COLLABORATIVE SCIENCE CONVERSATIONS

WEBINAR SERIES

A Collaborative Approach to Advancing Blue Carbon Research and Data

(Part 1: **Filling Blue Carbon Data Gaps**)

Date: Thursday, February 29, 2024
Time: 2:00pm-3:00 pm EST

Chris Janousek
Oregon State University

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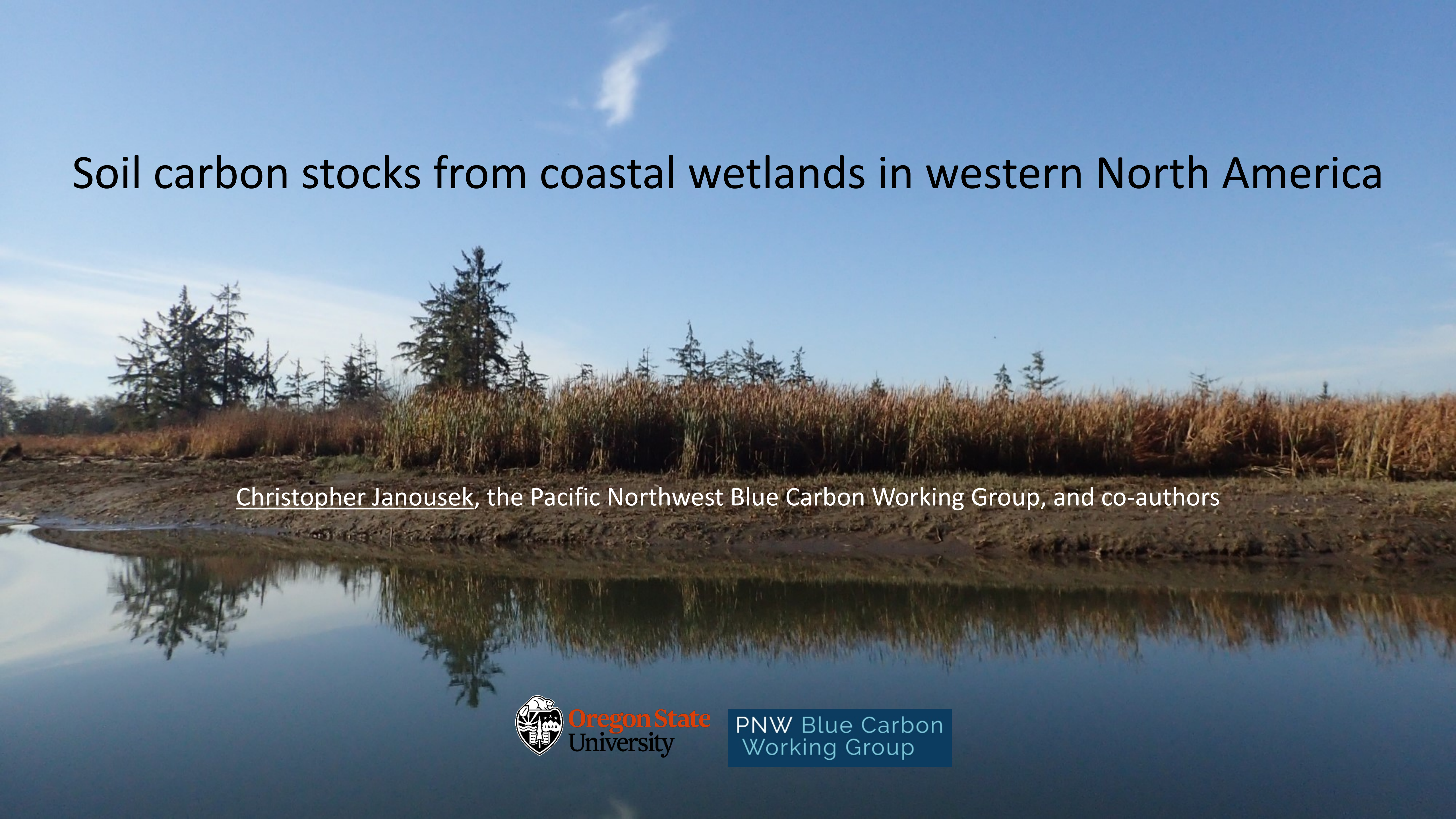
Oregon State University

Katrina Poppe
Western Washington University

Scott Bridgham
University of Oregon

National Estuarine
Research Reserve System
Science Collaborative

Soil carbon stocks from coastal wetlands in western North America



Christopher Janousek, the Pacific Northwest Blue Carbon Working Group, and co-authors

Oregon State University

PNW Blue Carbon Working Group

Blue carbon

- Blue carbon is one of many valued coastal ecosystem services
- Four dimensions to coastal blue carbon:
  - Quantifying (and conserving) existing blue carbon stocks
  - Measuring (and enhancing) coastal sequestration
  - Measuring (and reducing) GHG emissions such as methane
  - Determining lateral fluxes of carbon between ecosystems



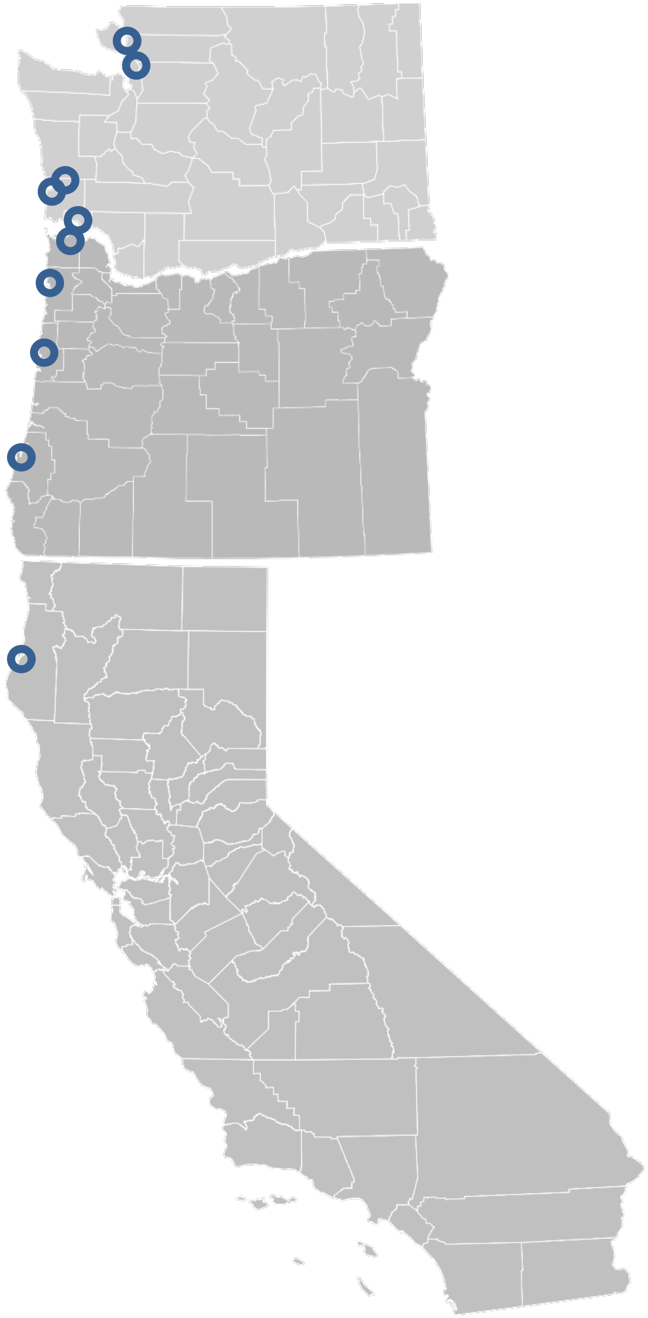

PNW Stocks project and database

- "Phase 1 project" (2016-2019)

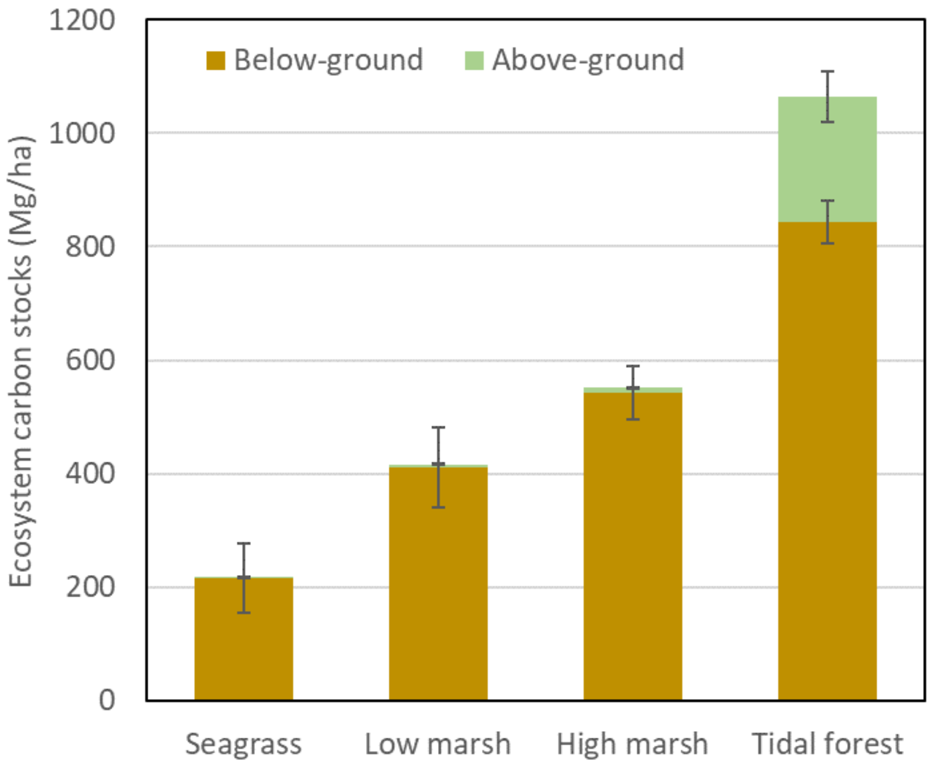
1. How do stocks differ between blue carbon ecosystem types?

2. How do stocks vary with environmental drivers?

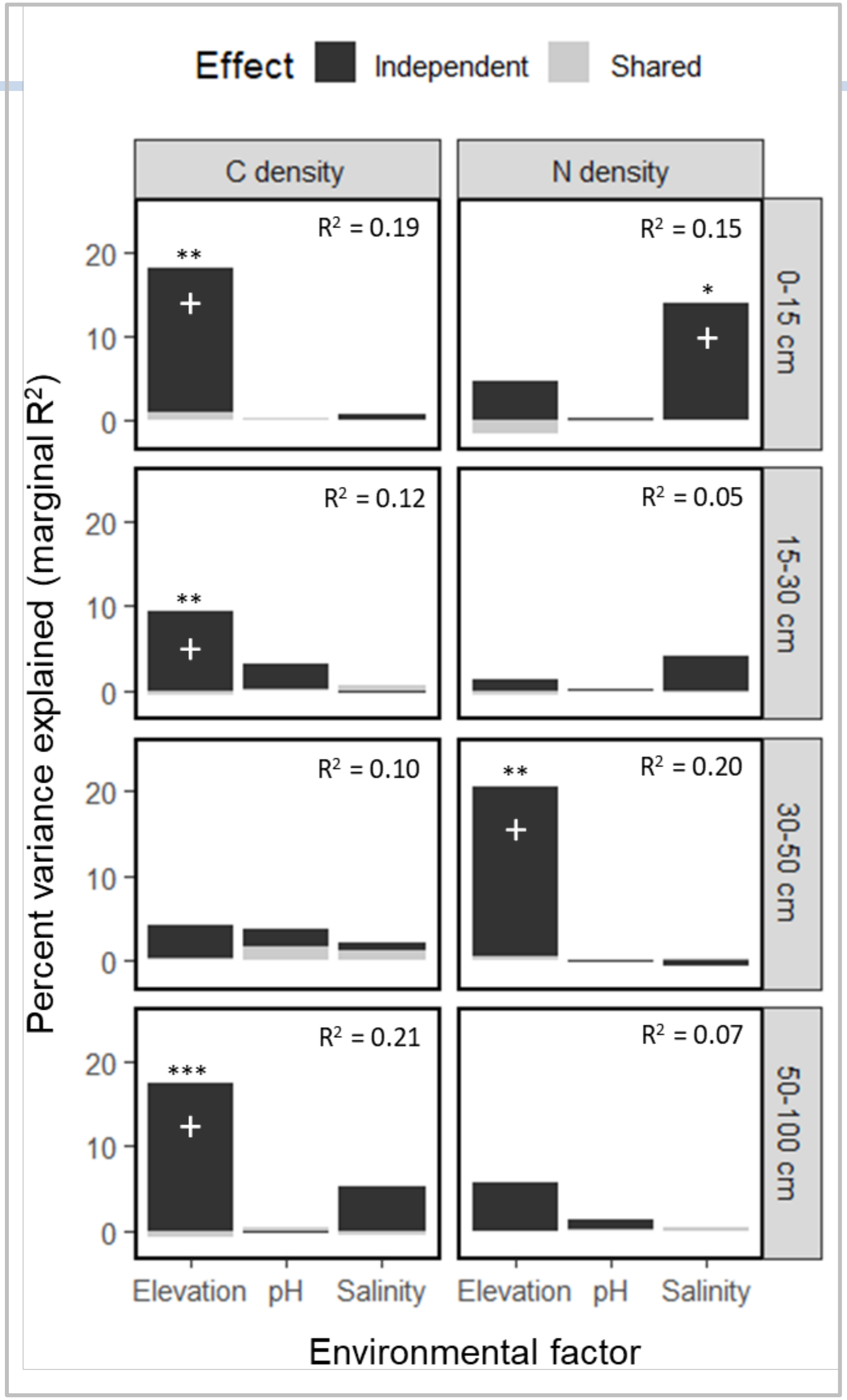
- 34 sites
- 6 plots per site
- Soil core (to 3 m depth) + AG and BG living and dead biomass



PNW Stocks project - results

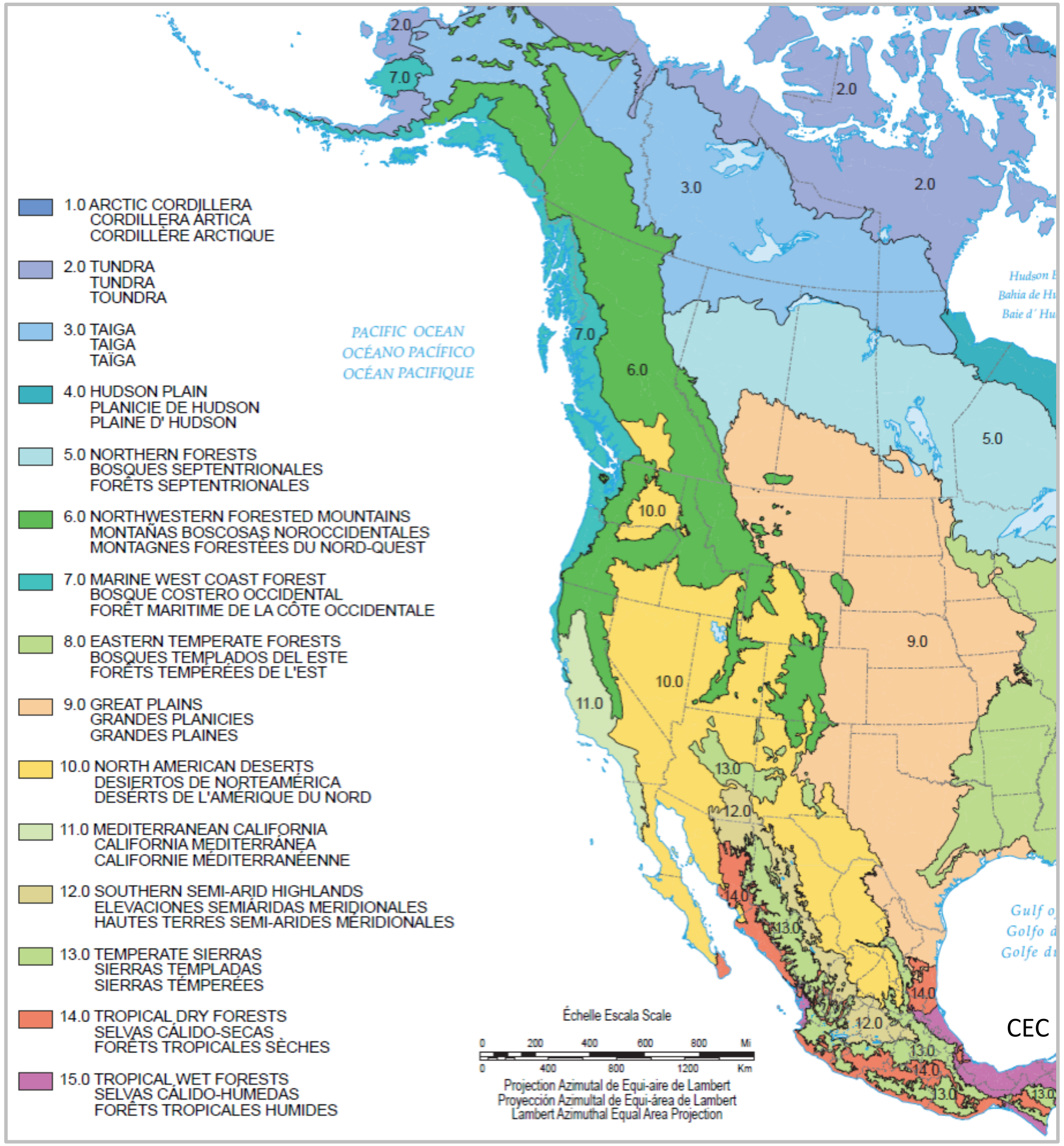


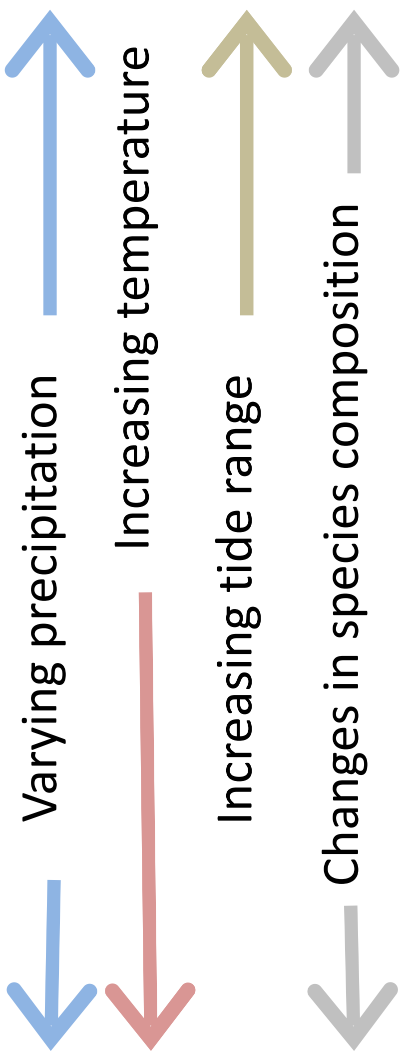
- Increasing C stocks along an elevation gradient
- Majority of ecosystem carbon is in the soils
- Elevation generally more important driver than salinity or pH



Northeast Pacific blue carbon database

- Established ~2018 and expanded from the PNW to all of western North America
- A “living” database that presently focuses mainly on soil C and N stocks





Conduct a synthesis of blue carbon stocks in least-disturbed coastal wetlands for the Pacific coast of North America

1. How do stocks differ between blue carbon ecosystem types?

2. How do stocks vary with environmental drivers?

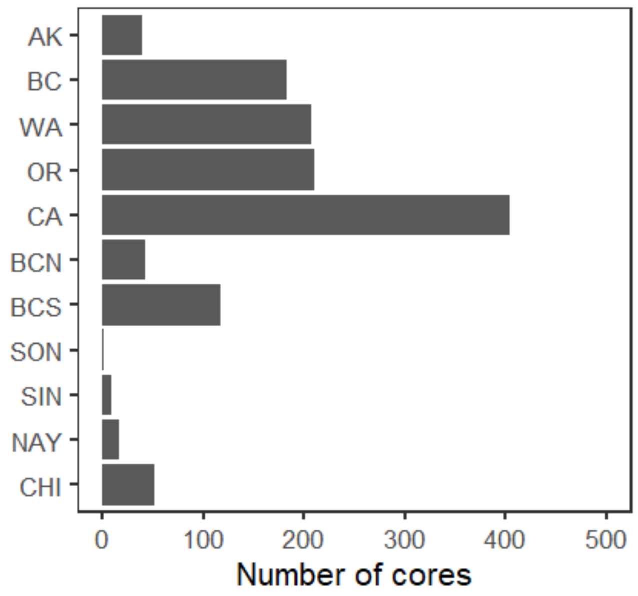
3. At what spatial scale(s) are stocks varying the most?

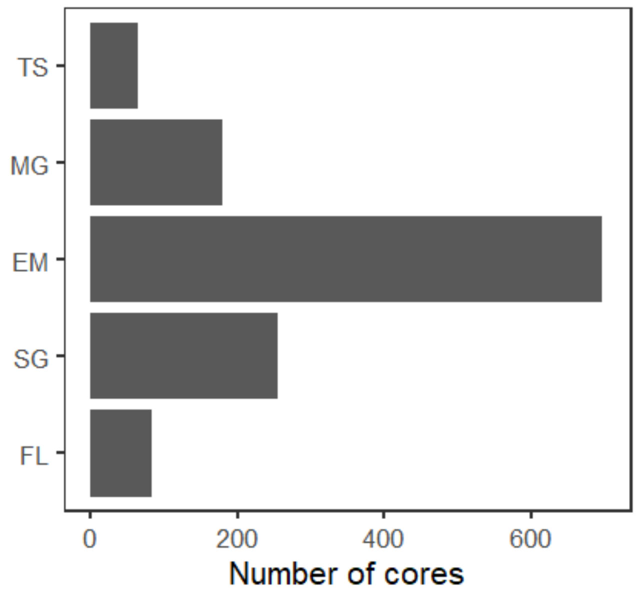
North America's blue carbon ecosystems

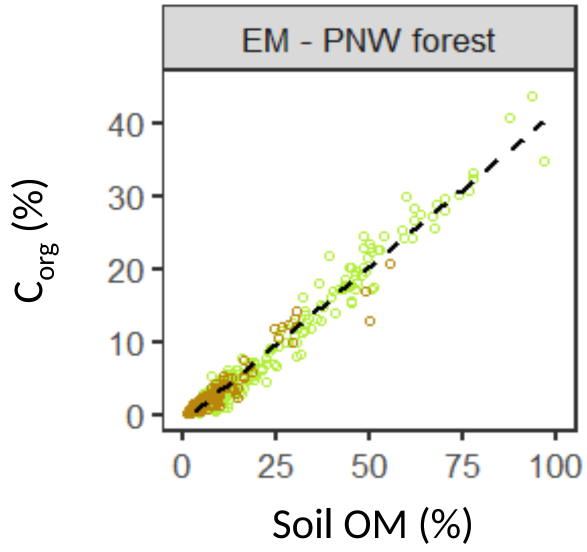
Wetland type	**Tideflats**	**Seagrass**	**Mangrove**	**Tidal marsh**	**Tidal swamps**
Vegetation	Algae	Emergent	Shrubs-trees	Emergent	Shrubs-trees
Elevation	Subtidal to low intertidal	Subtidal to low intertidal	Intertidal	Usually upper intertidal	Upper intertidal
Salinity	Fresh to euhaline	Brackish to euhaline	Euhaline	Fresh to euhaline	Fresh to brackish
Distribution	Throughout N America	Throughout N America	Mexico	Throughout N America	SF Delta to Pacific Northwest

Approach – data synthesis

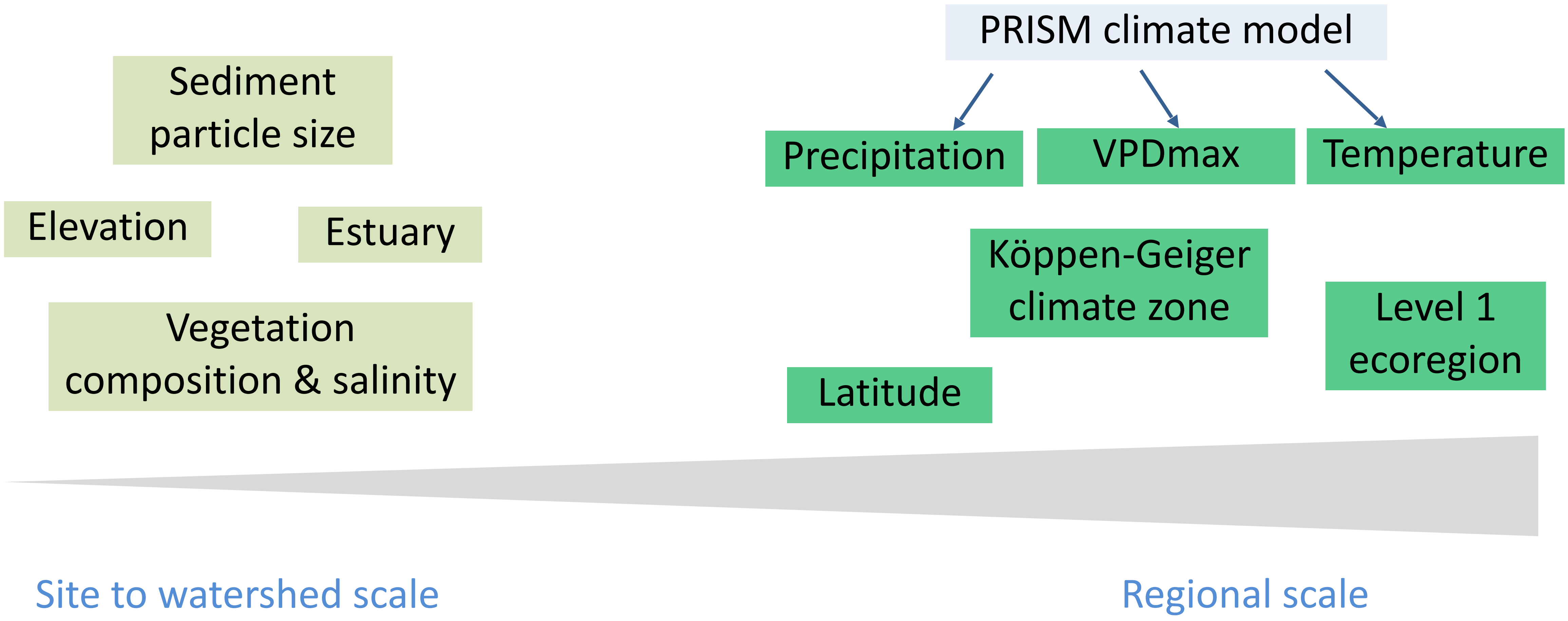
- Compiled data from 71 datasets
- 1282 vertical soil profiles
- >6500 km coastline; 86 estuaries/coastal regions
- Used a standard approach to determine C density from bulk density, %C_{org} and %OM data
- Integrated C density with depth to determine carbon stocks to 30, 50 and 100 cm depths (Mg/ha)



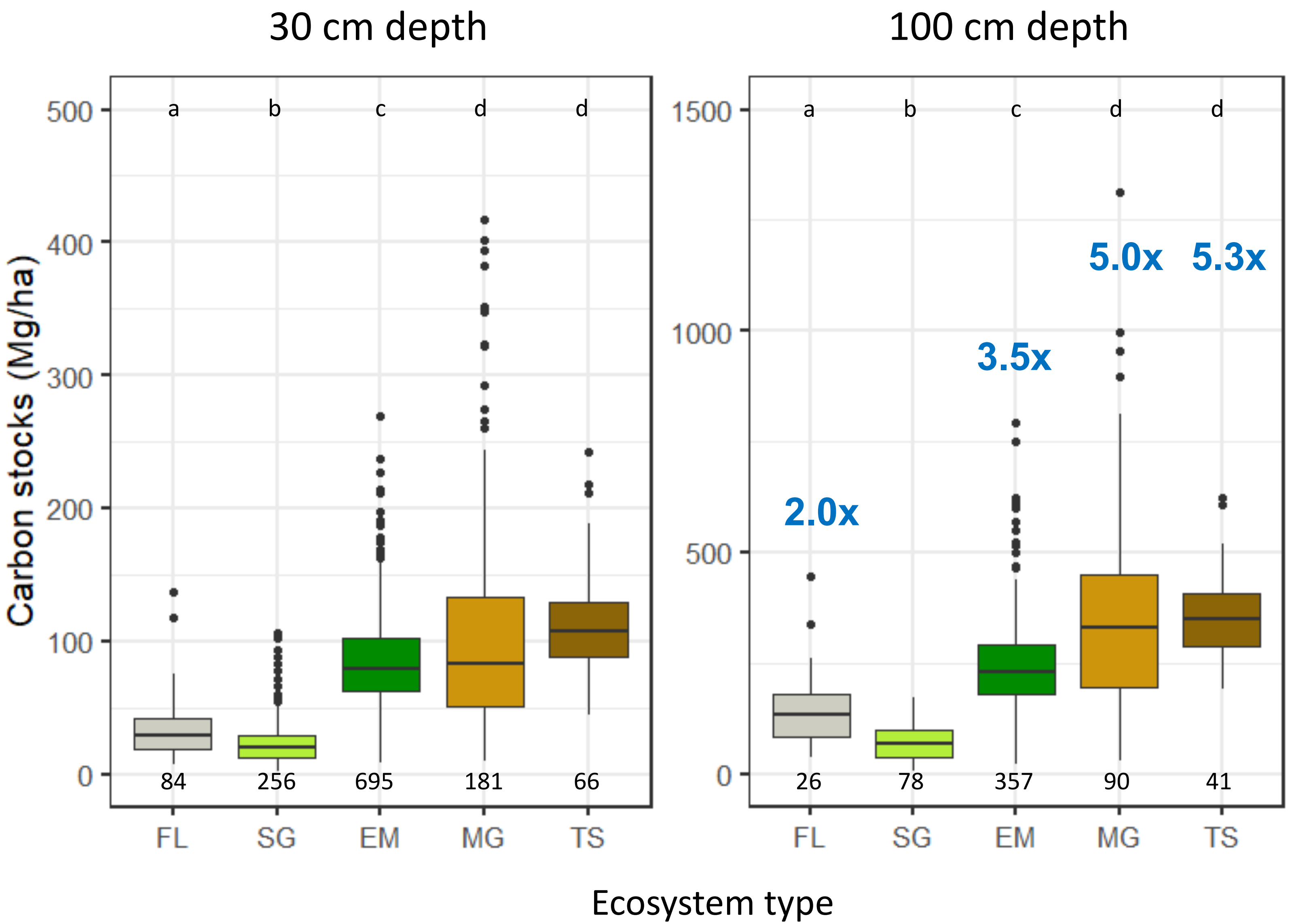




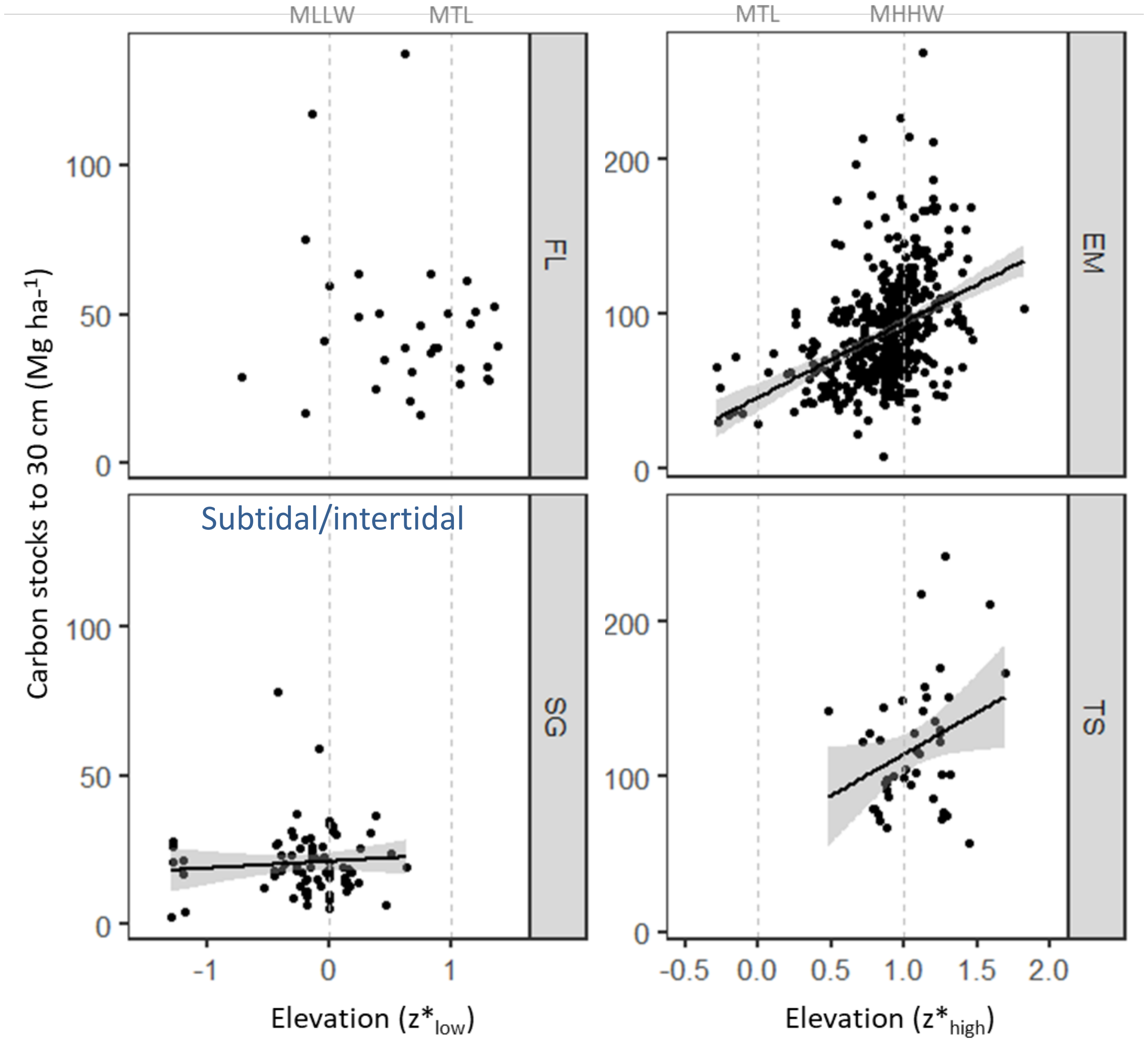
- Compiled associated environmental, geographic and climate data across a range of spatial scales



Results – 1. Stocks by blue carbon ecosystem



Results – 2. Local drivers (elevation)

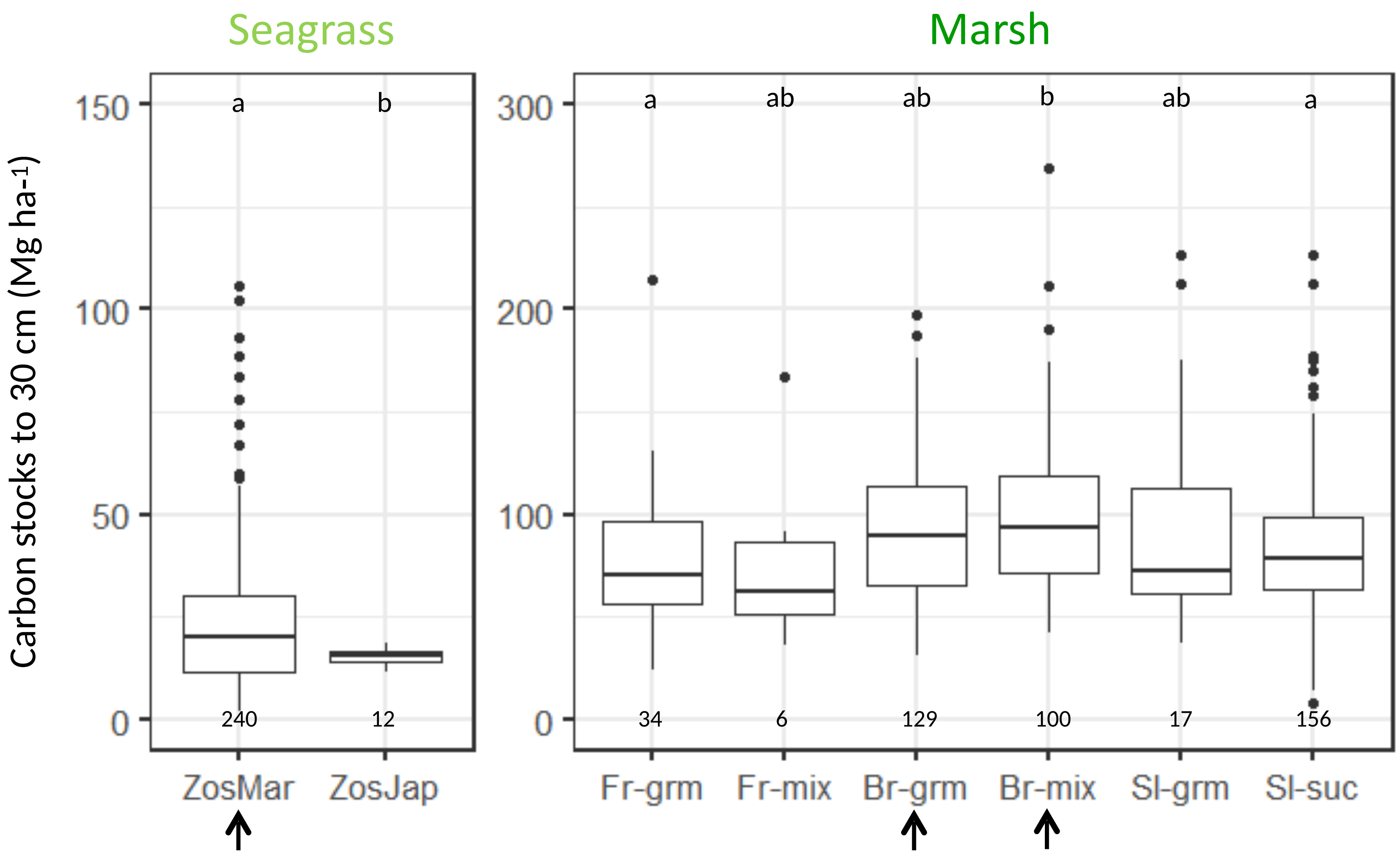


R^2_{adj} = 0.16, P < 0.0001
n = 477

R^2_{adj} = 0.11, P = 0.0006
n = 94

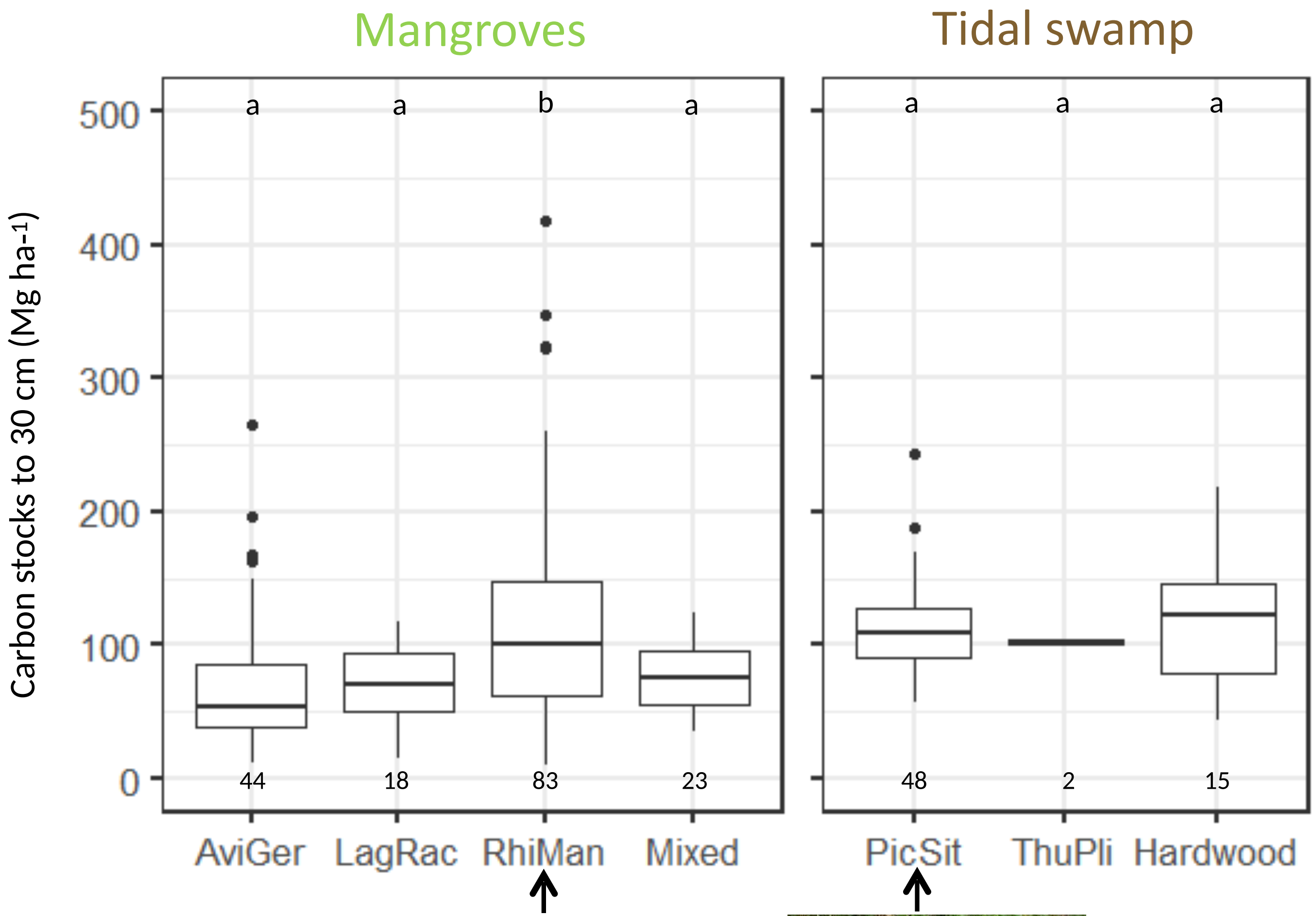
R^2_{adj} = 0.08, P = 0.04
n = 44

Results – 2. Local drivers (plant type)



- Native seagrass > non-native seagrass
- Brackish marshes > fresh and saline marshes

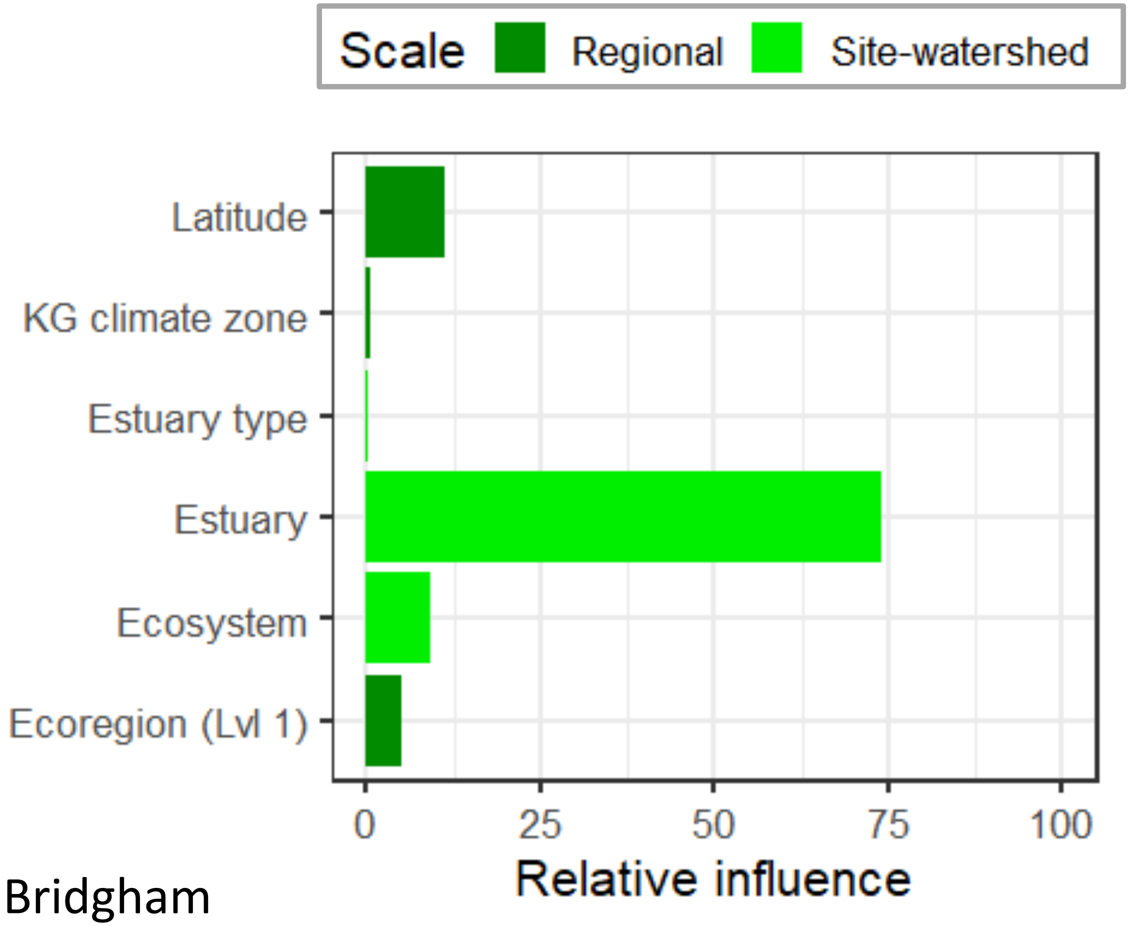
Results – 2. Local drivers (plant type)



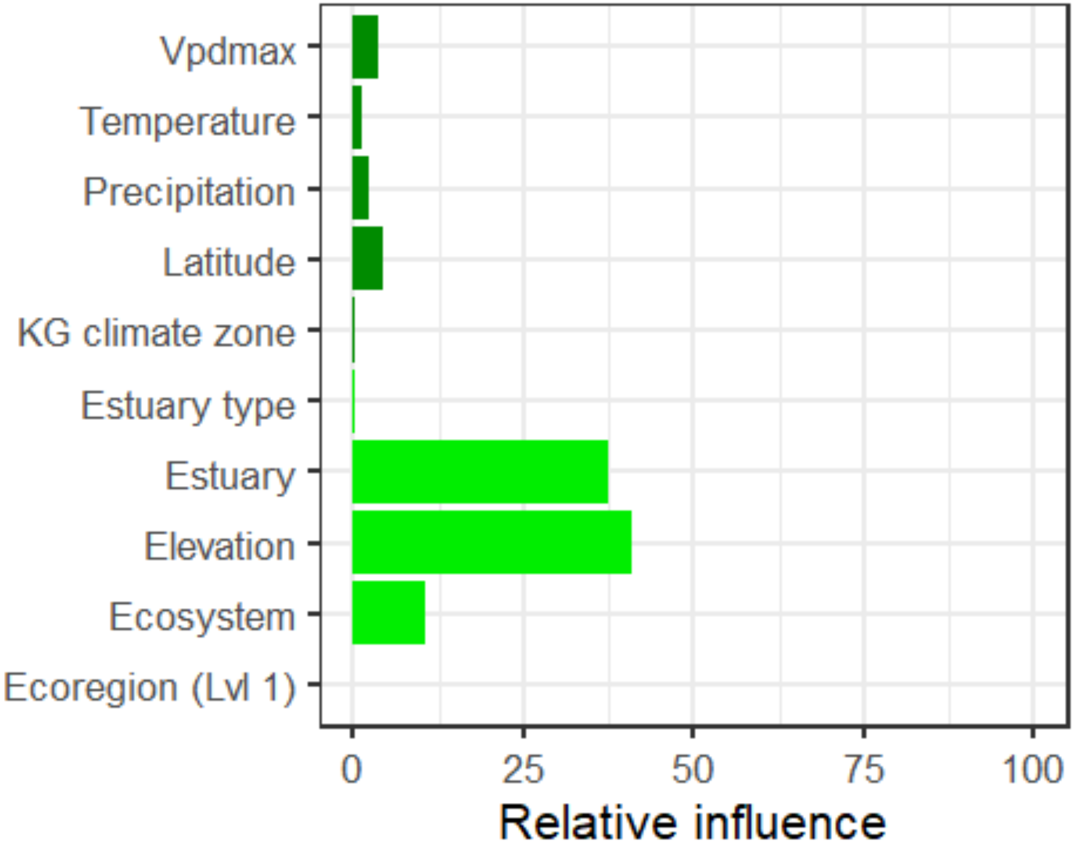
- Red mangrove > white and black mangroves
- Sitka spruce swamps similar to other swamp types (e.g. willow, dogwood)

- Boosted Regression Tree models (multivariate, non-linear machine learning models) to assess the relative importance of factors across scales

All cores in MX, US, CA



CONUS cores



<- S. Bridgham

Closing thoughts

- Tidal swamps are under-appreciated blue carbon ecosystems along the Pacific coast but have very substantial carbon stocks
- Spatial variability in stocks may be driven more by local factors (e.g., elevation, plant composition, local watershed), than by larger-scale climate gradients
- Our work has led to a significant improvement in understanding of blue carbon stocks regionally

National Estuarine Research Reserve System Science Collaborative

NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Pew Charitable Trusts

Citations:
Janousek et al. in prep a,b; Kauffman et al. 2020

Christopher.Janousek@oregonstate.edu

Patterns and predictors of soil carbon accumulation rates across multiple Pacific Northwest estuaries

Katrina Poppe, John Rybczyk, Christopher Janousek, Scott Bridgham, Craig Cornu, Trevor Williams,
Finn Tobias, Heather Perillat, Erin Peck, Sara Knox

Compiled core data across 3 collaborative projects

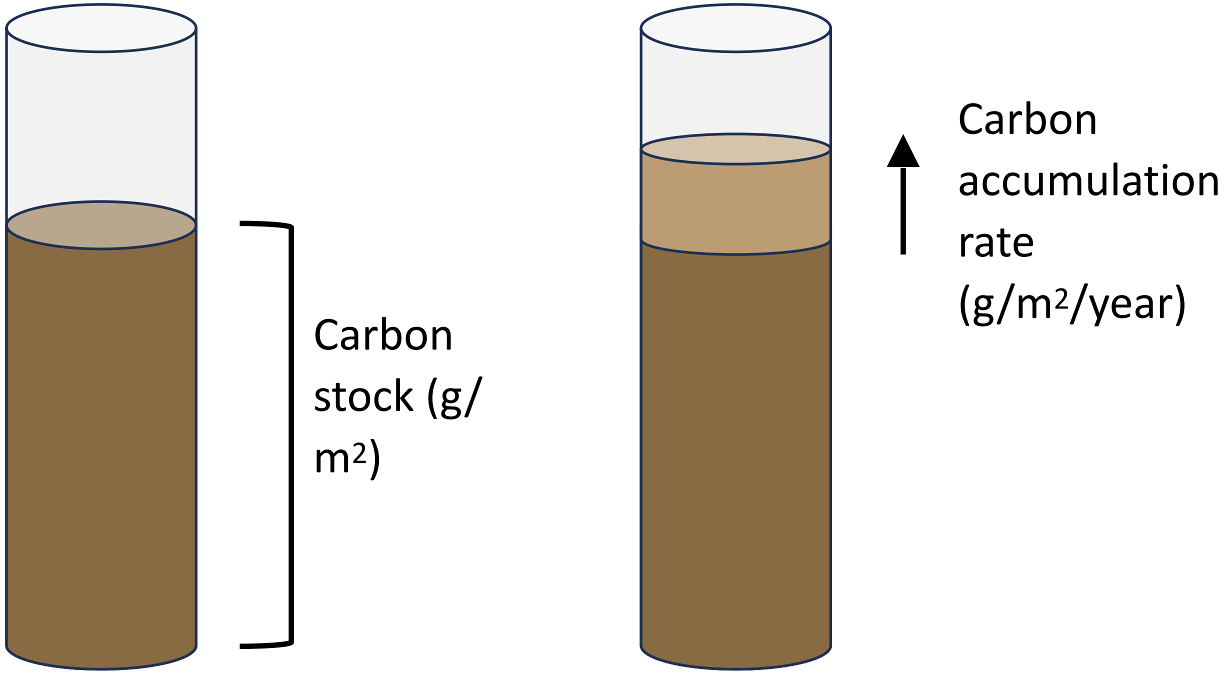
Coordinated measurements at same sites:

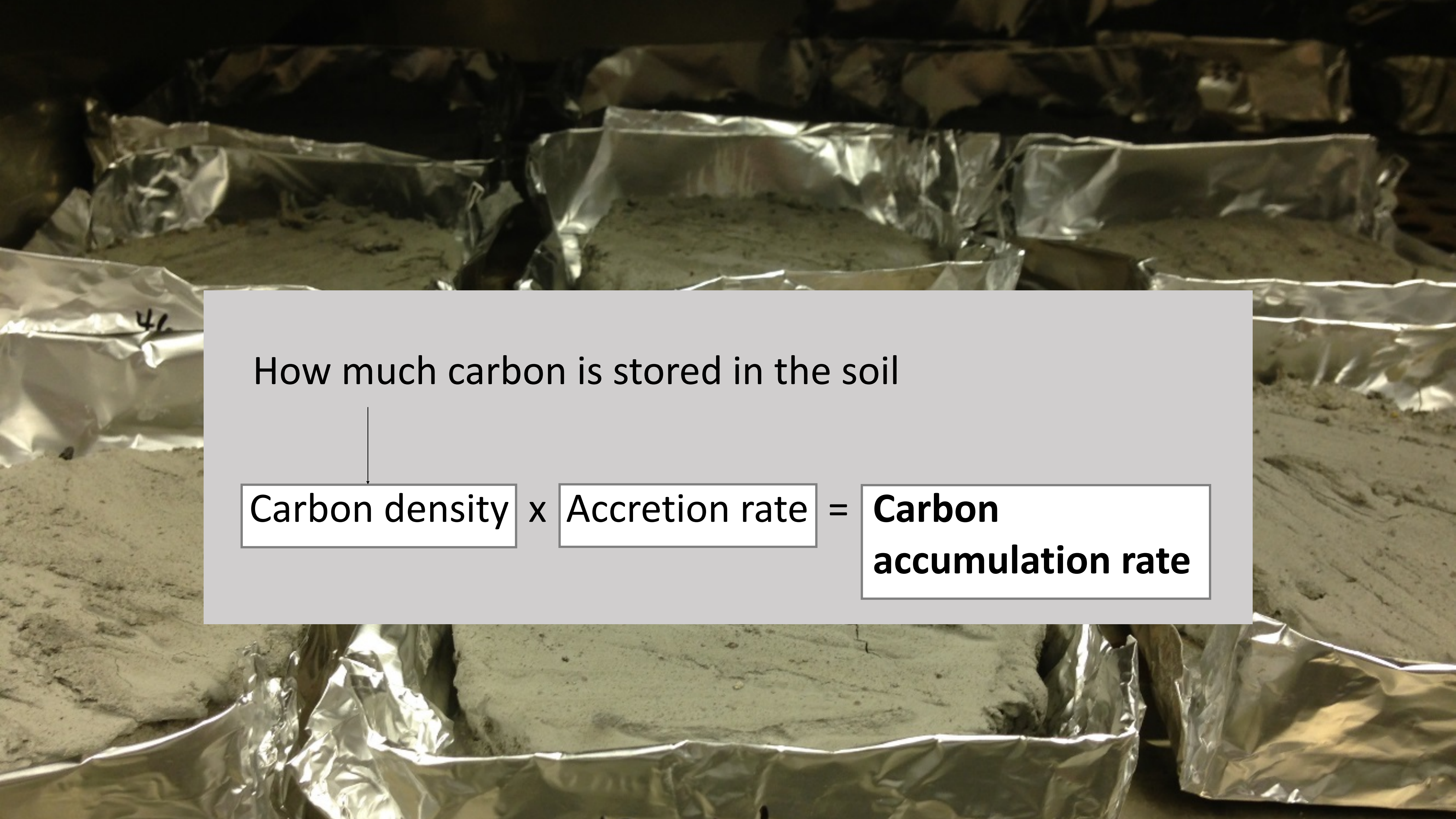
- soil carbon accumulation rates
- methane emissions
- potential environmental drivers

	Reference	Restored	Disturbed
Marsh	15	8	-
Swamp	8	-	-
Pasture	-	-	8

Total number of sites with cores = 39

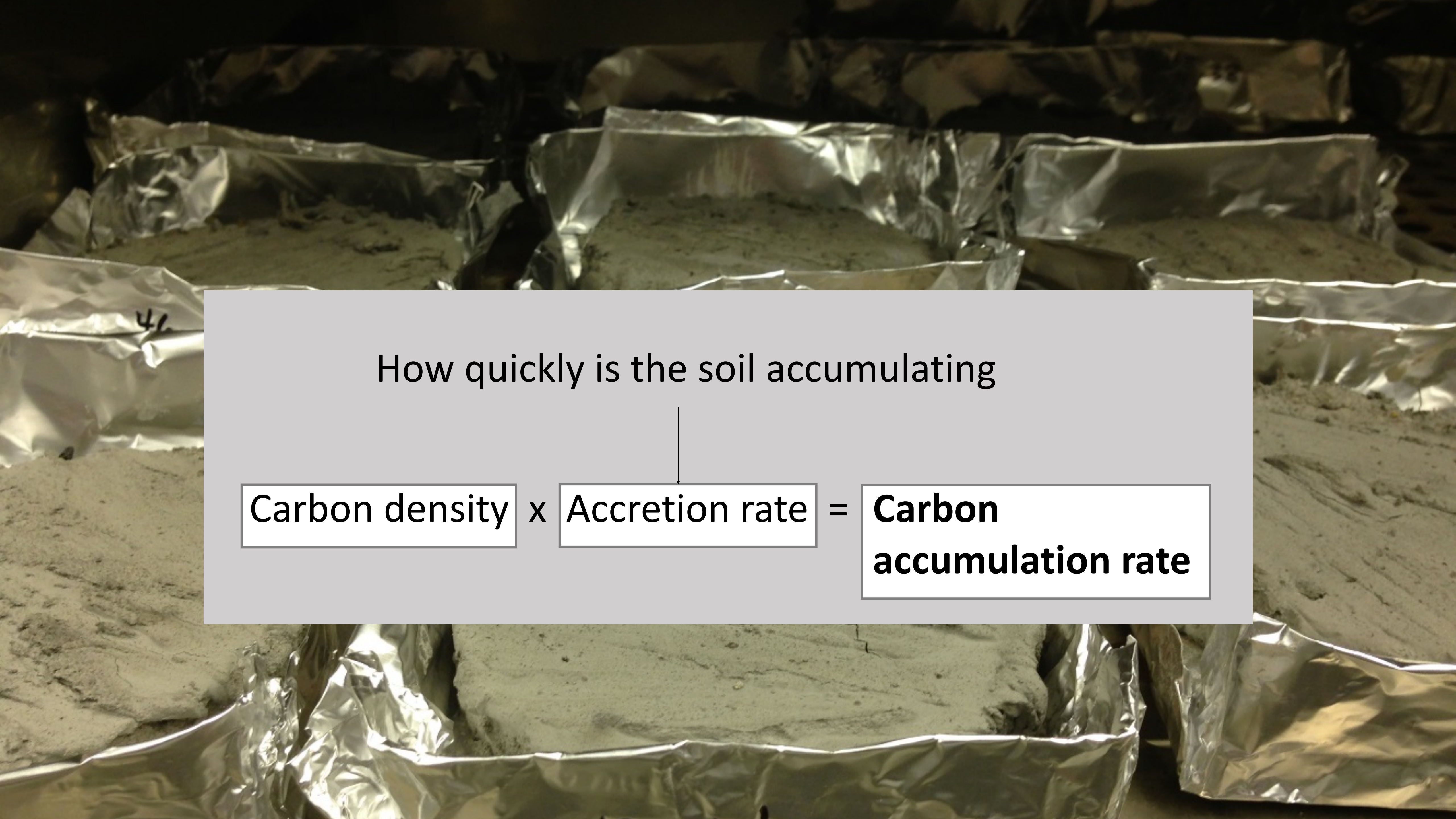
Methods – Soil cores





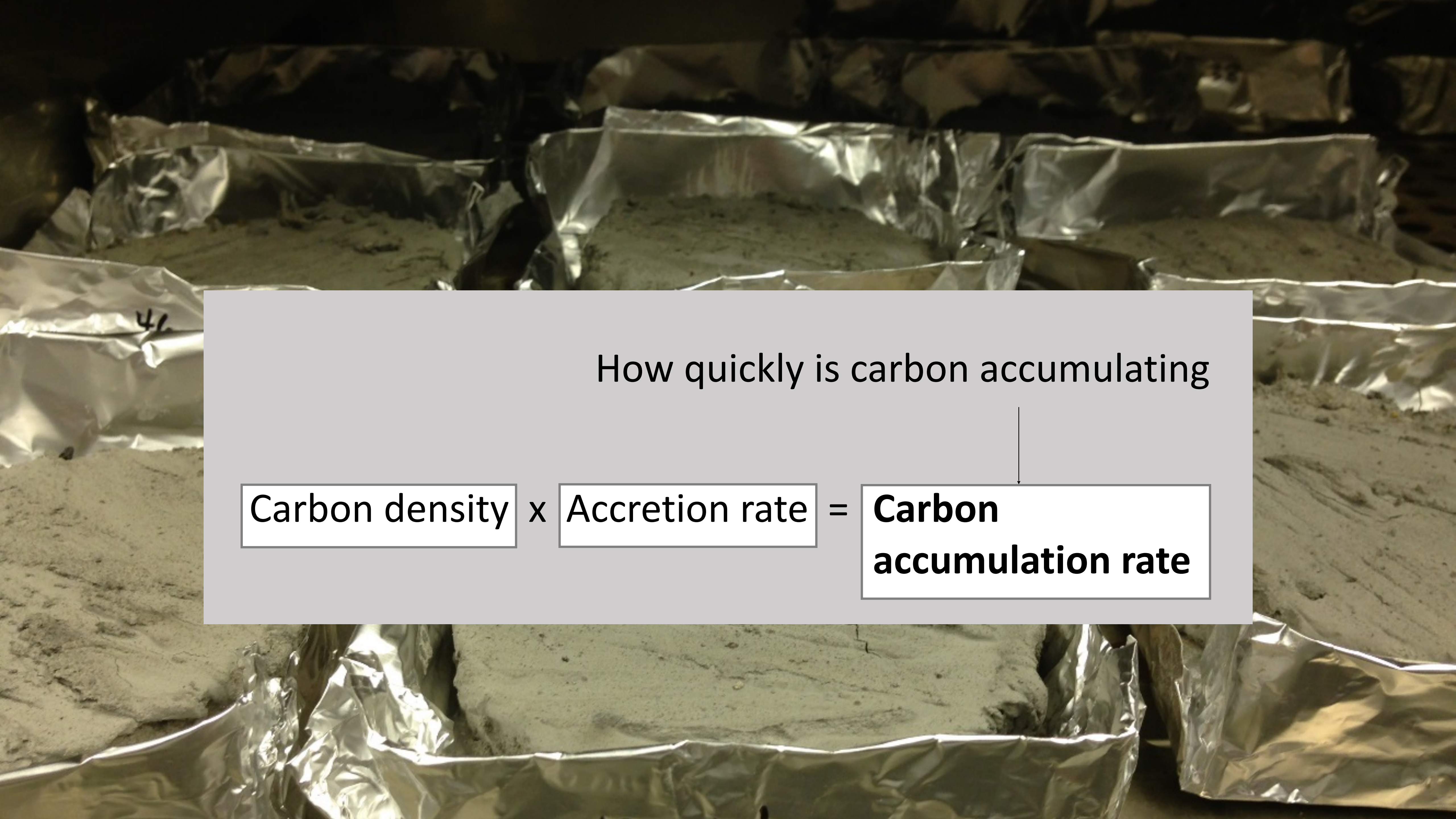
How much carbon is stored in the soil

Carbon density x Accretion rate = **Carbon accumulation rate**



How quickly is the soil accumulating

Carbon density	x	Accretion rate	=	**Carbon accumulation rate**

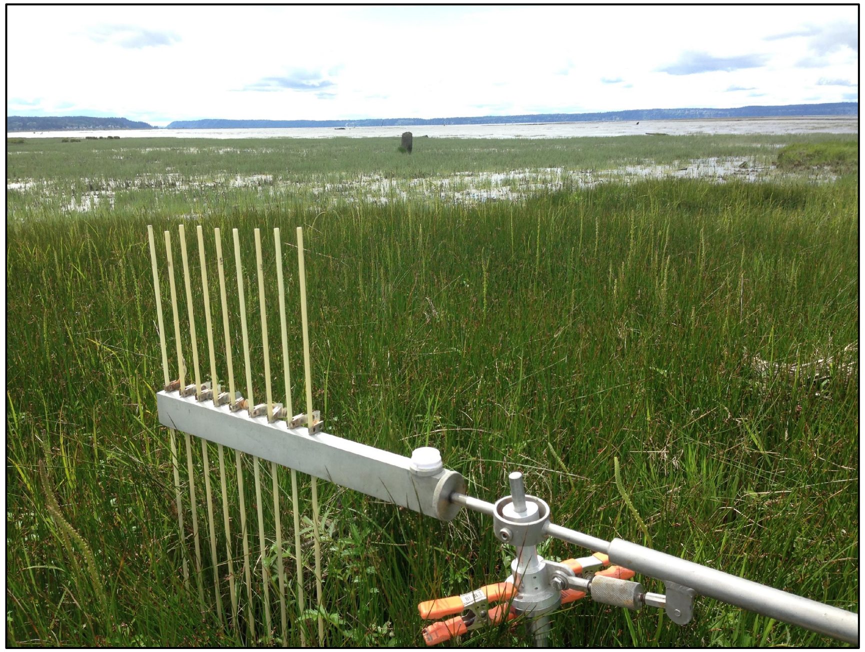


How quickly is carbon accumulating

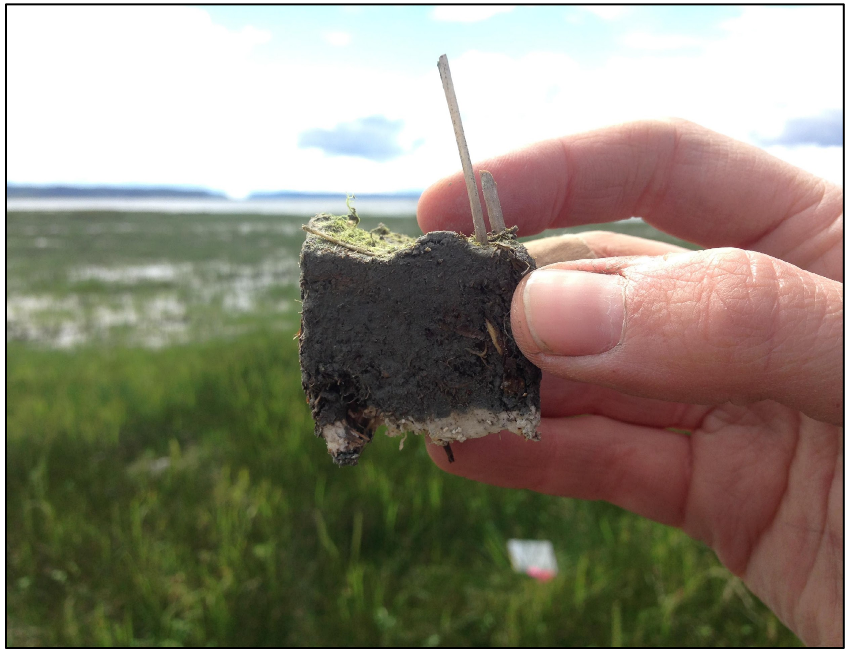
Carbon density x Accretion rate = **Carbon accumulation rate**

Three accretion measurement methods

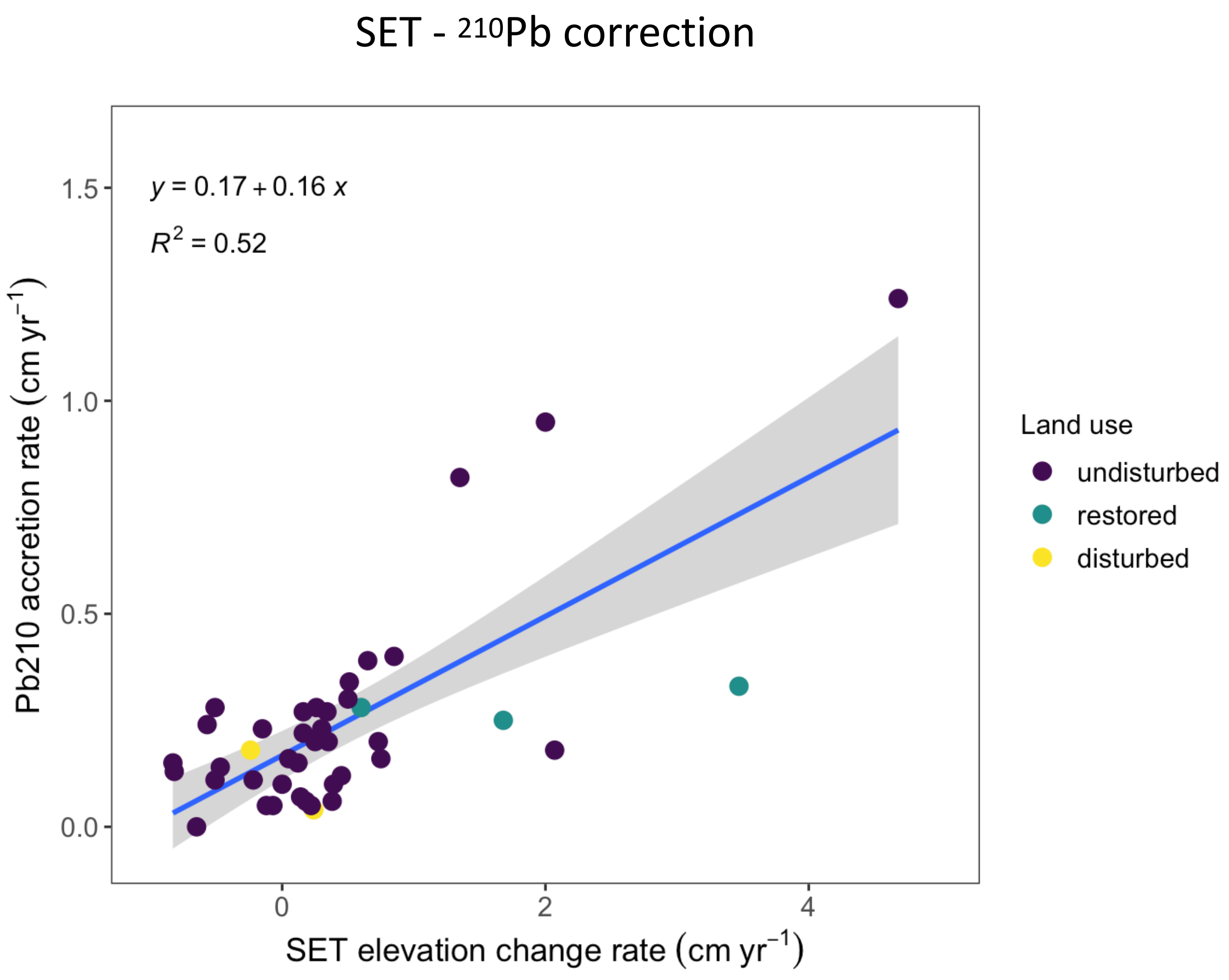
Pb-210



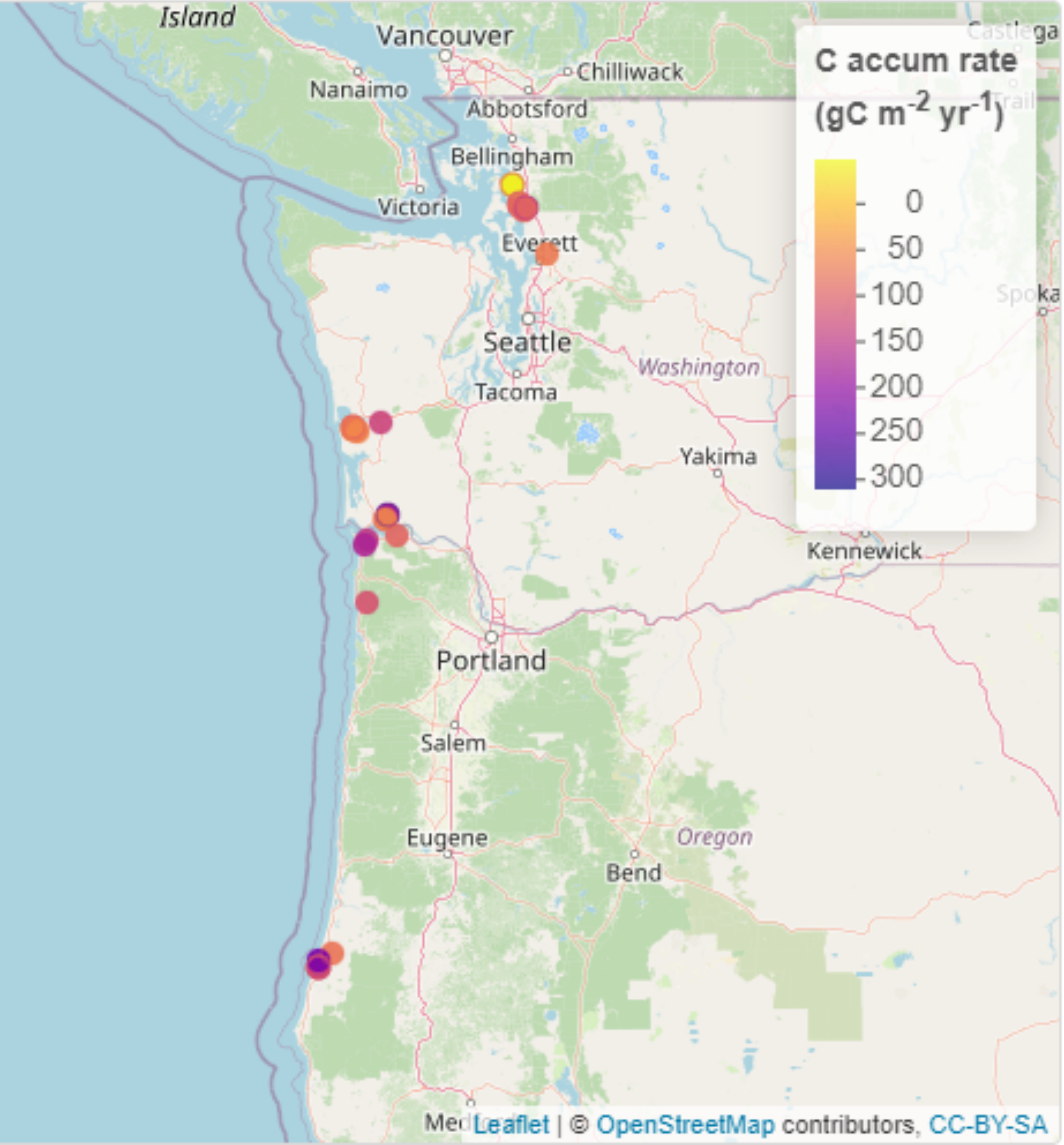
SETs



Feldspar



SET - ^{210}Pb correction
$y = 0.17 + 0.16\,x$
$R^2 = 0.52$
1.5
1.0
0.5
0.0
0
2
4
Pb210 accretion rate (cm yr^{-1})
SET elevation change rate (cm yr^{-1})
Land use
undisturbed
restored
disturbed

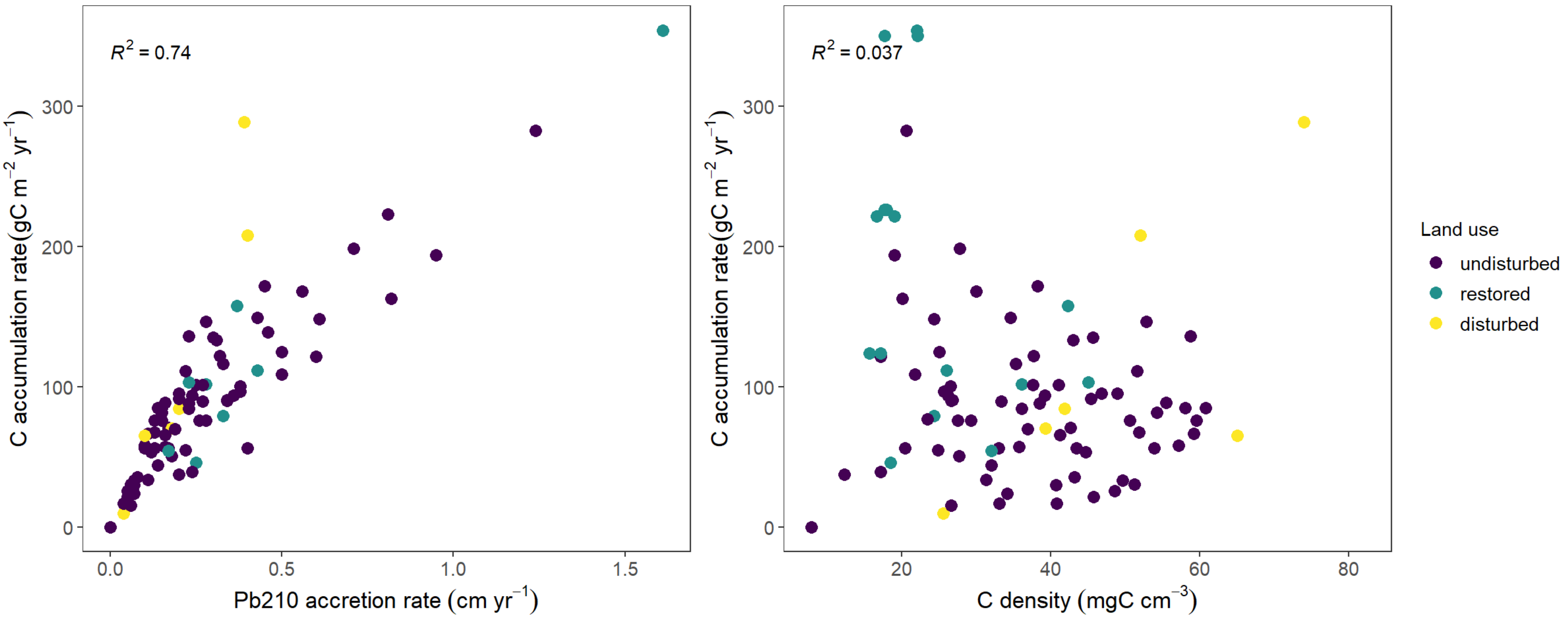


Carbon accumulation rates

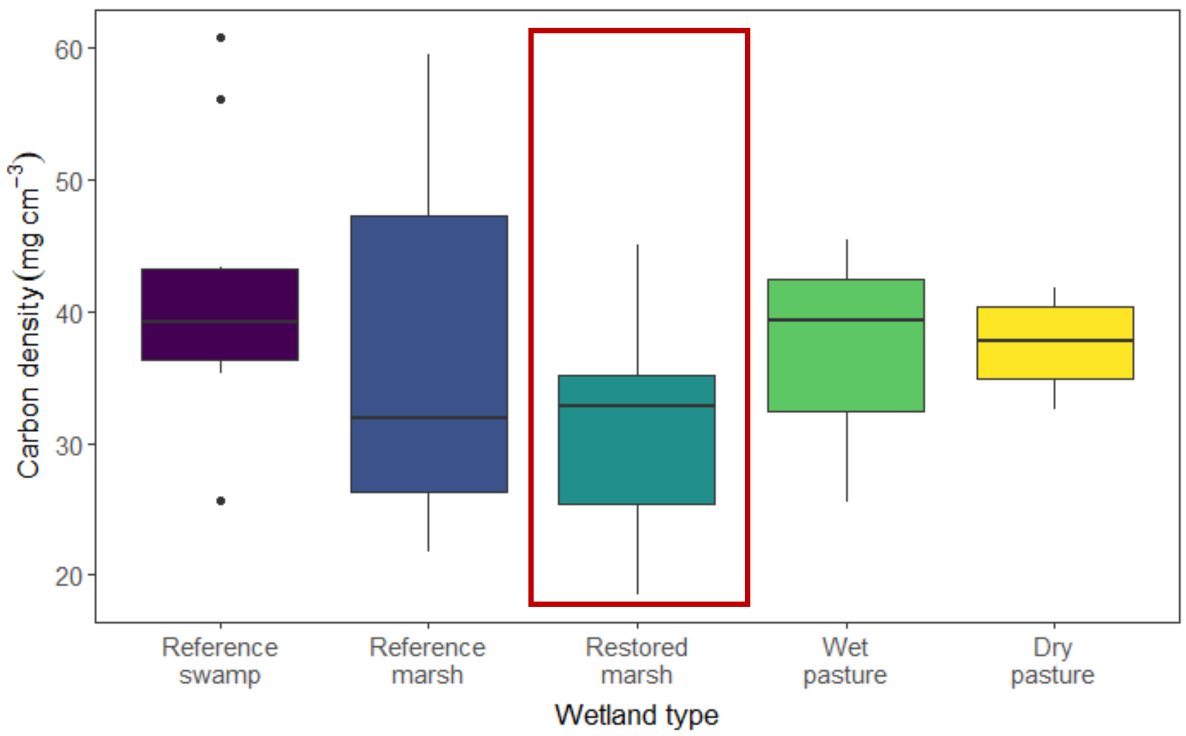
Range
-35 to 300 gC m^{-2} yr^{-1}

Median at undisturbed sites
90 to 95 gC m^{-2} yr^{-1}

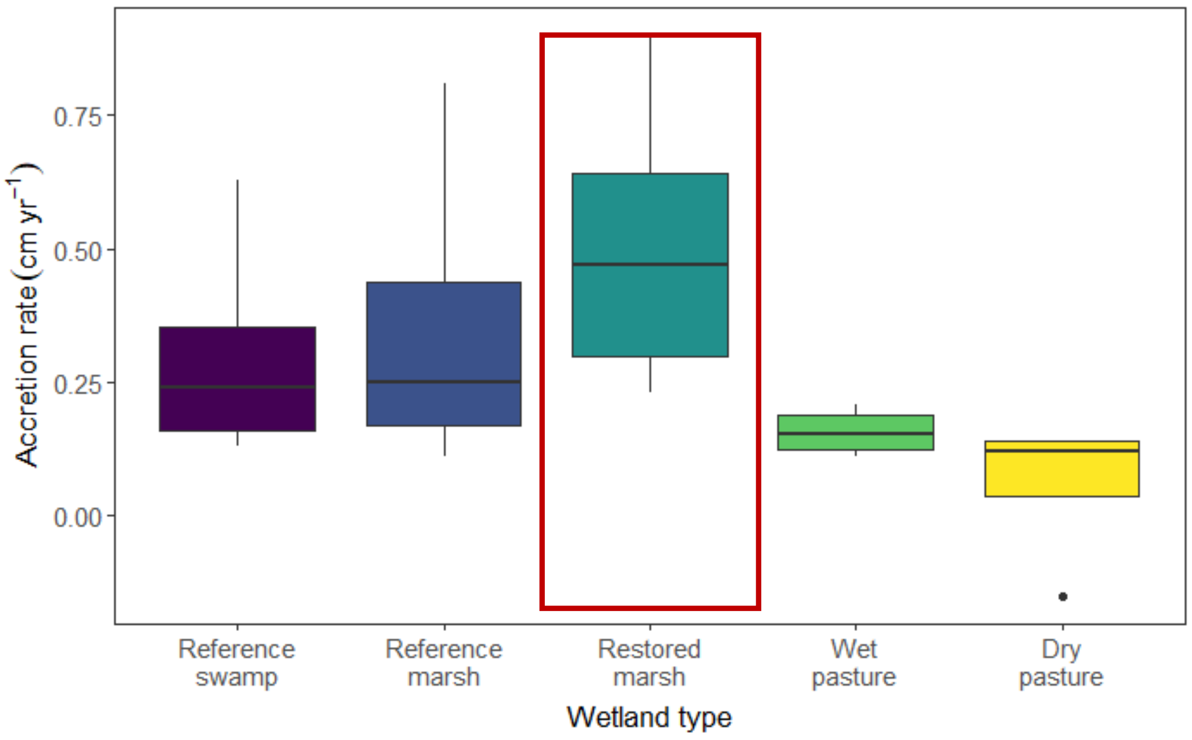
Carbon accumulation rates are a product of both accretion rates and soil carbon density, but accretion has greater influence



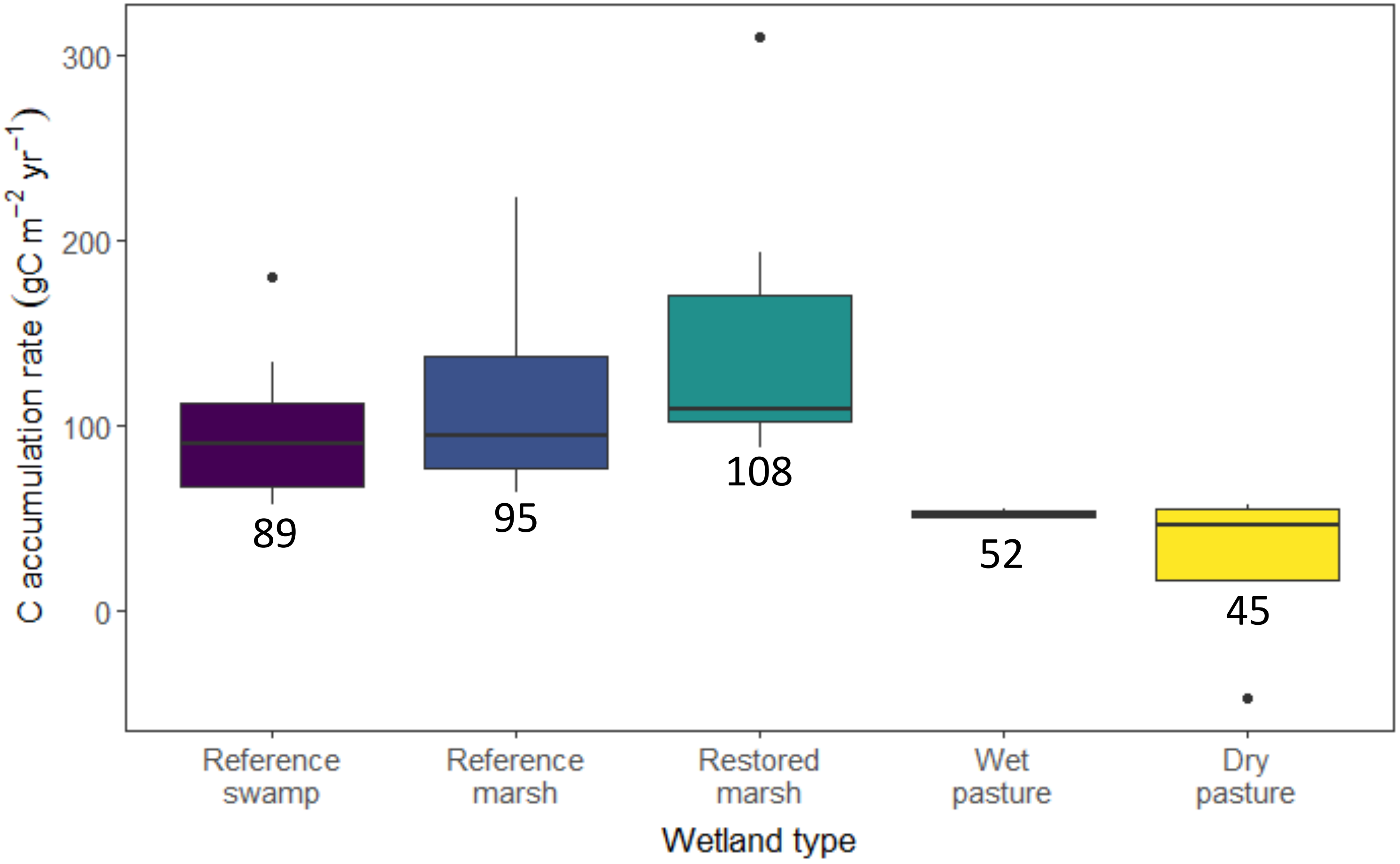
Soil carbon density

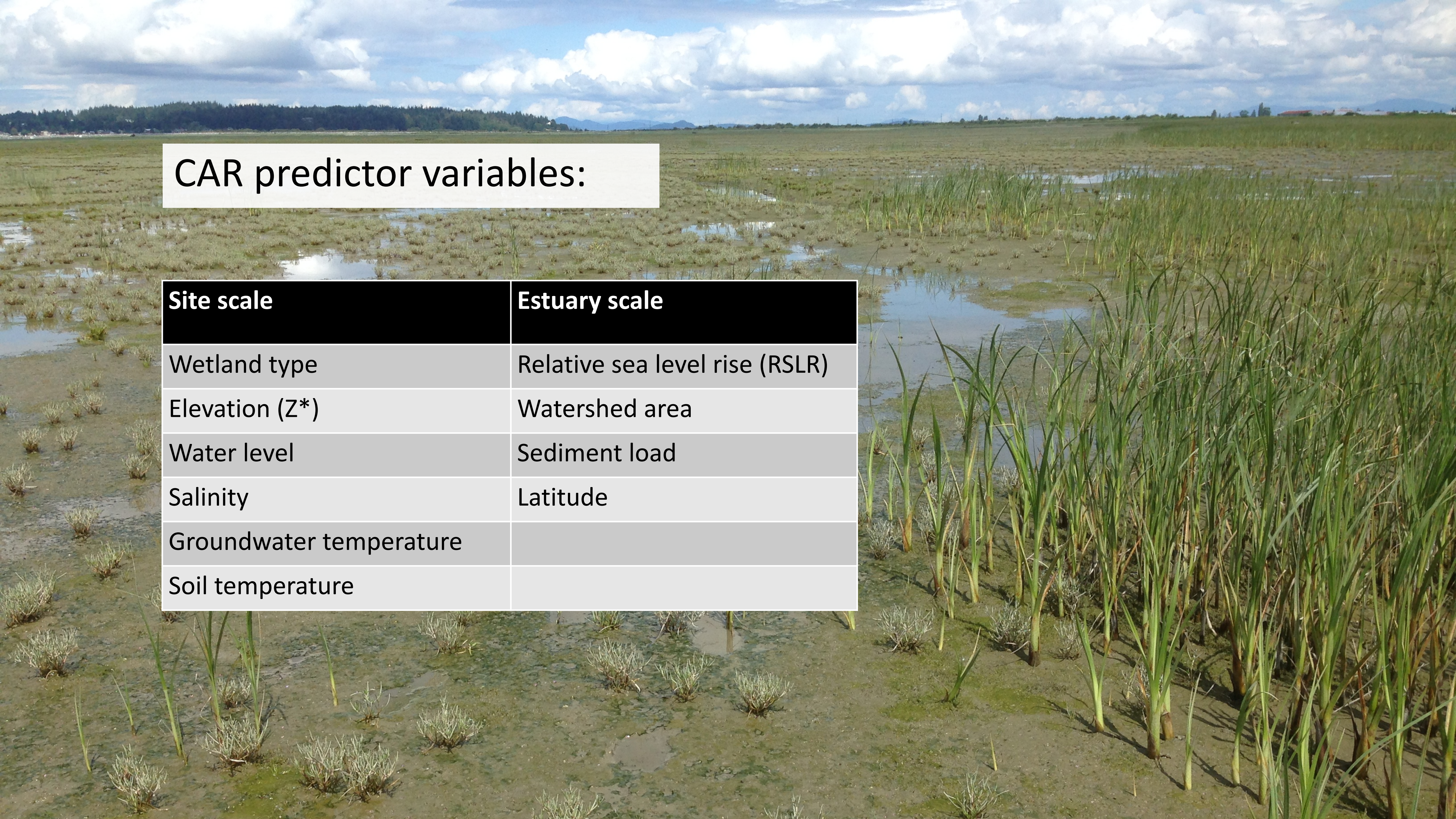


Accretion rate



CAR in restored marshes significantly higher than pastures (~ 2x)



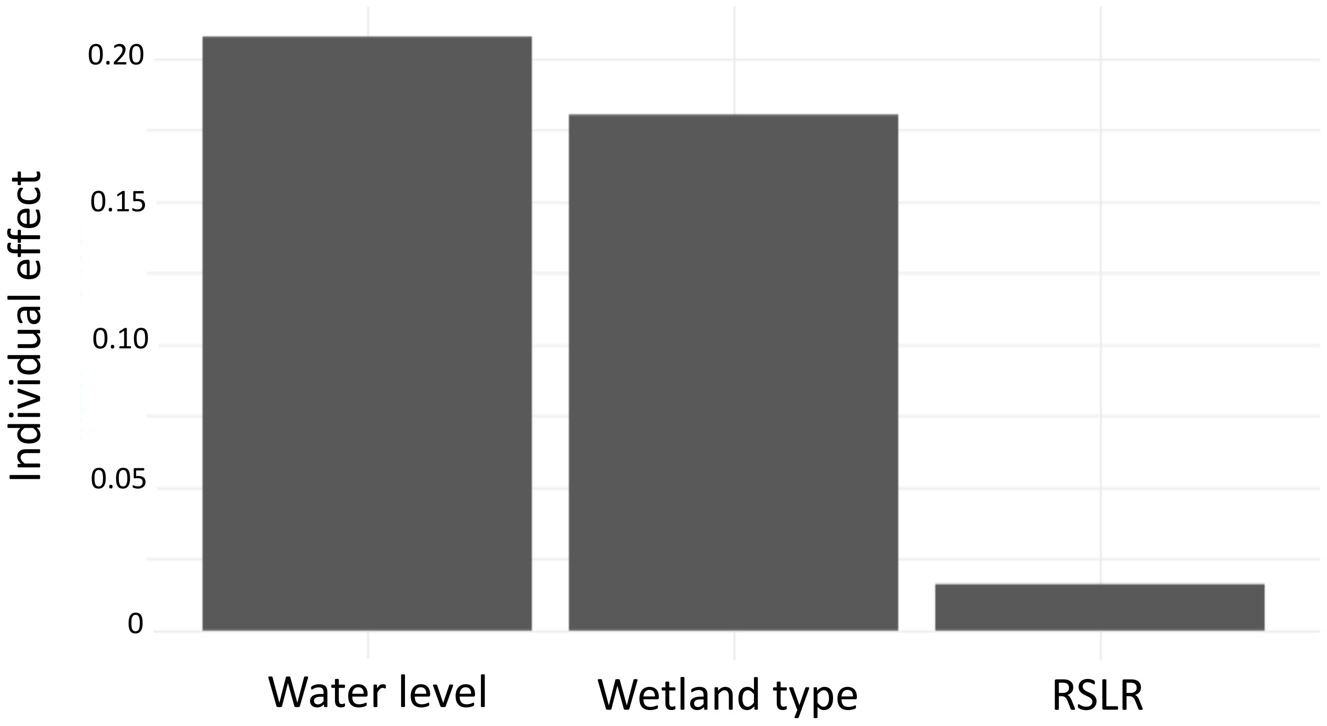


CAR predictor variables:

Site scale	Estuary scale
Wetland type	Relative sea level rise (RSLR)
Elevation (Z*)	Watershed area
Water level	Sediment load
Salinity	Latitude
Groundwater temperature	
Soil temperature	

LME: Best model includes water level, wetland type, and RSLR

Model explains 50% variation in CAR



But water level is also an important driver of methane emissions…

Summary

- Can use adjusted SET rates in place of Pb210 accretion rates
- Accretion rate more predictive of carbon accumulation rate (CAR) than carbon density
- CAR roughly doubles from diked pasture to restored tidal marsh
- CAR predicted best by water level, wetland type, and RSLR
- Next: Autochthonous vs allochthonous sources of soil carbon

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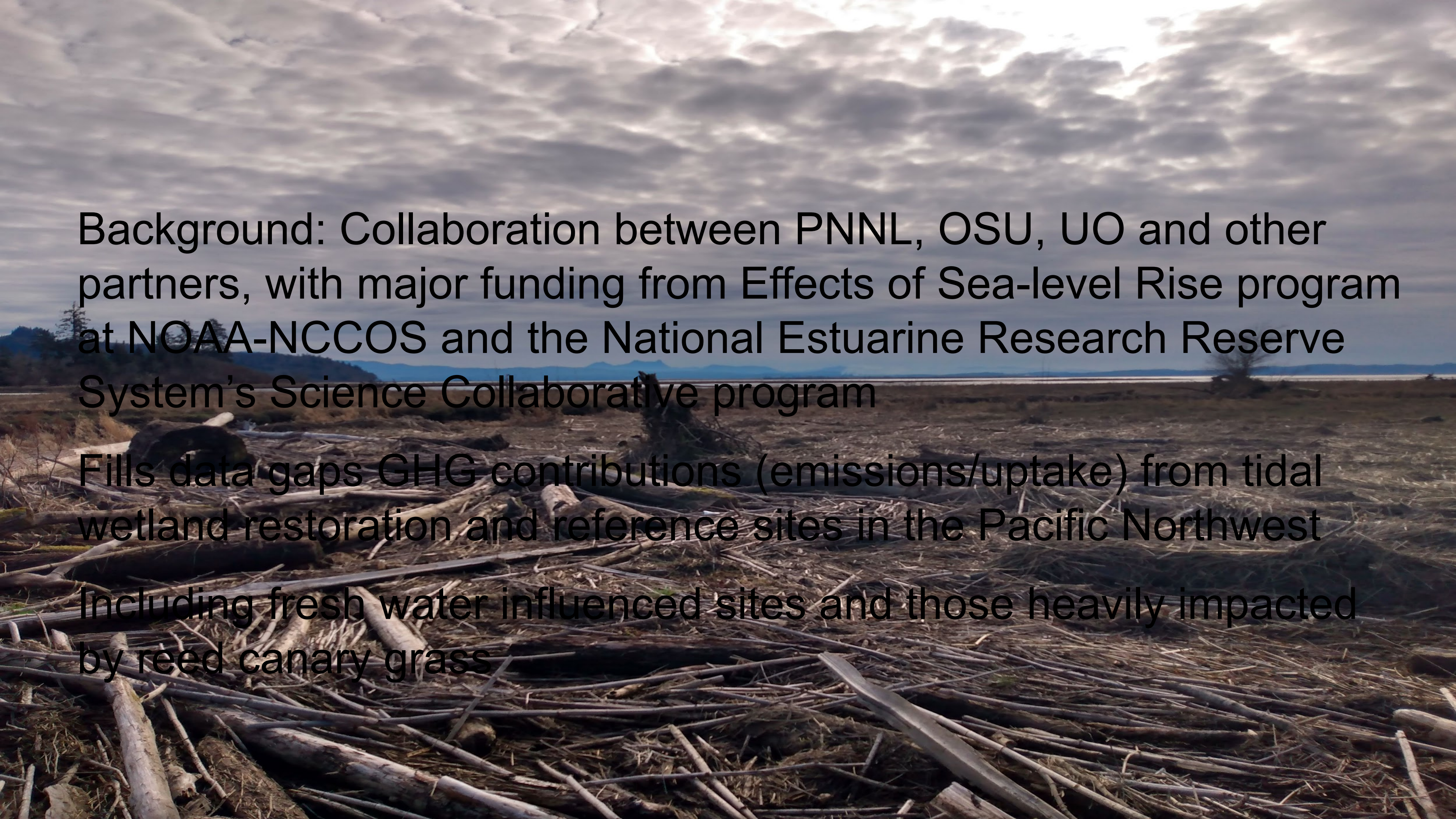
A regional assessment of methane and nitrous oxide emissions from reference, restored, and disturbed estuarine wetlands in the Pacific Northwest, USA

Trevor Williams[1], Christopher N. Janousek[1], Maggie A. McKeon[2], Heida L. Diefenderfer[2], Craig E. Cornu[3], Amy B. Borde[4], Jude Apple[5], Laura Brophy[3], Matt Norwood[2], Matthew Schultz[6], Scott Bridgham[6*]

1. Department of Fisheries, Wildlife and Conservation Sciences, Oregon State University
2. Pacific Northwest National Laboratory, Sequim, WA
3. Institute for Applied Ecology, Corvallis, OR
4. Columbia Land Trust, Vancouver, WA
5. Padilla Bay National Estuarine Research Reserve, Mt. Vernon, WA
6. Institute of Ecology and Evolution, University of Oregon, Eugene, OR


Background: Collaboration between PNNL, OSU, UO and other partners, with major funding from Effects of Sea-level Rise program at NOAA-NCCOS and the National Estuarine Research Reserve System’s Science Collaborative program
Fills data gaps GHG contributions (emissions/uptake) from tidal wetland restoration and reference sites in the Pacific Northwest
Including fresh water influenced sites and those heavily impacted by reed canary grass

Background: Tidal wetlands have the potential to store great amounts of carbon.

Methane can be emitted by natural processes in tidal wetlands.

How much?

Under what conditions?

Method synopsis

5 estuaries, 5 wetland types, 34 sites, 6 collars per site, sampled 8 - 9 times between Spring 2021-2022

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5 estuaries, 5 wetland types, 34 sites, 6 collars per site, sampled 8 - 9 times between Spring 2021-2022

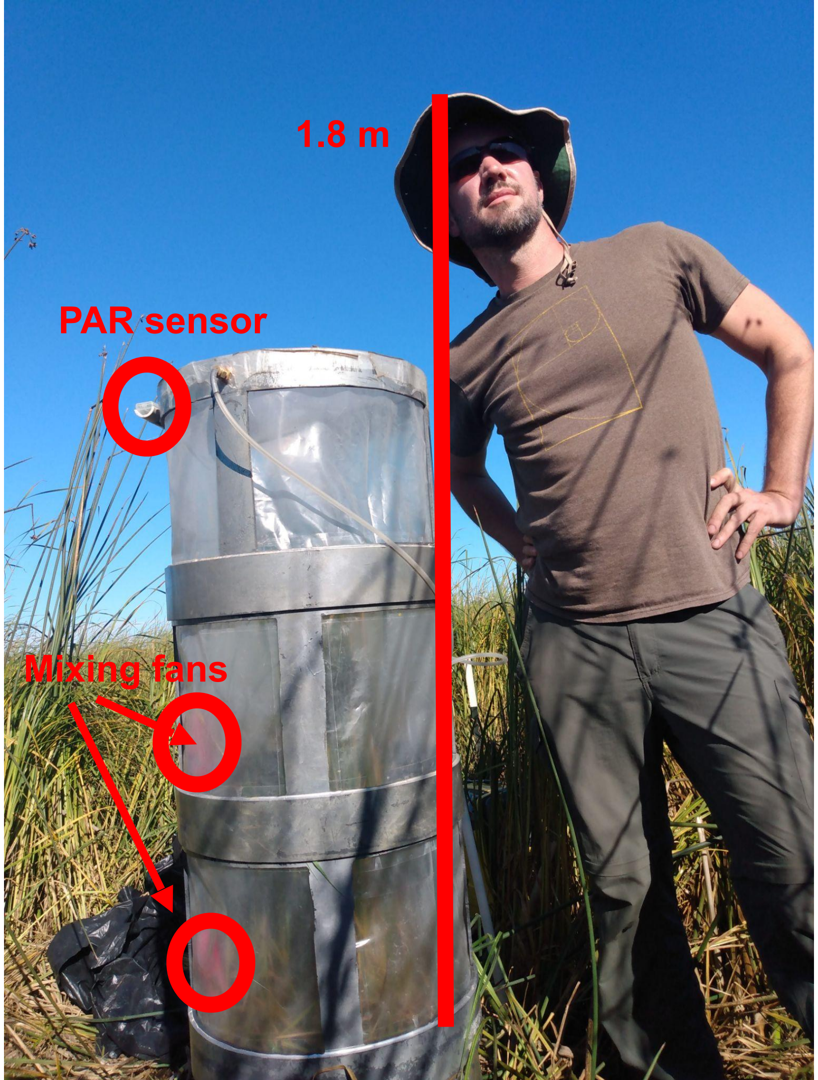
Closed-chamber, portable gas analyzers (Licor and Gasmet), continuous concentration slope (~5 mins) and flux calculation

Method synopsis

5 estuaries, 5 wetland types, 34 sites, 6 collars per site, sampled 8 - 9 times between Spring 2021-2022

Closed-chamber, portable gas analyzers (Licor and Gasmet), continuous concentration slope (~5 mins) and flux calculation

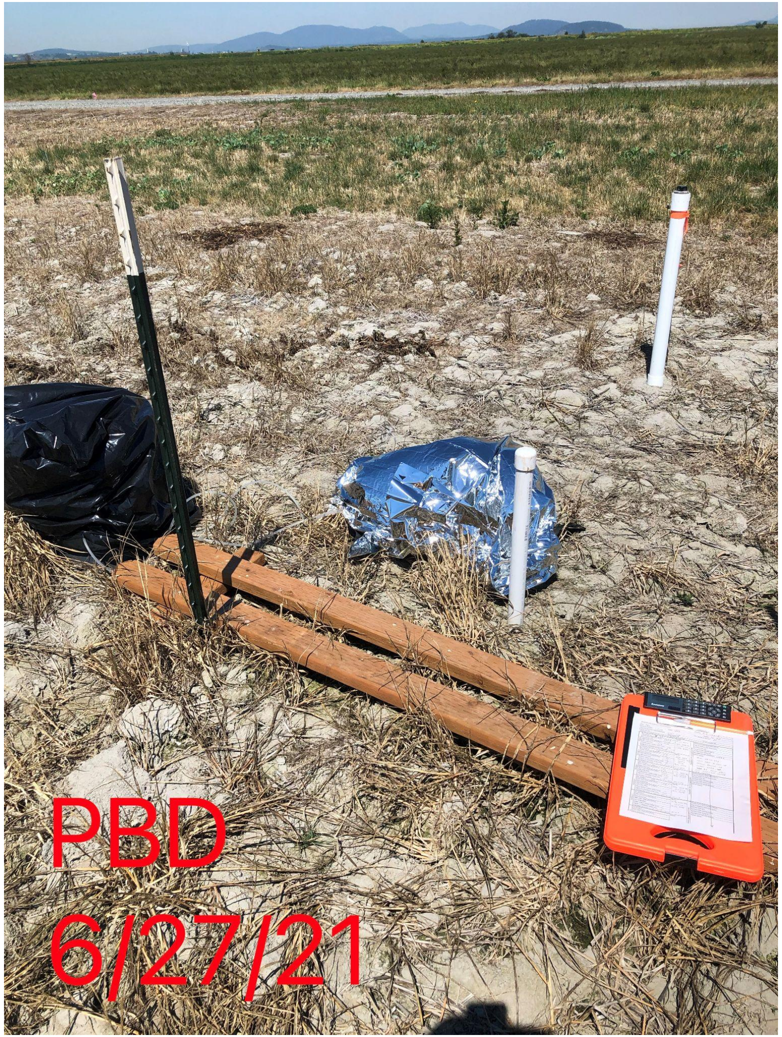
Incorporated plants, adding translucent chambers as plants grew up to 2 m



Method synopsis

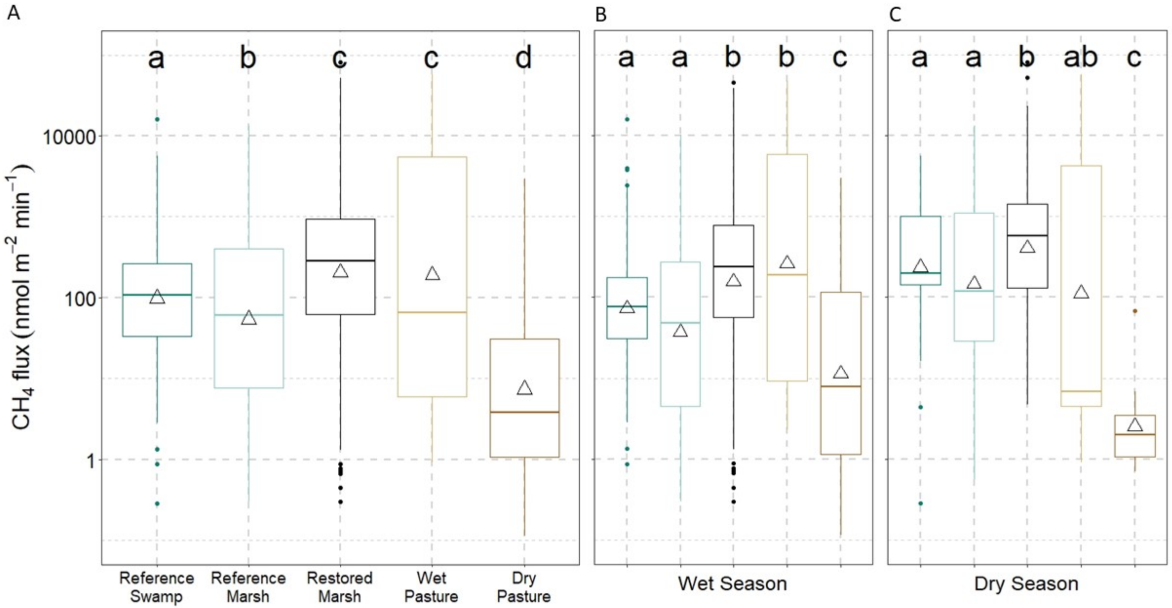
Continuous and spot measurements of potential drivers: groundwater level, rate & direction, salinity, temperature, and pH; air temperature and pressure; soil temperature; and soil surface elevation, plant cover, richness and biomass

Used Boosted Regression Tree modelling to find influences on GHG flux



Results takeaways

The highest CH_4 fluxes were measured in the restored marsh and wet pasture classifications, which also had the highest mean fluxes.



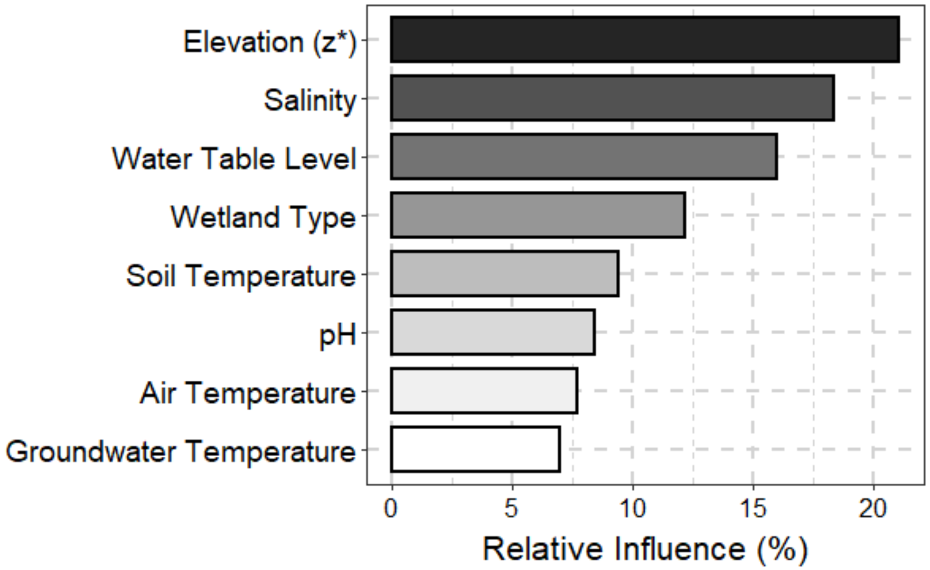
Boxplots of CH_4 flux by wetland type in all seasons (A) and separated into wet (B) and dry (C) seasons in PNW estuaries (log_{10} scale). Median = solid lines in the box plots, mean = triangles. Wetland classes not sharing the same lowercase letters were significantly different.

Results takeaways

The highest CH4 fluxes were measured in the restored marsh and wet pasture classifications, which also had the highest mean fluxes.

Our model showed CH4 flux was most influenced by three factors: elevation (z*), salinity and water table level.

Our results identify the degree of soil saturation (as indicated by both water-table level and wetland surface elevation) and groundwater salinity as major drivers of CH_4 fluxes.



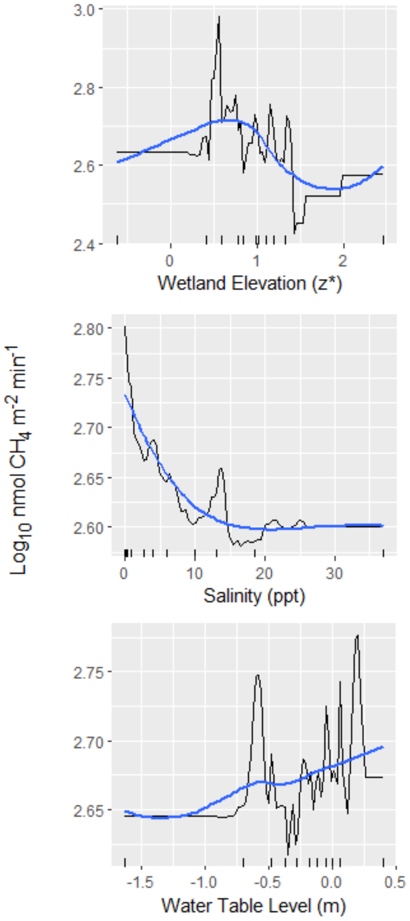
The relative influence of eight environmental variables on CH_4 fluxes in the BRT model for PNW coastal wetlands.

Results takeaways

The highest CH4 fluxes were measured in the restored marsh and wet pasture classifications, which also had the highest mean fluxes.

Our model showed CH4 flux was most influenced by four factors: soil temperature, elevation (z*), salinity and water table level.

Modeling using Boosted Regression Trees (BRTs) can be used to estimate CH_4 fluxes in coastal tidal wetlands of the Pacific NW if provided with adequate training using major environmental drivers.



Partial plots of CH_4 fluxes and the three most influential variables in the BRT model. Loess-smoothed lines are in blue (right) Rugs on the x-axis denote 10% quantiles of data. Partial plots show the influence of single variables on fluxes with other variables held constant.

Results takeaways

The highest CH4 fluxes were measured in the restored marsh and wet pasture classifications, which also had the highest mean fluxes.

Our model showed CH4 flux was most influenced by four factors: soil temperature, elevation (z*), salinity and water table level.

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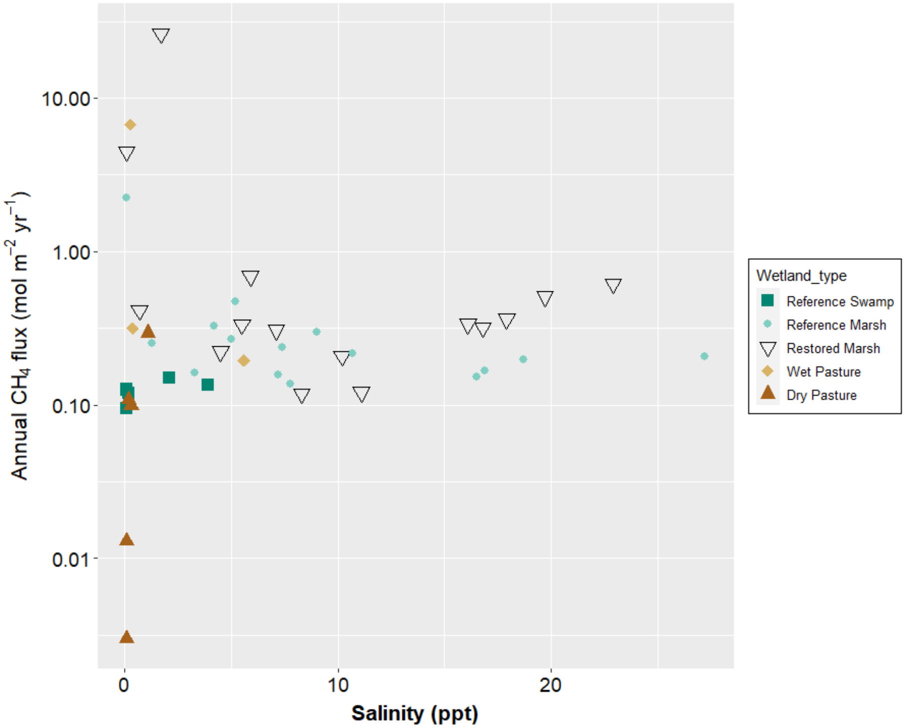

Annual CH_4 flux plus a constant of 0.09 relative to average groundwater salinity from sites in this study and Schulz et al. (2023). Wetland classes are shown by different colors and shapes. Note that the y-axis is on a log_{10} scale.

Thank you

Paper in final revisions for publication by early 2024

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Land use effects on climate forcing in PNW tidal wetlands

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Maggie McKeon, Pacific Northwest National Lab.

Christopher Janousek, Oregon State Univ.

John Rybczyk, Western Washington Univ.

Heida Diefenderfer, Pacific Northwest National Lab.

Any Borde, Columbia Land Trust

Jude Apple, Padilla Bay NERR

Some Necessary Definitions:

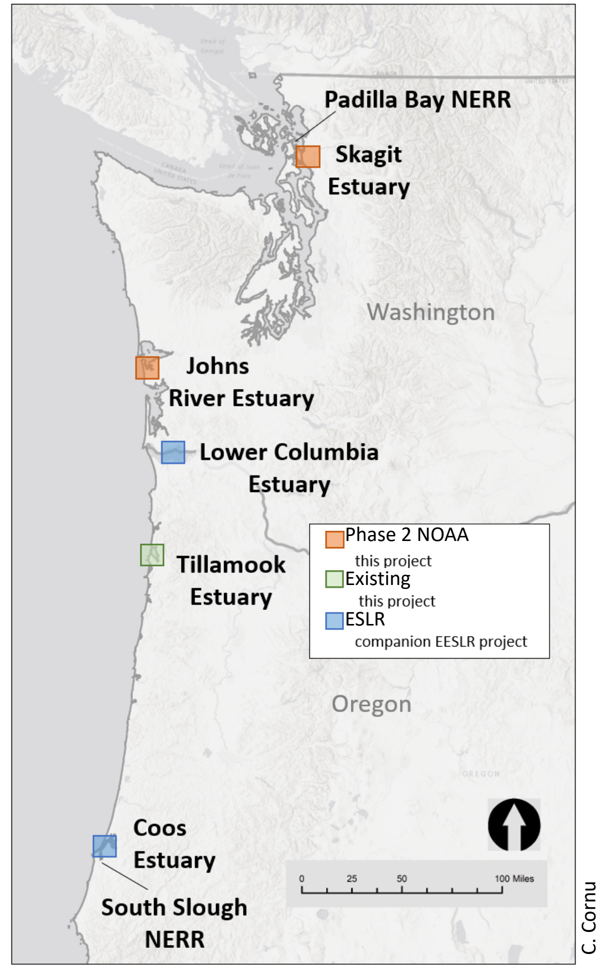
Radiative balance = CH_4 flux$_{CO2\text{-}eq}$ - soil C sequestration$_{CO2\text{-}eq}$

- *Both processes are* converted into CO_2 equivalents ($CO_{2\text{-}eq}$)
- *Must multiply the* CH_4 flux by *its sustained GWP, which is 96 and 45 at 20 and 100 years, respectively.*

Radiative forcing, or the climate effect, is the change in the radiative balance over time (e.g., from a degraded to a restored wetland).

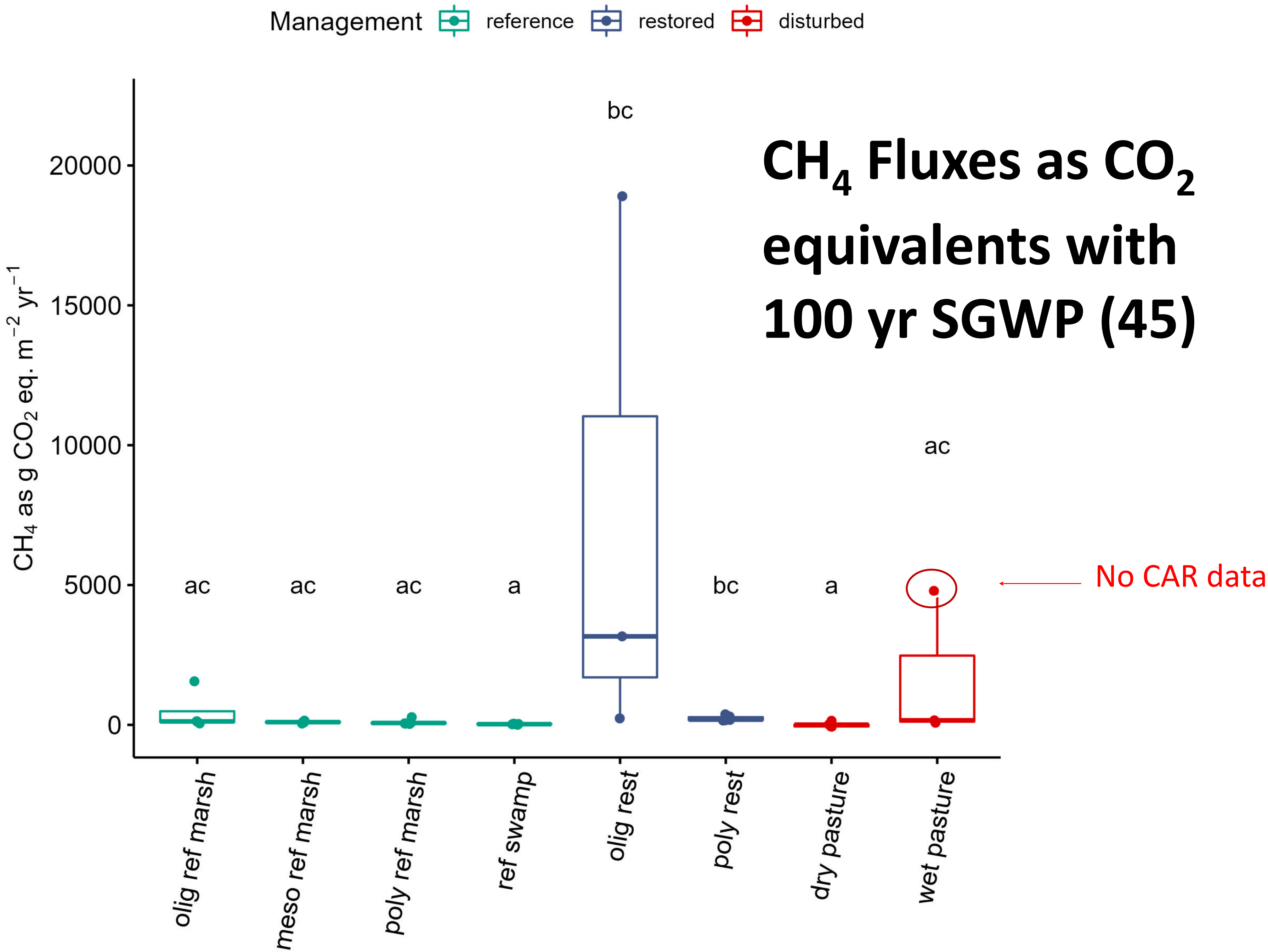
A regional evaluation of the GHG benefits of estuarine wetland restoration

- Evaluate greenhouse gas (GHG) emissions and C sequestration in natural, restored, and former tidal wetlands across salinity gradients in 5 estuaries in the PNW.

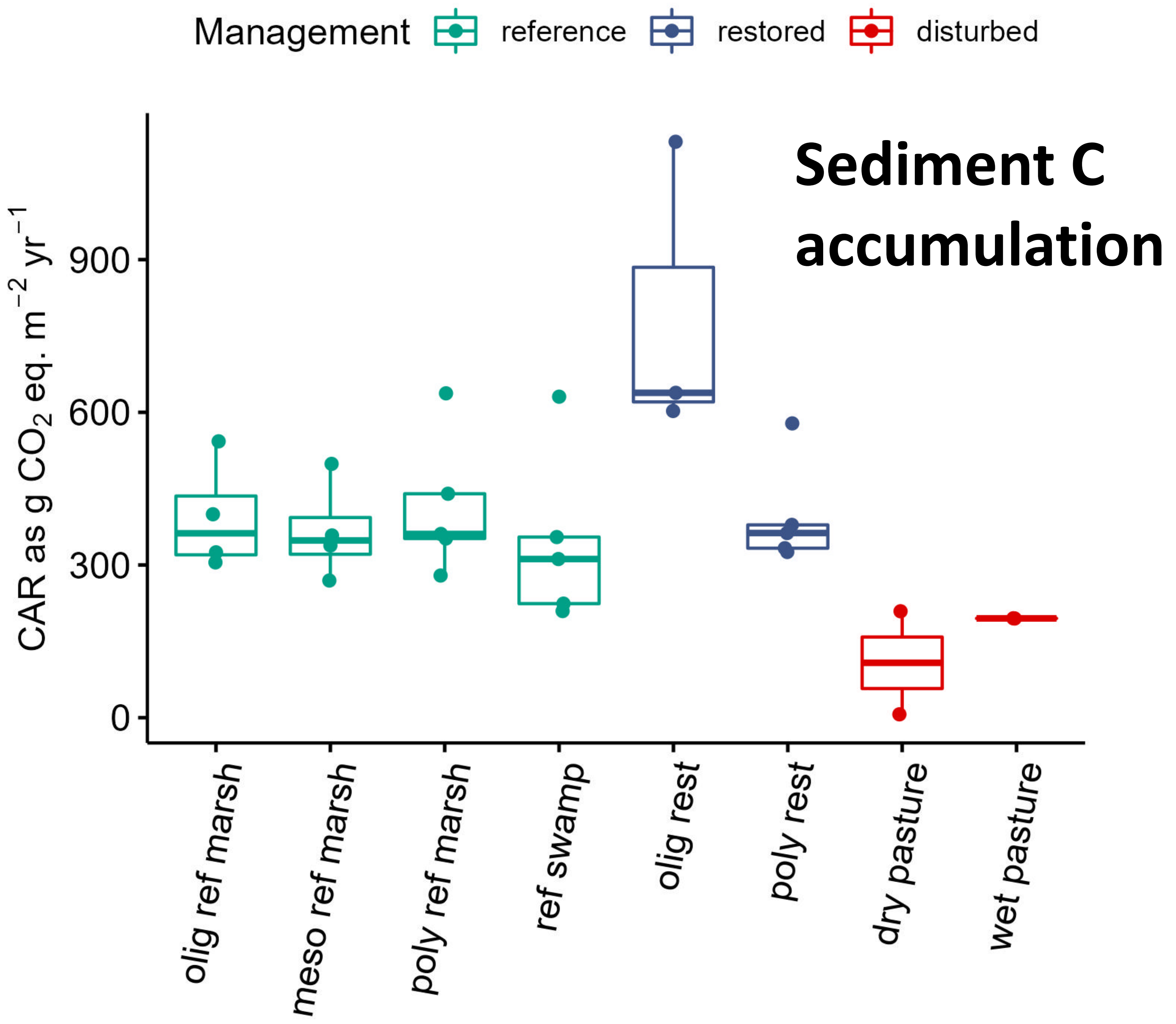


Distribution of Sampling Sites

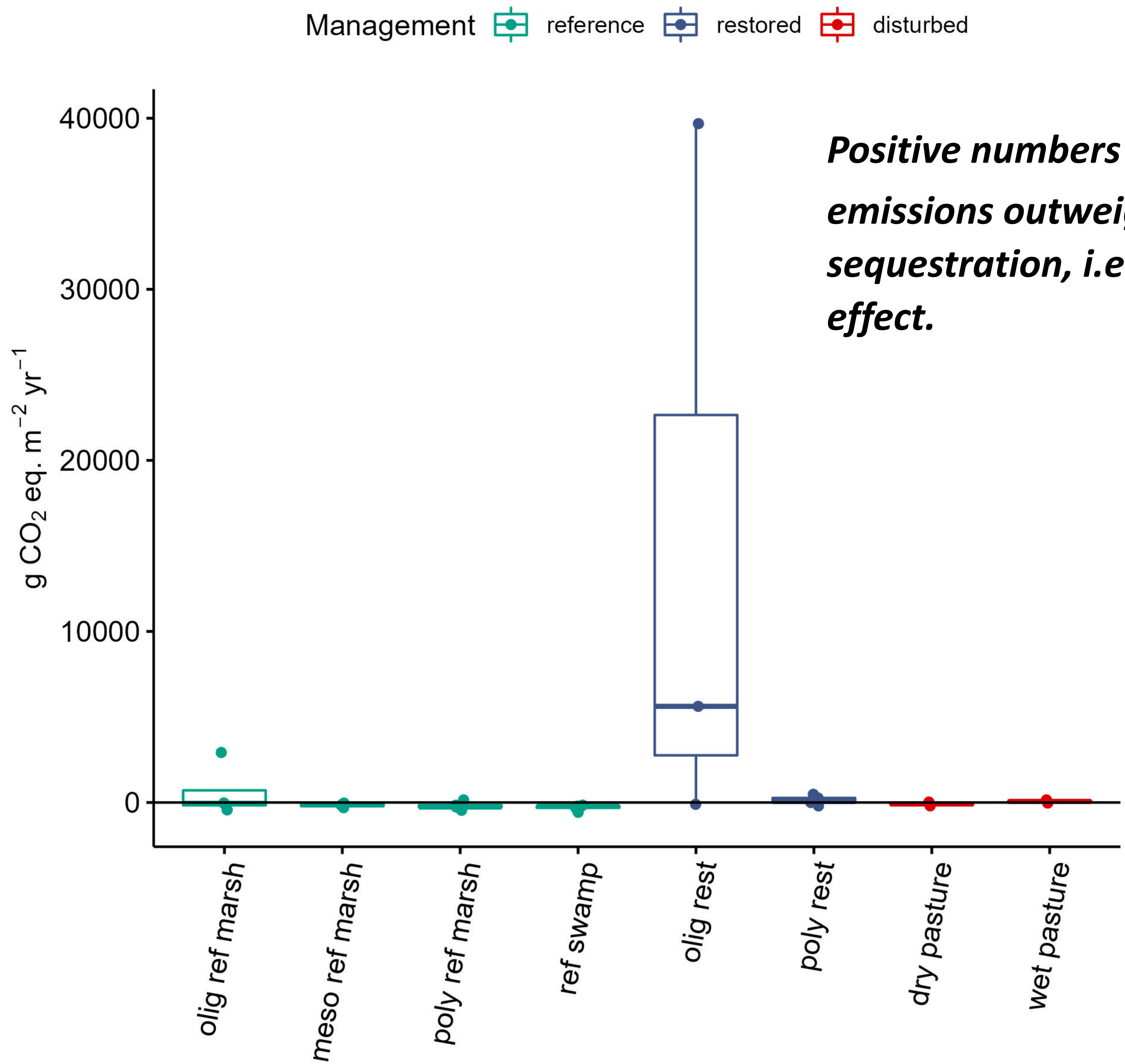
	Annual CH_4	Soil C accum. (CAR)	Radiative balance
Fr./oligo. reference marsh	4	4	4
Meso. reference marsh	4	4	4
Poly. ref. marsh	6	5	5
Ref. swamp	5	5	5
Fr. /oligo. restored marsh	3	3	3
Meso./poly. restored marsh	6	5	5
Dry pasture	5	2	2
Wet pasture	3	2	2
Total	36	30	30



CH_4 Fluxes as CO_2 equivalents with 100 yr SGWP (45)

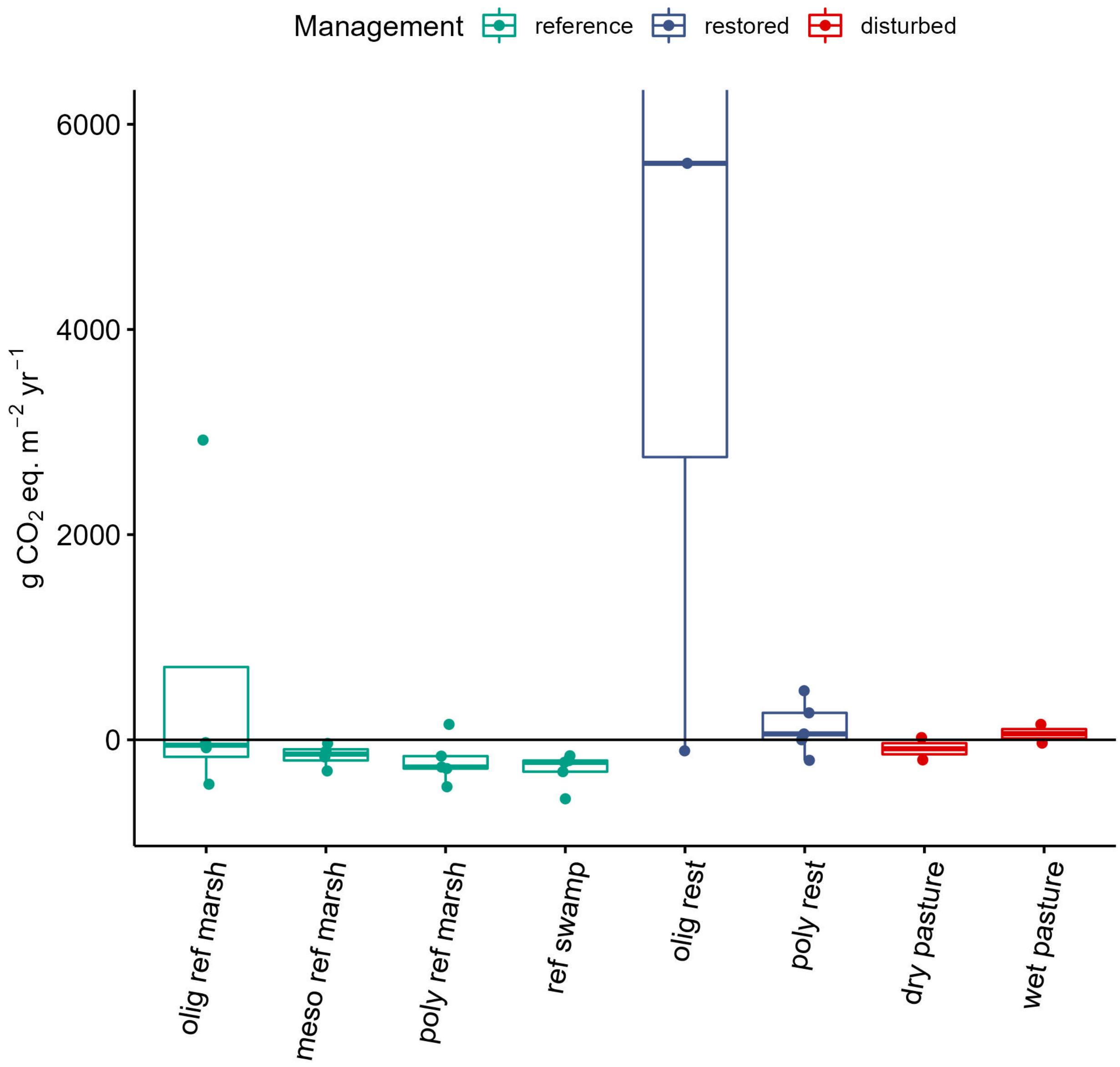

Management
reference
restored
disturbed
Sediment C accumulation
CAR as g CO_2 eq. m^{-2} yr^{-1}
900
600
300
0
olig ref marsh
meso ref marsh
poly ref marsh
ref swamp
olig rest
poly rest
dry pasture
wet pasture

20-year Radiative Balance

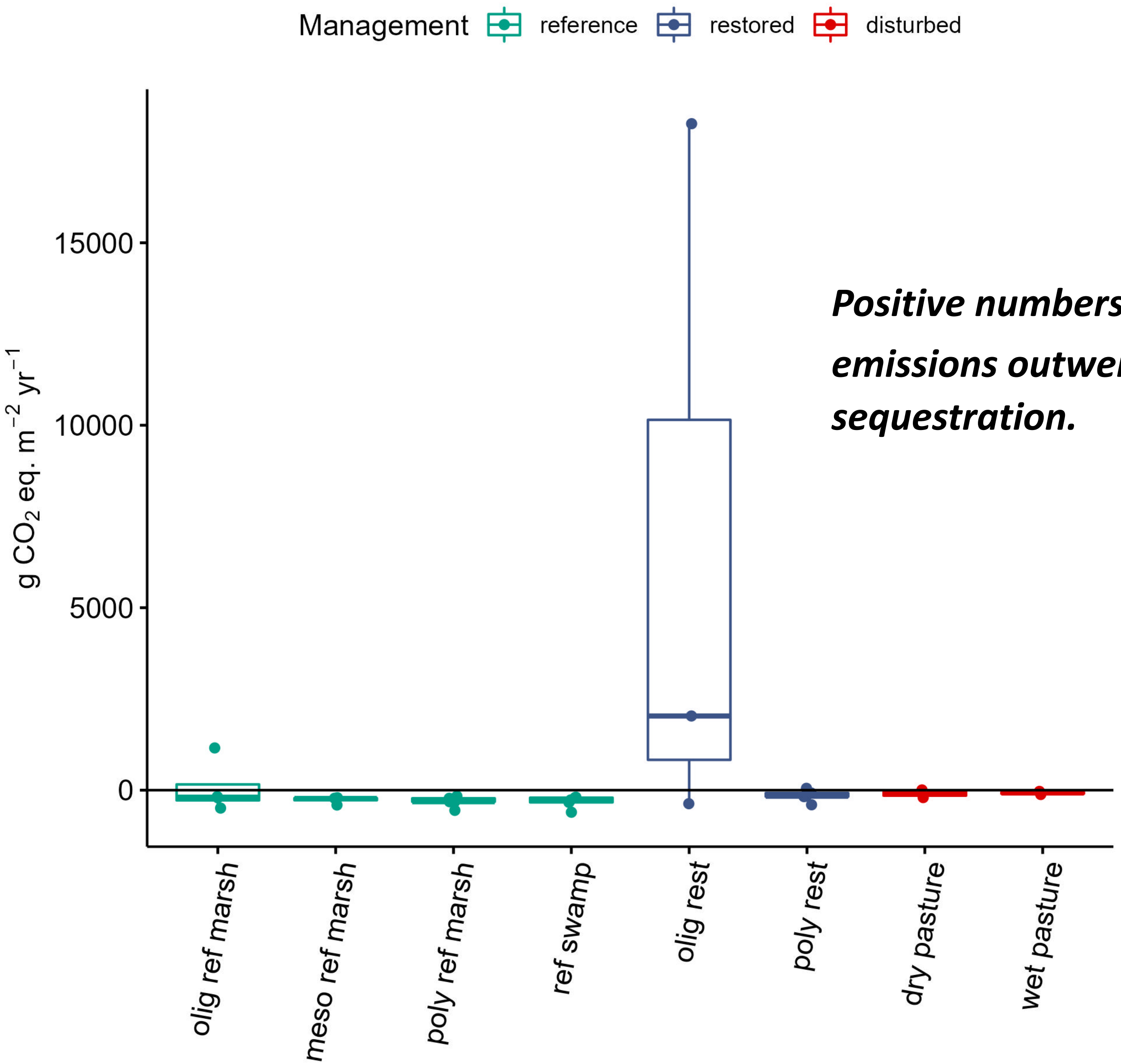


Positive numbers indicate CH_4 emissions outweigh soil C sequestration, i.e., a net warming effect.

20-year Radiative Balance *(One outlier not shown)*

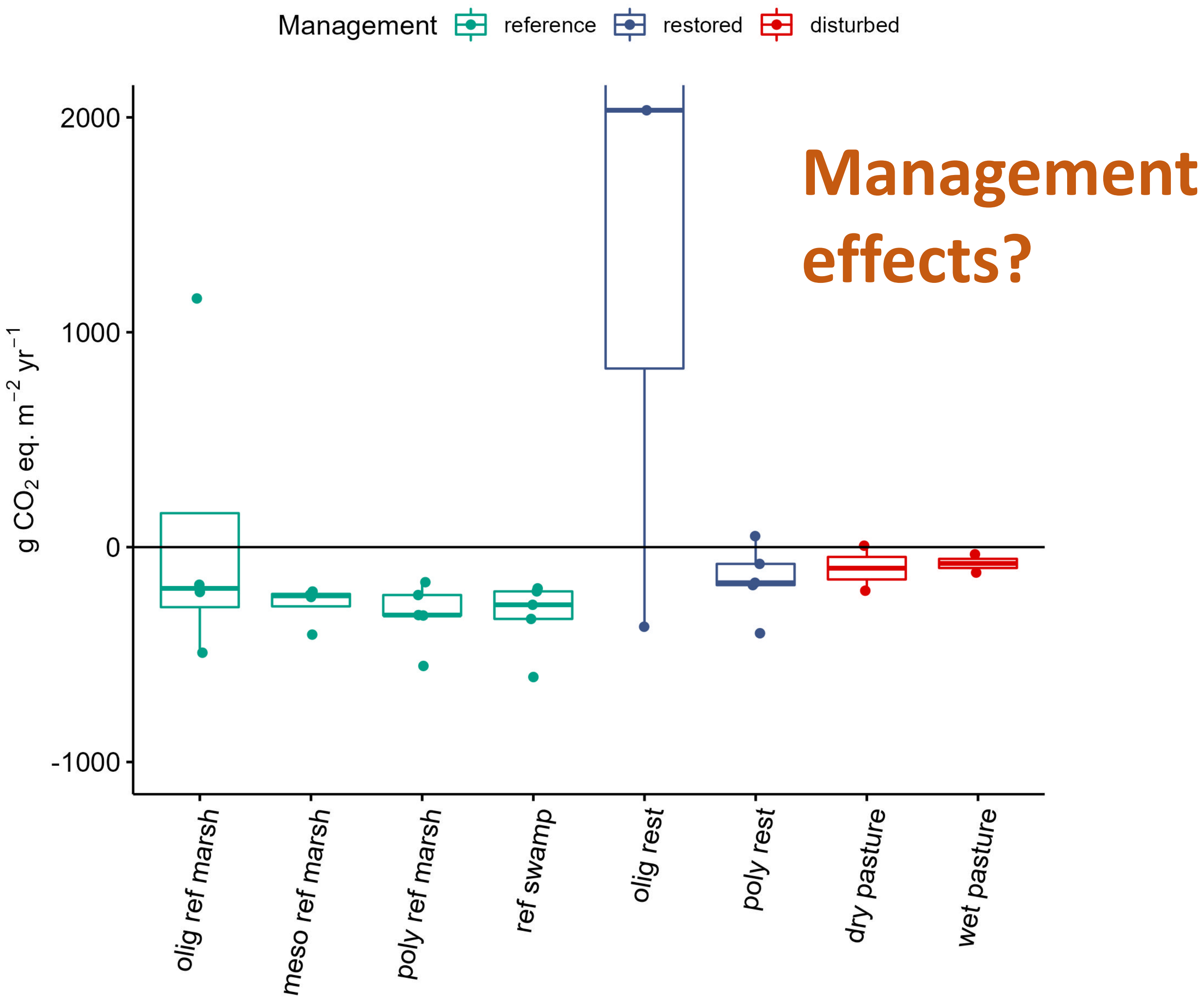


100-year Radiative Balance



Positive numbers indicate CH_4 emissions outweigh soil C sequestration.

100-year Radiative Balance *(One outlier not shown)*



Conclusions

- The variability in CH_4 fluxes dominates the climate balance of PNW tidal wetlands. This variability cannot be solely explained by salinity classes.
- Restoration often results in low elevation sites that have high CH_4 emissions. Prioritizing saline wetland restoration and hydrologic alterations that result in lower water tables, such as adding fill and providing channels for rapid tidewater removal, will result in lower CH_4 emissions.
- Restoration of wet pastures to polyhaline tidal sites is most promising from a climate forcing perspective.
- The difficulty of reliably measuring sediment C accumulation in disturbed and restored sites is a major obstacle in estimating their climate balance *(unless you have eddy flux towers)*.
- Future research should focus on horizontal gas fluxes and allochthonous vs. autochthonous C.

Thanks!

Acknowledgments

Matthew Schulz, Emil Sadofsky, Heather Perilat

Funding by NOAA (ESLR & NERR Science Collaborative)

Q&A

Q: How did the sampling strategy account for patchiness?

- **A (Chris):** We had six chambers per site in the study, and we accounted for some of that patchiness in plant communities. We had a site, for example, dominated by Carex lyngbyei, but we had a few open areas and we had one or two chambers that fell into those areas.
- **A (Scott):** We did transects away from the major waterway to intentionally sort of measure the hydrologic variability within the site and then after that it was basically random along a transect. I think with a regional approach like this we don't capture variability greater than any single site, but the intention was to capture regional variability and hopefully we've done a reasonably good job with the sampling scheme across all the different sites. You have 36 sites times six chambers per site, so we had lots of chambers in very different types of vegetation communities across the whole study. In the paper we look a little bit at plants but not too extensively because the study was not designed to look at plant effects on methane per se.

Q: What is the restoration age range for the polyhaline and oligohaline restored sites included here?

- **A (Scott):** They varied from about a year to about 25 years. It'd be the early 1990's I think were the older sites.

Q: Given the results of the radiative balance, how would you respond to the possible criticism that, over a 100 year timeframe, restoration of these ecosystems for climate benefits alone does not appear to be worth the effort and resources would be better used on protection of reference sites or on other methods to draw down carbon?

- **A (Scott):** In general, I would say that protection of existing sites is always really important, particularly if they have high soil carbon because if you lose that soil carbon it's a really major CO_2 emission to the atmosphere. So I would always prioritize protection. In terms of these fresh and oligohaline storage sites, I do think there are management activities that you could try to do to reduce the methane emissions and I discussed some of them. Either initially or overtime you would expect that they would rapidly rise in tidal elevation and eventually their methane emissions should decrease. On the other hand, there are lots of ecosystem benefits from these oligohaline marshes and I think we're often these days focused on carbon balances and climate forcing, but certainly, locally, the other ecological benefits of these sites are doing way more, in my personal opinion. But if you are doing it intentionally for carbon credits or something like that, then these results are really highly pertinent.

Q&A

Q: What take-home messages do you think most stakeholders need to know, and what parameters are the most significant as my organization collects data on Blue Carbon Systems?

- **A (Katrina):** There are many take-home messages but one is that we could get very different conclusions on management implications if we just focused on stocks vs carbon accumulation rates vs greenhouse gas emissions and so we're finding that it's important to measure all of them to understand the different considerations in managing for carbon. I would also reiterate what Scott said that we could get really into the details about carbon but we still want to be restoring these ecosystems because they are so important for other reasons too. So, if we're restoring maybe there are ways we can accelerate that trajectory towards lowering carbon emissions by adding sediment or increasing channel networks but I think we should still be focusing on restoration for other reasons.
- **A (Craig):** It's tough to say what parameters are most significant without knowing what other data might be available in this person's region. figuring out what's missing might be one place to start and start filling some data gaps.

Q: Charting restoration effects is difficult because of the extended recovery times. Do you have a sense of recovery age that is necessary to yield stable results?

- **A (Scott):** No, not yet. We're in the process of modeling, where we're beginning to think about these things and also sea level rise within those. Many of these restored sites. as Katrina showed, accrete sediments very rapidly, so I think up to a centimeter or more per year. It doesn't take 100 years to accumulate a whole lot of elevation in some of these sites. They are accumulating an inch in several years at some of them. It's more rapid that moving up in the tidal frame than the question presented, in many of our sites.
- **A (Katrina):** At the restored sites 1-3 cm per year, initially
- **A (Chris):** What we don't really know is how rapidly soil and groundwater conditions change. We've only within the last decade or 15 years been starting to monitor groundwater in tidal wetland in the PNW, so we don't yet have a good sense of how that water table is changing over time. Presumably as the wetland gains elevation it's water table will be more similar to a reference site, which trevor showed had pretty low methane emissions, but we don't java good empirical data on that yet.