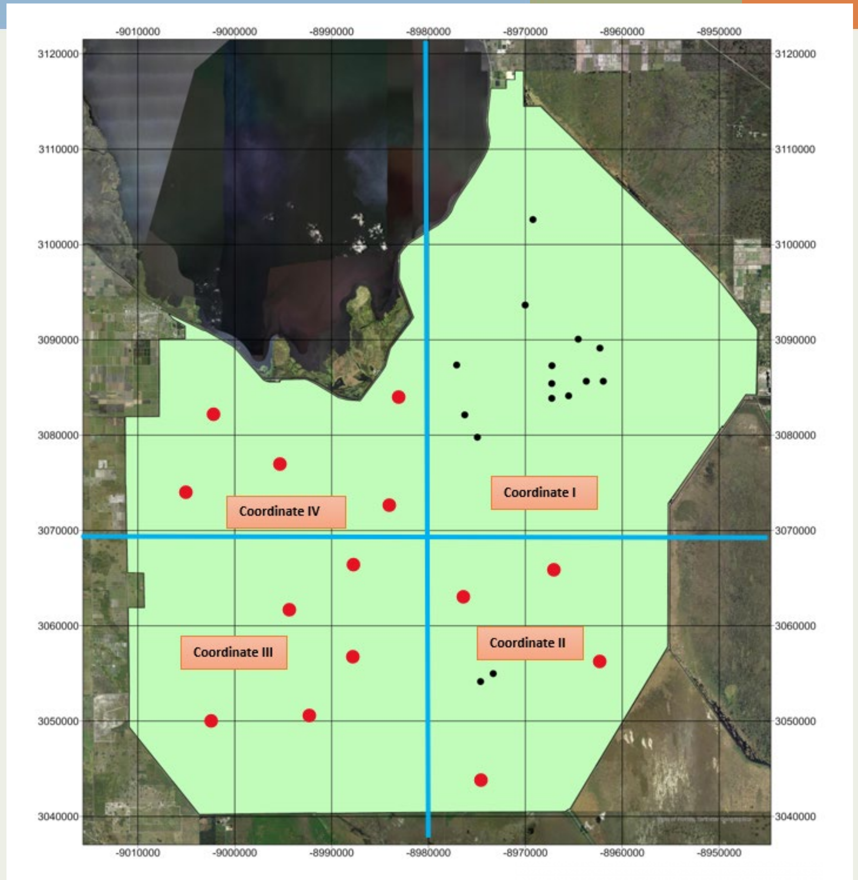




Mumtahina Riza



Can fine silt/clay addition slow oxidation in cultivated histosols?



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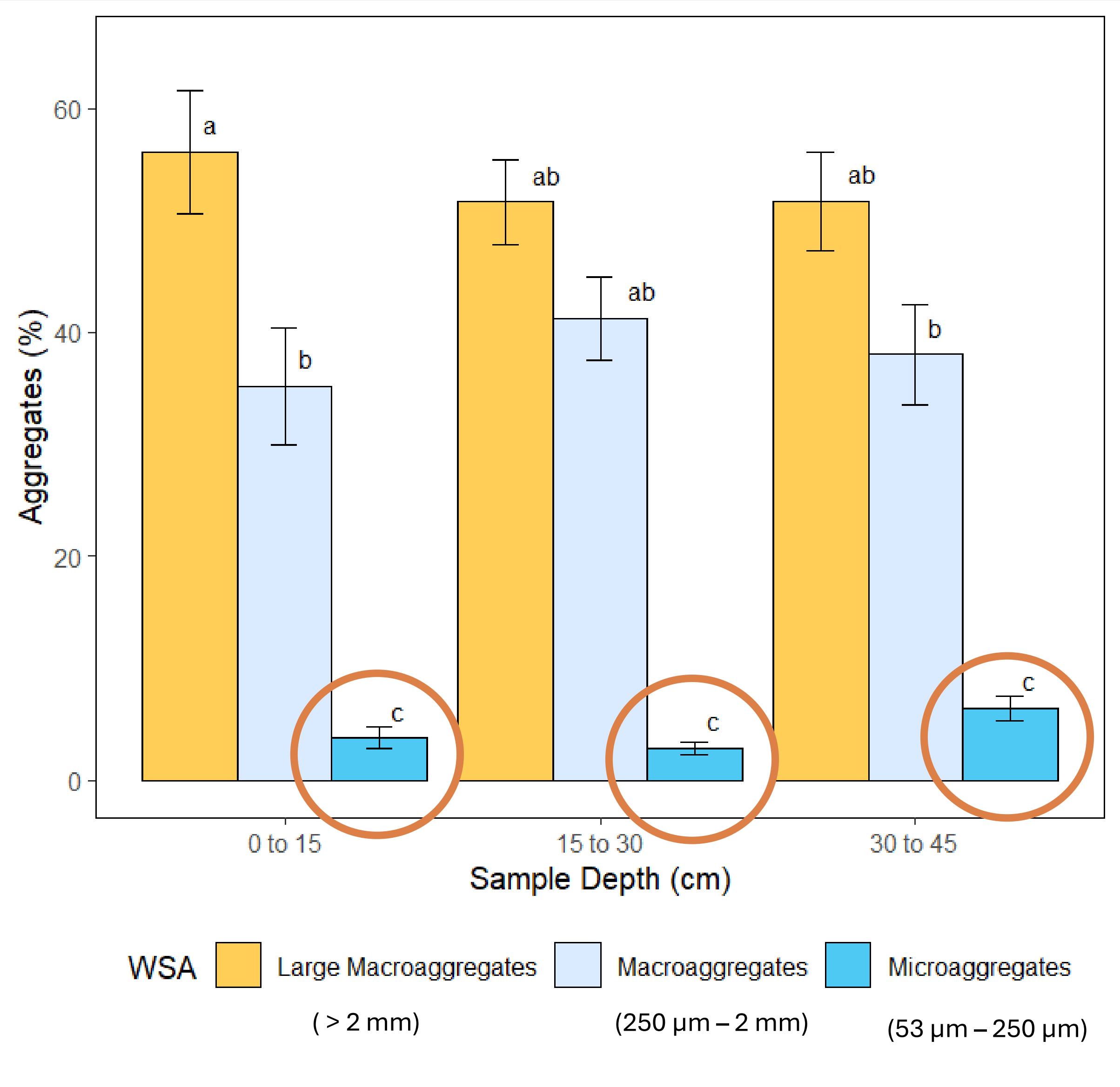
USDA National Institute of Food and Agriculture

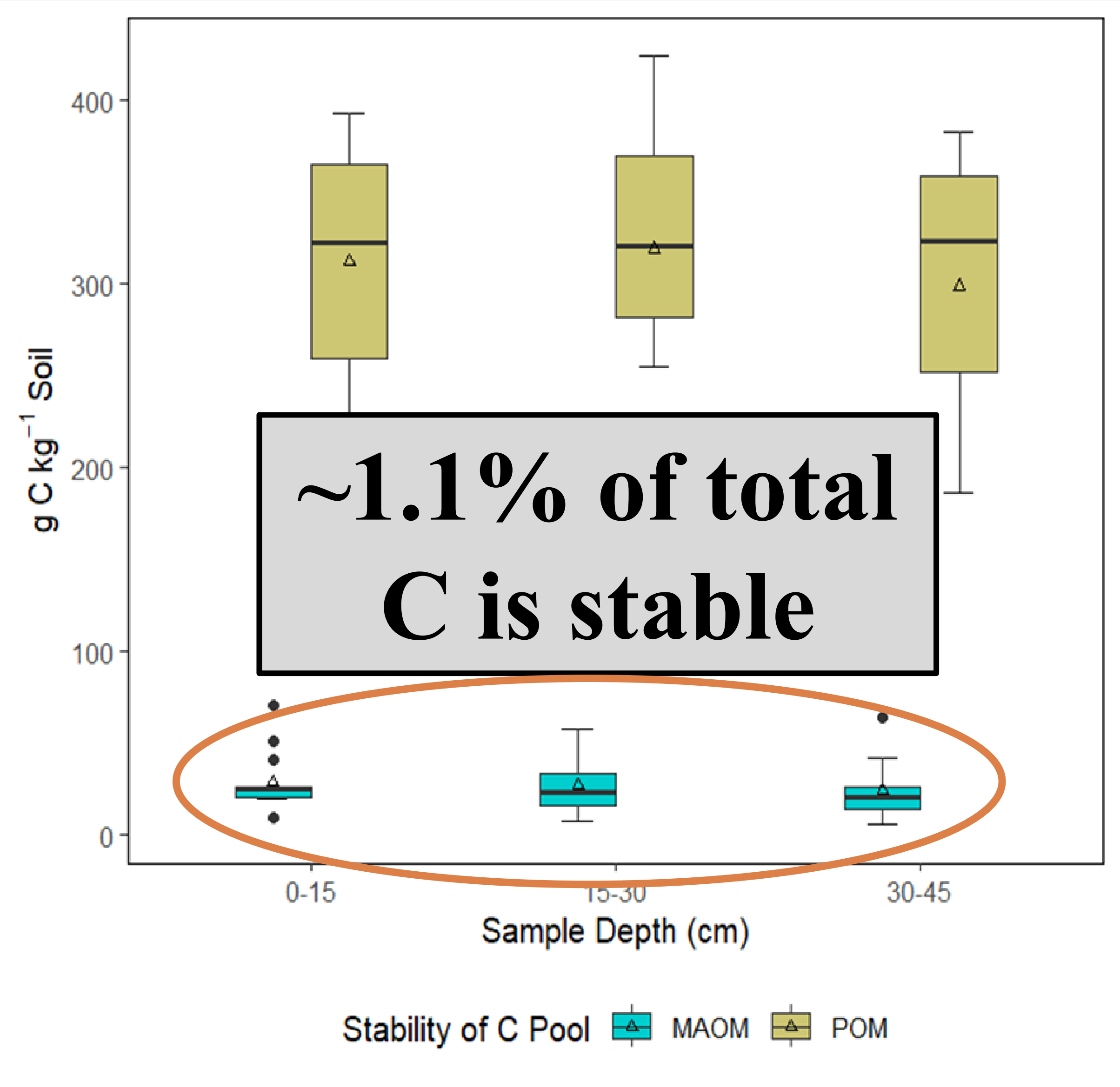
UNITED STATES DEPARTMENT OF AGRICULTURE

Collaborators: Jango Bhadha and Jing Hu

Aggregates



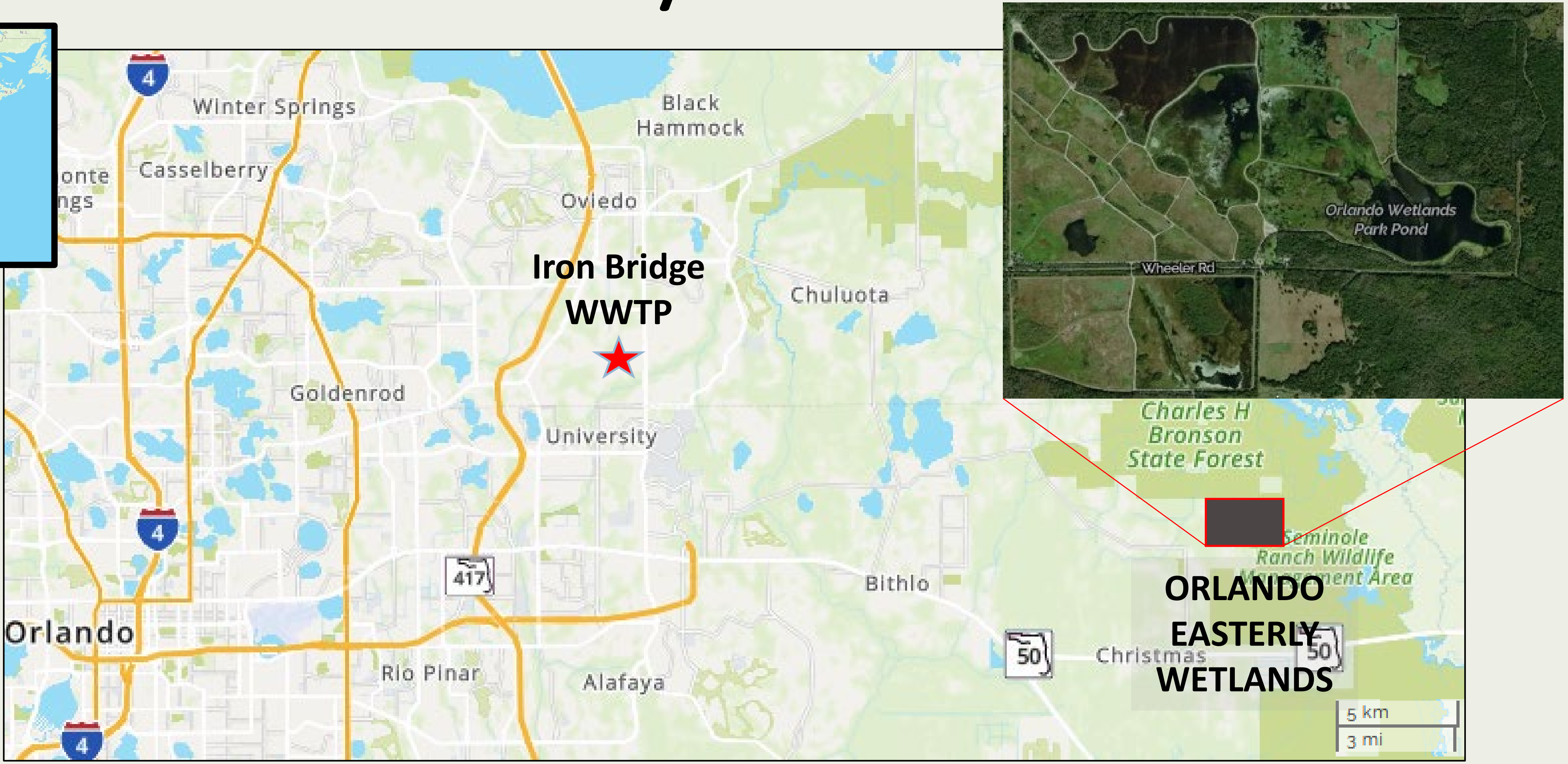
MAOM



Thursday 10:30-10:50am

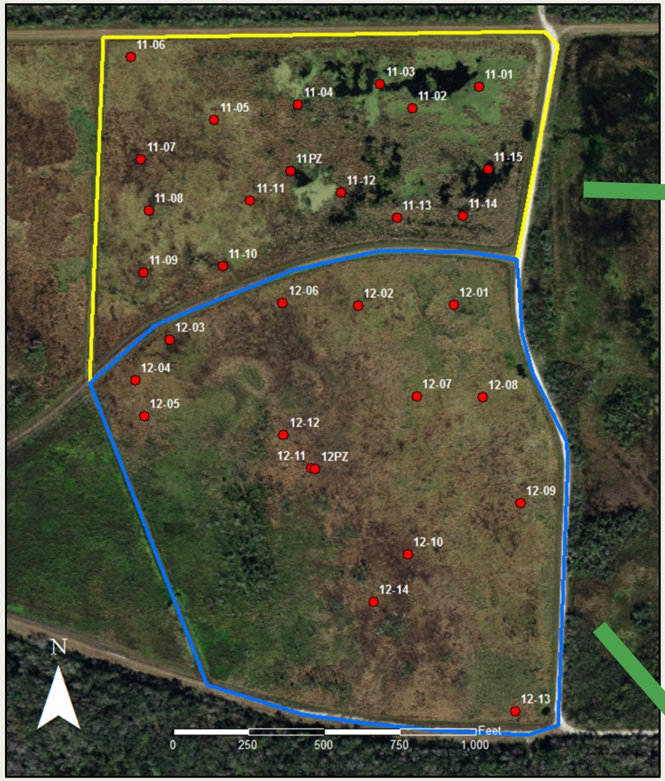
Mumtahina Riza, *How to Increase Mineral-Associated Organic Matter Formation in Organic Rich Soils*

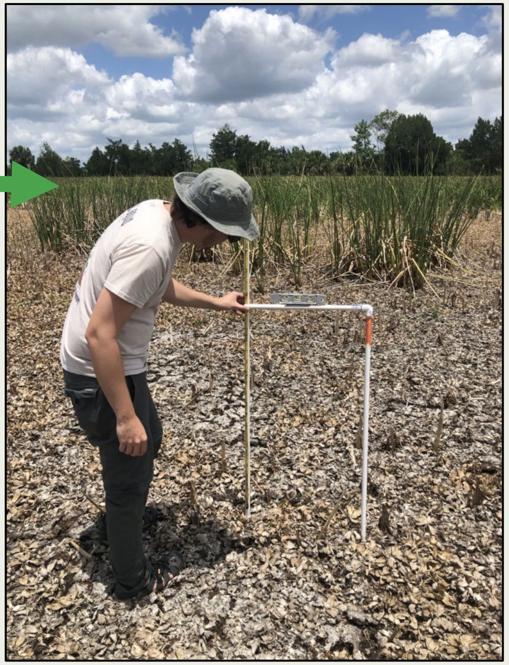
Using management to minimize C stability: Orlando Easterly Wetlands

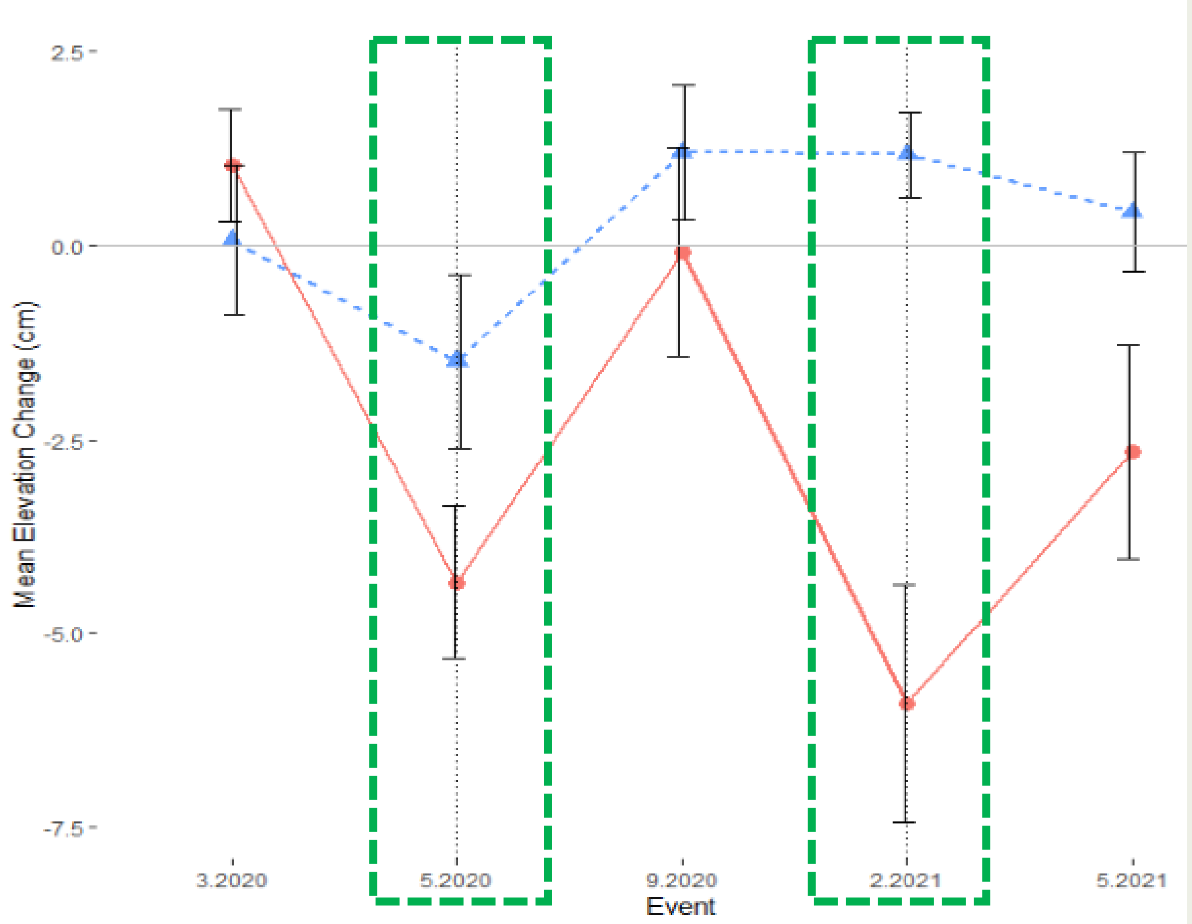


Paul Boudreau

Wetland renovation (“demucking”)



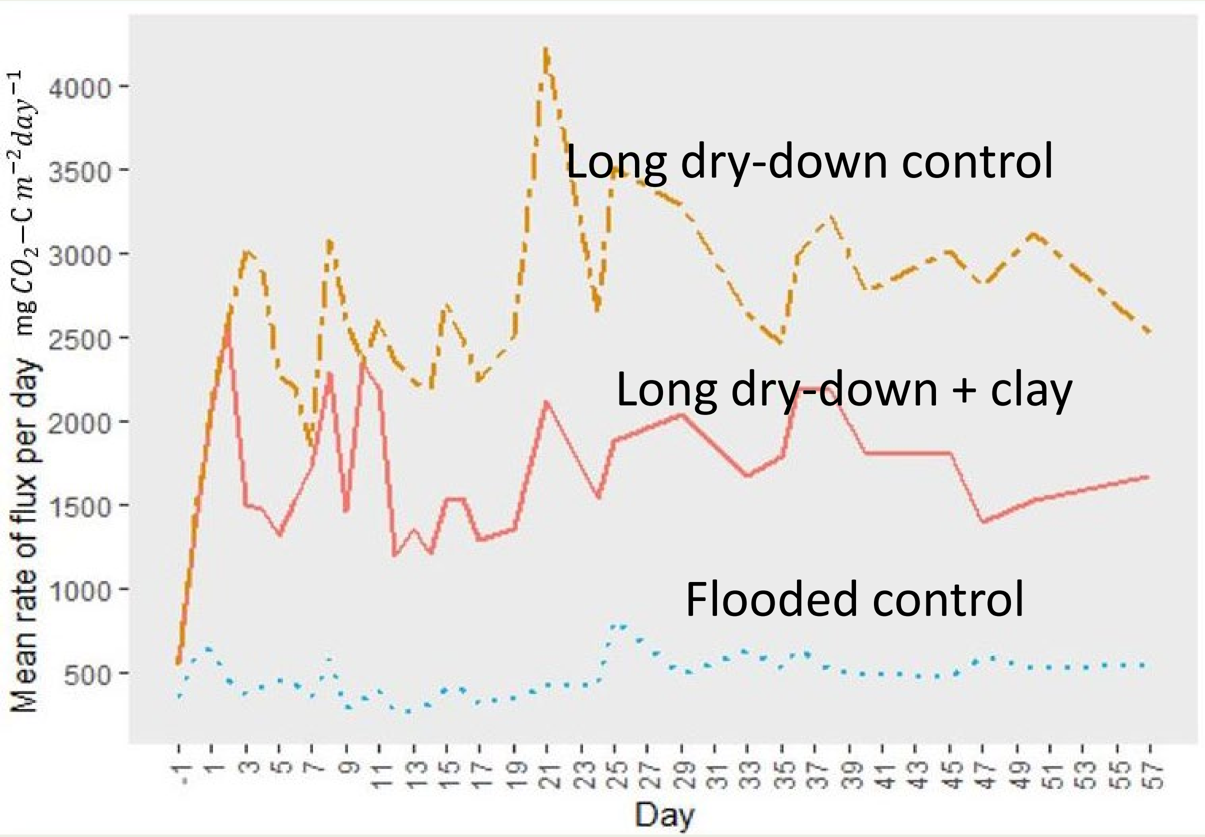




Can temporary water level draw-down remove the excess organic matter?

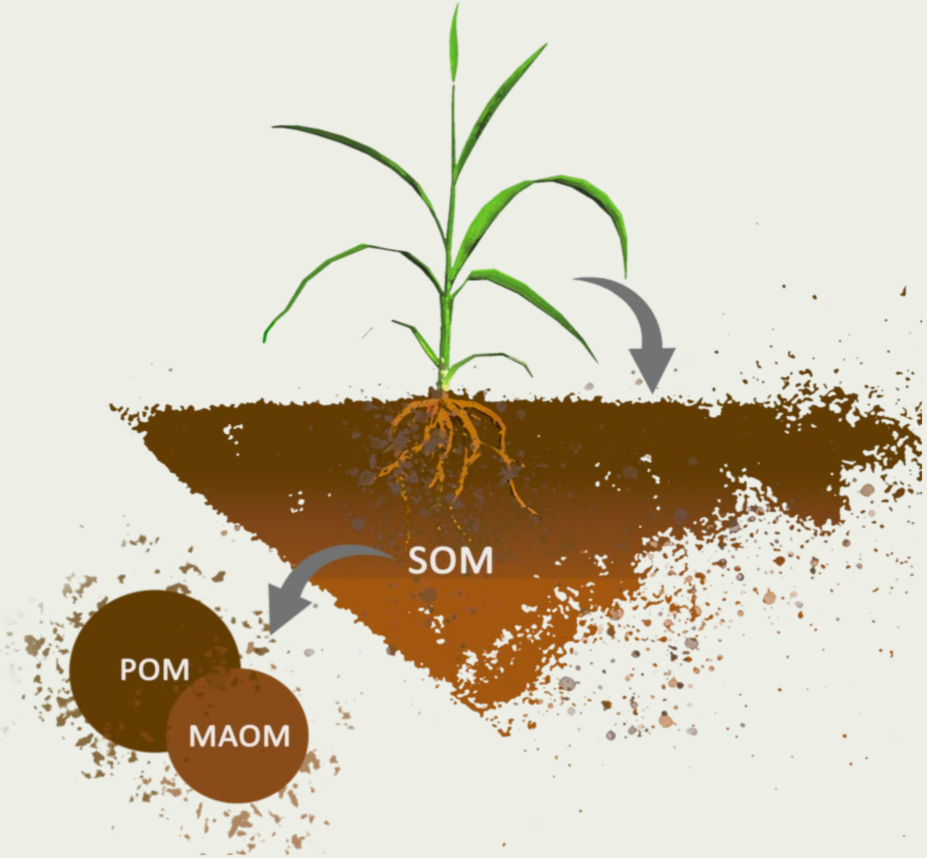
CITY OF ORLANDO℠

20g clay decreased CO_2 flux by 30%, and increased MAOM content by 50%



(Boudreau et al., 2024)

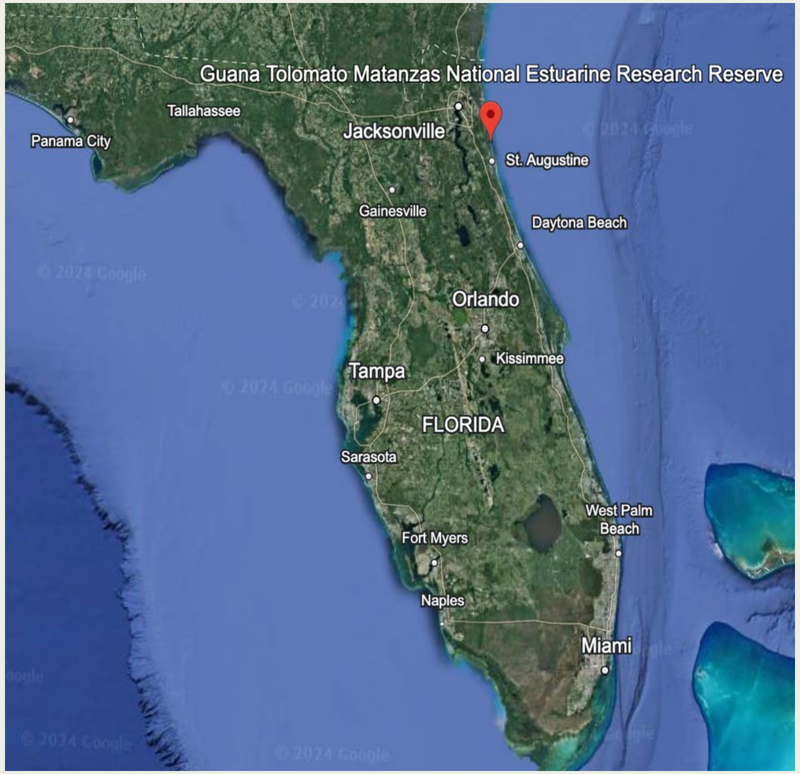
Documenting impacts of mangrove encroachment + nitrogen enrichment carbon stability



Mercedes Pinzon

Collaborators: Samatha Chapman and Adam Langley

What are the dominate pathways of MAOM formation in marsh and mangrove?



Thursday 9:50-10:10am

Mercedes Pinzon-Delgado, *Tracing Nitrogen Pathways in Coastal Wetlands: The Role of MAOM in a Changing Landscape*

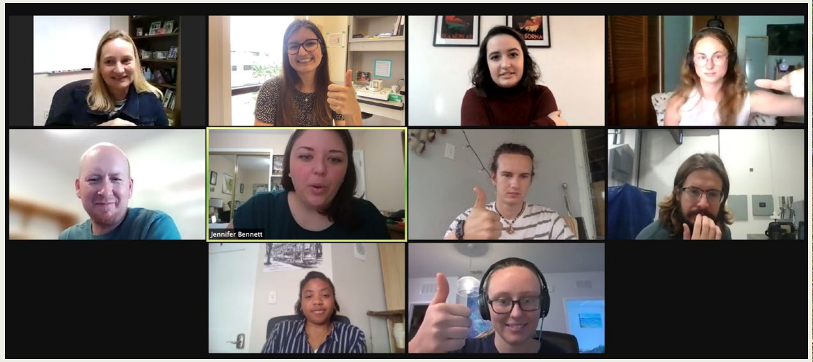
Key Findings

- Wetlands with the most soil C, typically have the least amount of stable C (as MAOM)
- Texture (presence of silt & clay) and metal composition play a key role in MAOM formation
- MAOM can decrease CO_2 loss
- Aggregates can also be present in wetlands with minerals
- Future work should measure both total C and C stability to understand vulnerability of the soil C pool

On a dynamic planet, we must consider not just soil carbon quantity, but also *stability*.

Thank you!

Lisa.Chambers@ucf.edu



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