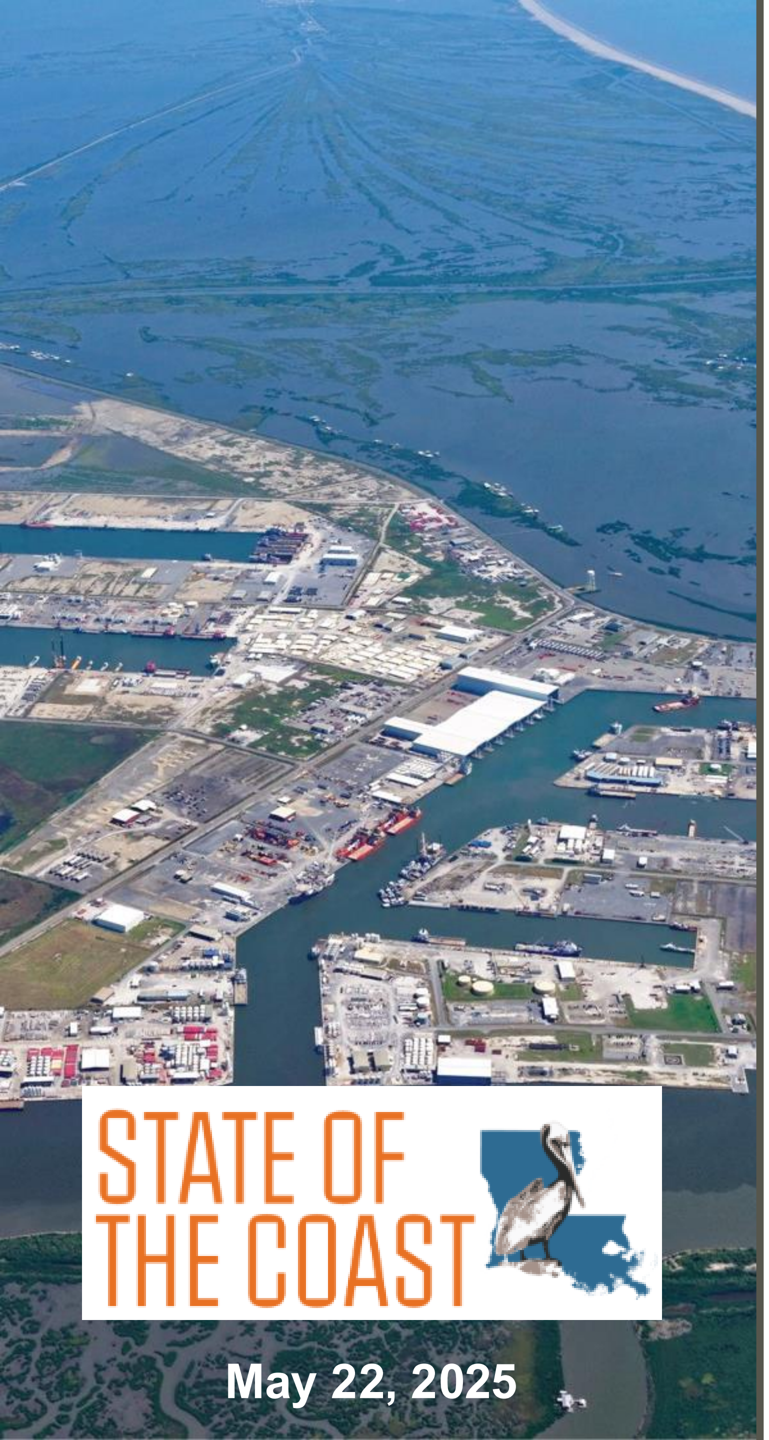


THE WATER INSTITUTE

QUANTIFYING SPATIAL AND TEMPORAL UNCERTAINTY IN LOUISIANA'S COASTAL CARBON

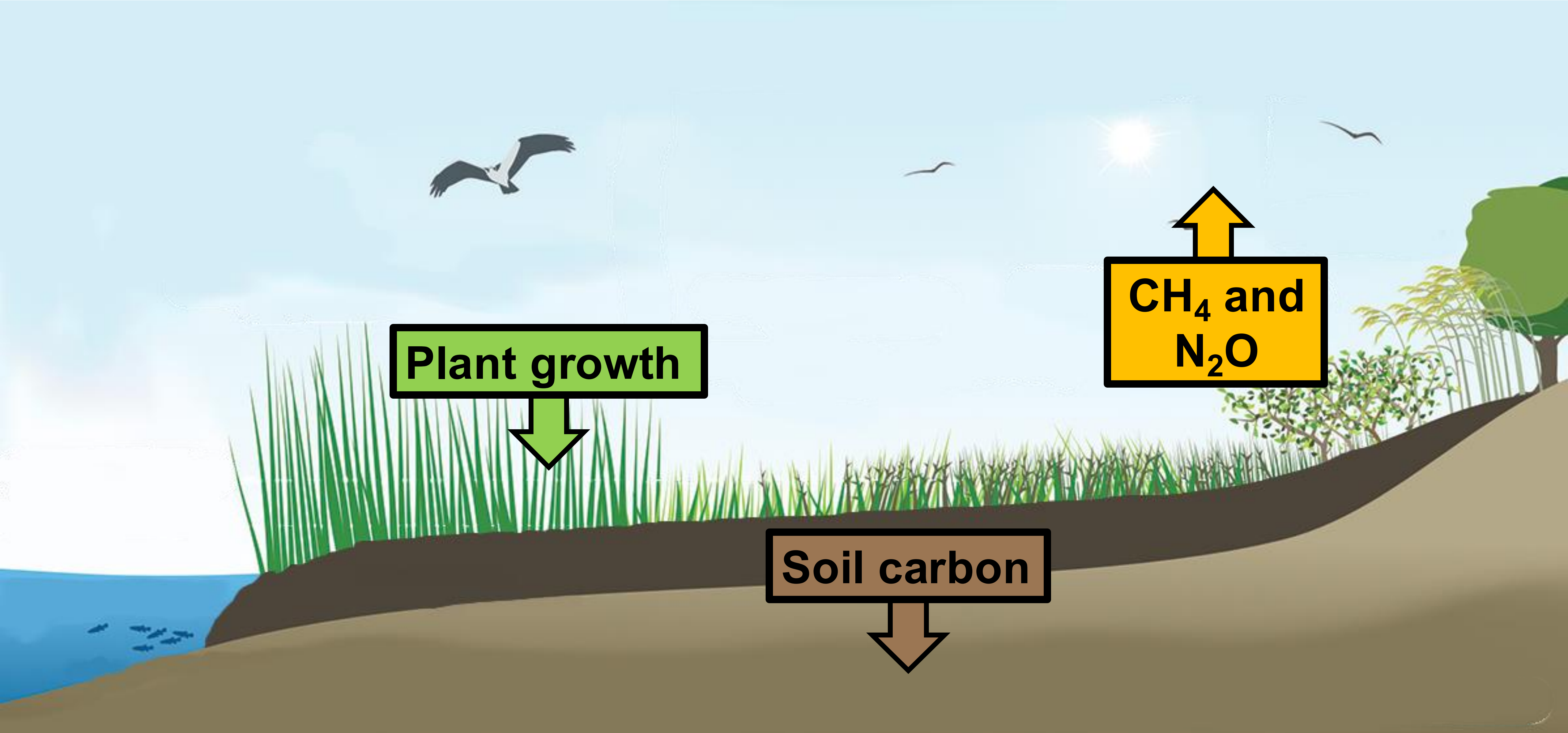
Shawn Doyle

sdoyle@thewaterinstitute.org

Co-Authors: Hoonshin Jung, Tim Carruthers

5/22/2025

Quantifying Net Carbon Flux



Current unknowns under a changing landscape

Current Assumptions and Uncertainties

How much CO_2 is captured each year by plants?

ANPP: Aboveground net primary productivity

Varies over space and time

species composition
soil nutrients
temperature
precipitation
hurricanes/storms
freeze events

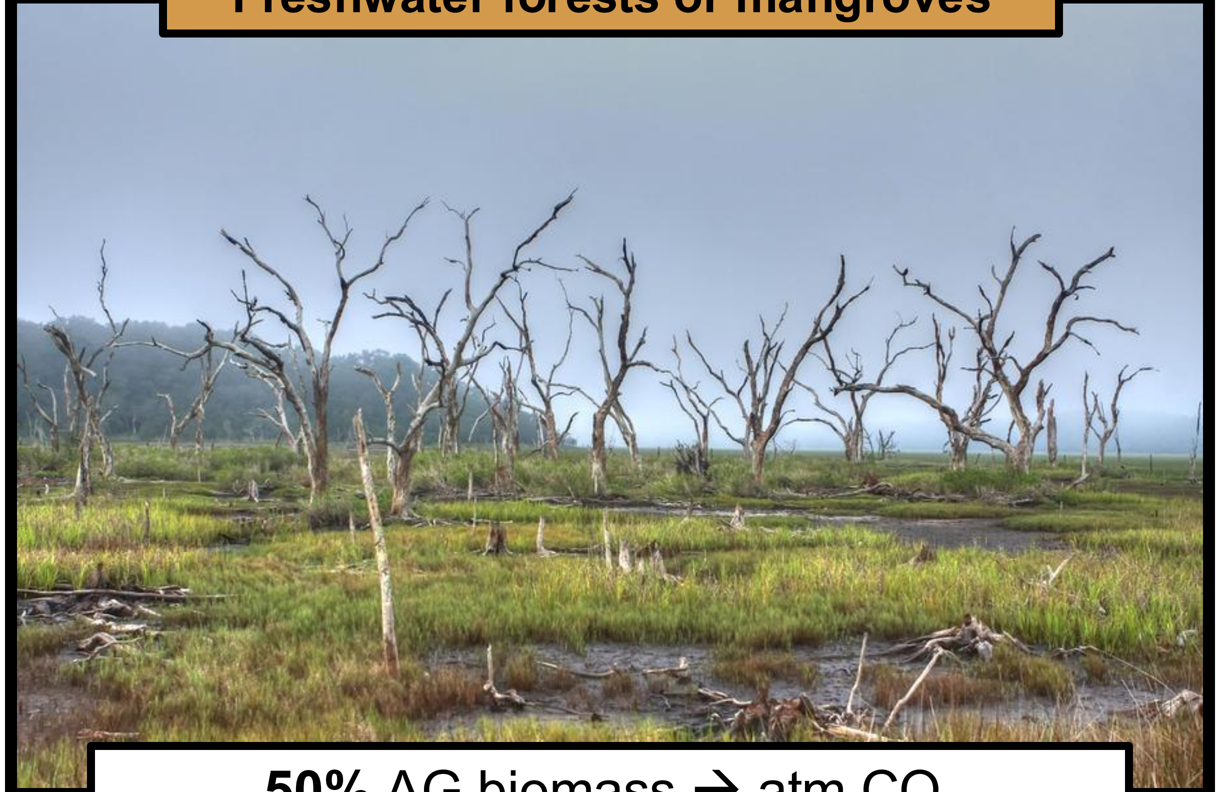
What happens to plant biomass?

After conversion to open water, all the aboveground biomass is assumed to die.

Herbaceous marshes

100% AG biomass → atm CO_2

Freshwater forests or mangroves

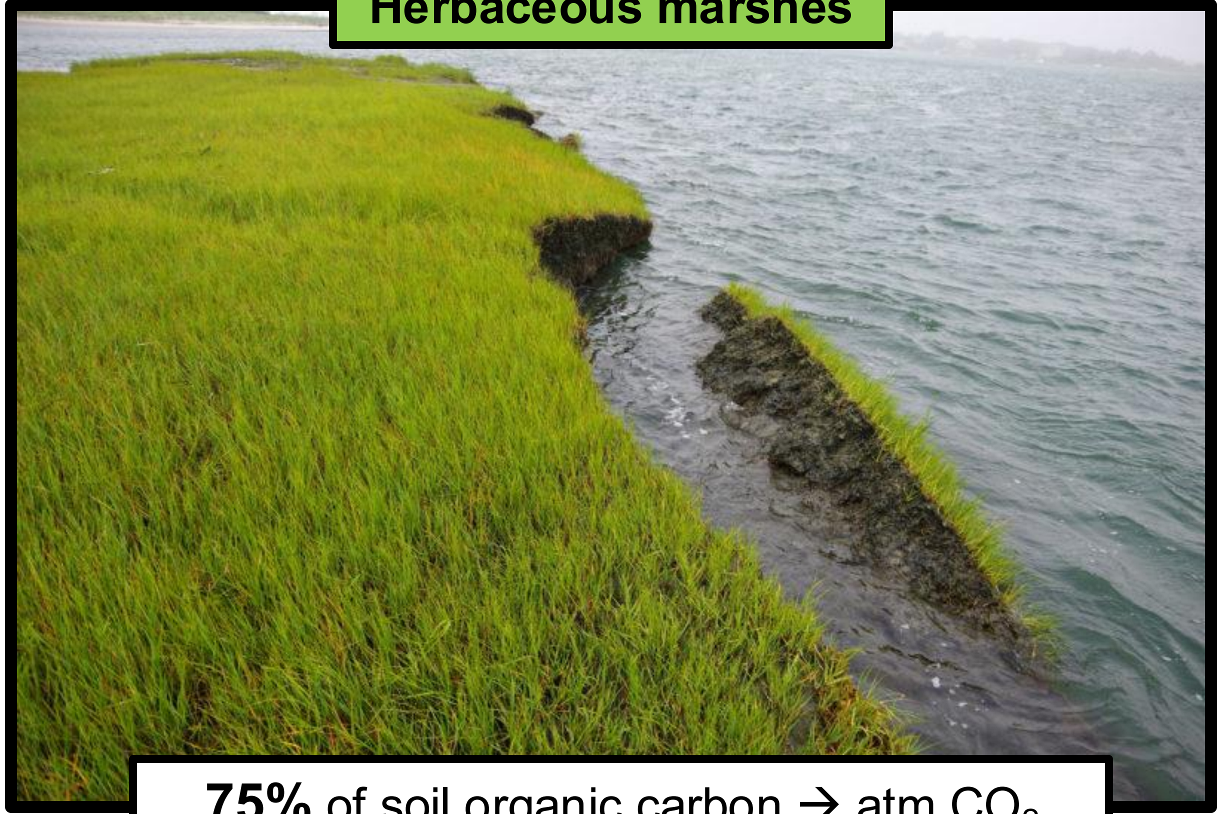


50% AG biomass → atm CO_2

What is the fate of stored soil carbon stocks?

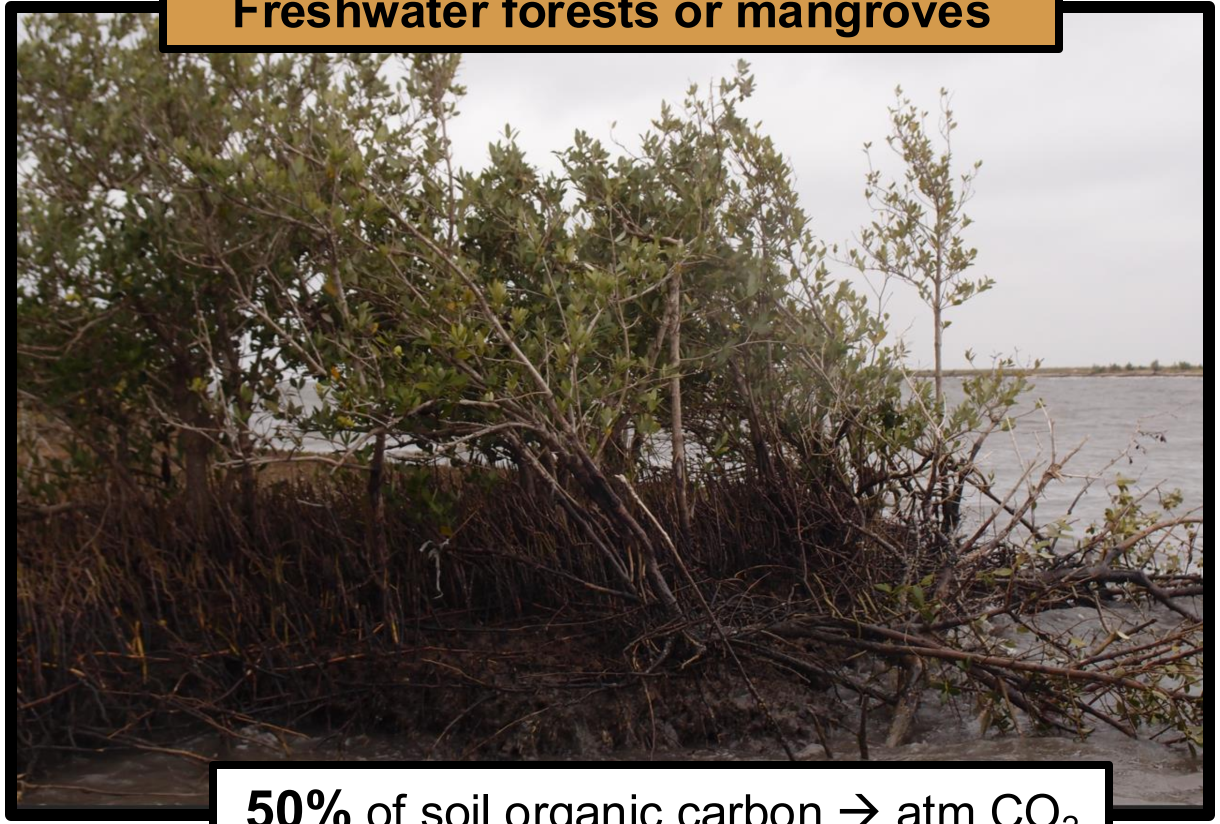
After conversion to open water, the **<u>top ~1 m</u>** of soil erodes.

Herbaceous marshes



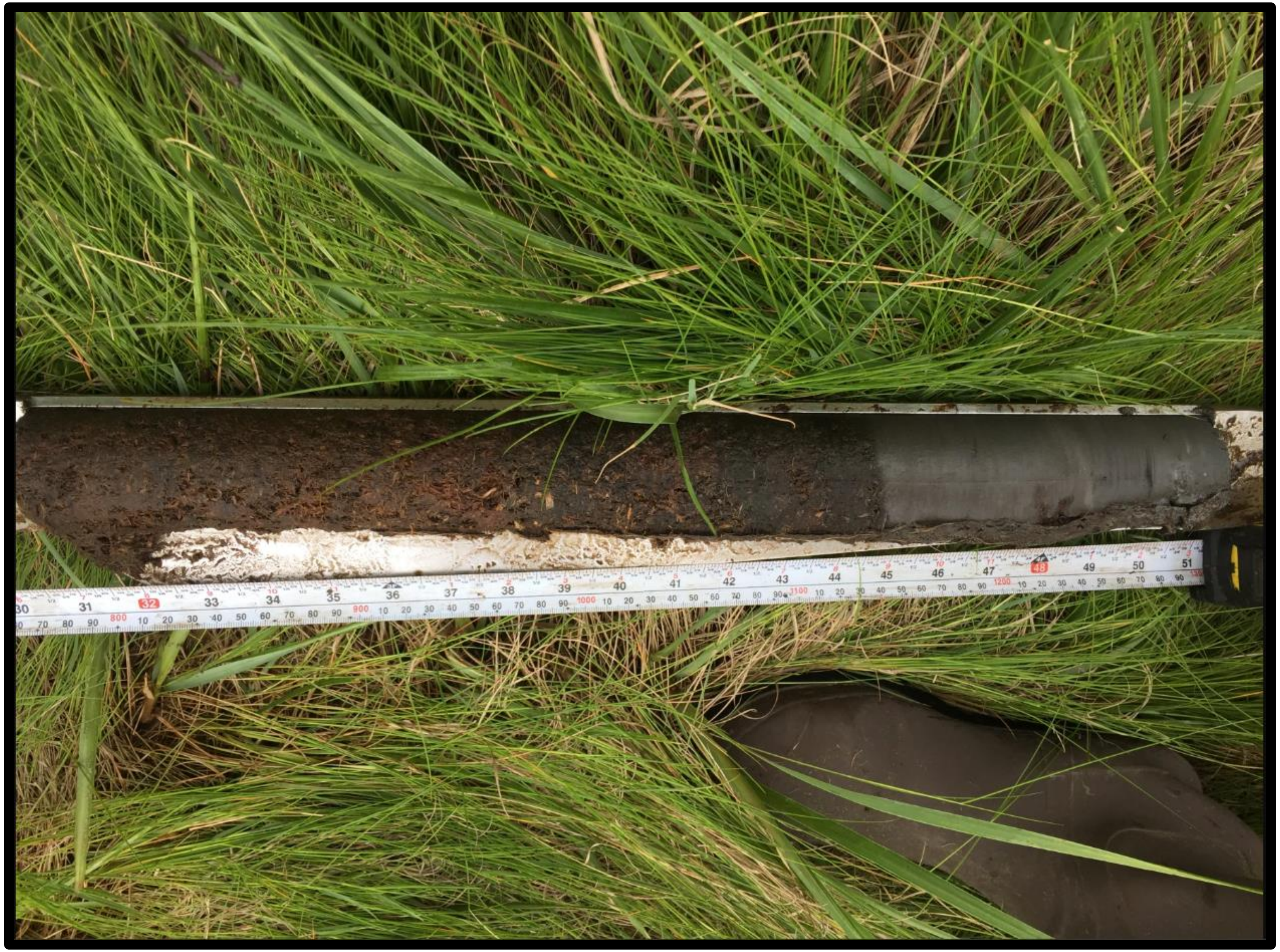
<u>75%</u> of soil organic carbon → atm CO_2

Freshwater forests or mangroves



<u>50%</u> of soil organic carbon → atm CO_2

How much soil carbon is being eroded?



<u>Assumption</u>

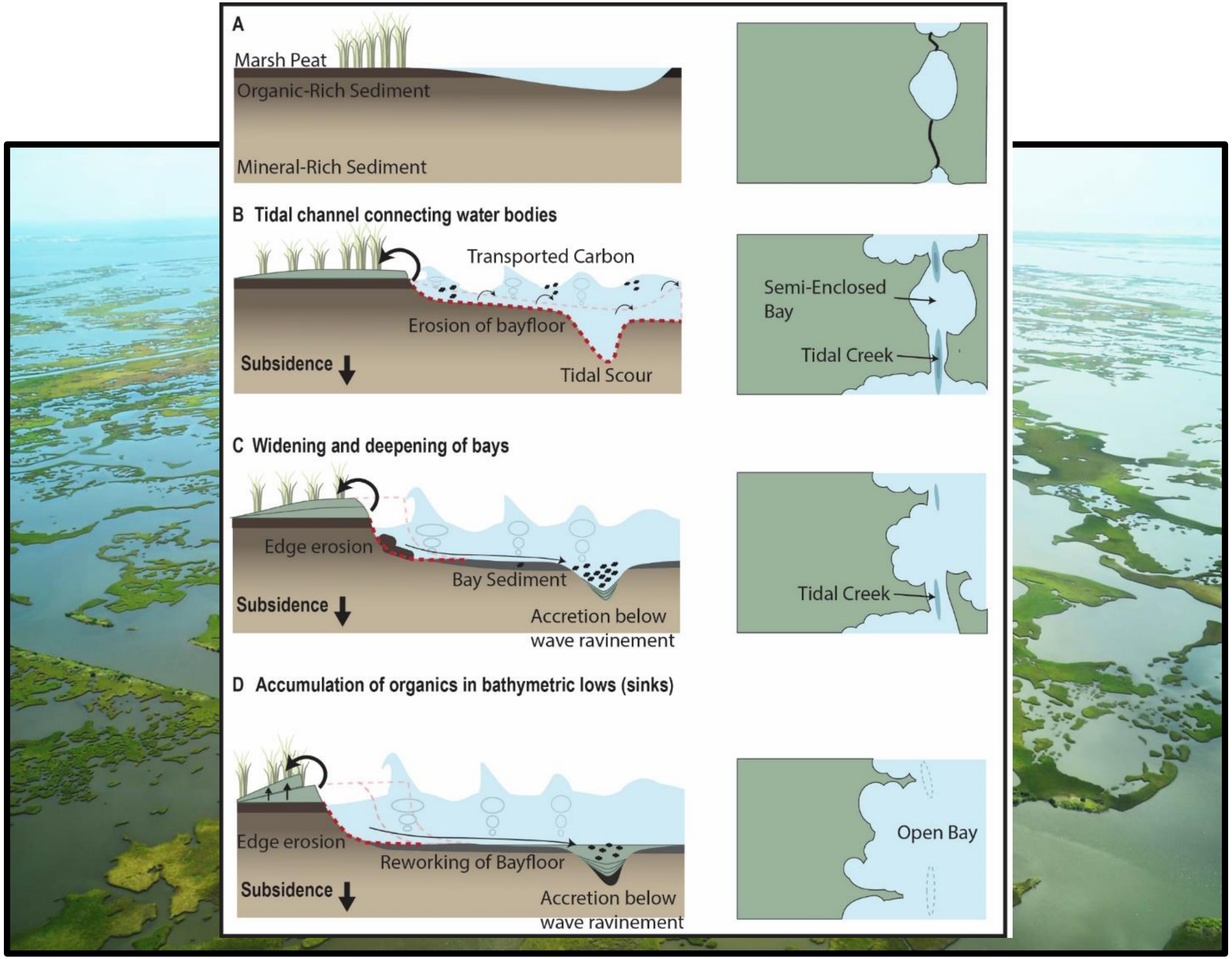
The top 1m of soil stores ~189 years of accumulated soil carbon

Baustian et al. 2021

Uncertainty in methane emissions

Habitat	CH_4 and N_2O flux (tons CO_2e ha^{-1} y^{-1})
Fresh forested wetland	24.6 ± 24.1
Freshwater marsh	29.6 ± **33.58**
Intermediate marsh	29.6 ± **33.58**
Brackish marsh	5.9 ± 6.3
Saline marsh	3.8 ± 9.3
Mangroves	9.6 ± **20.0**

How much soil carbon accumulates annually in open water habitats?

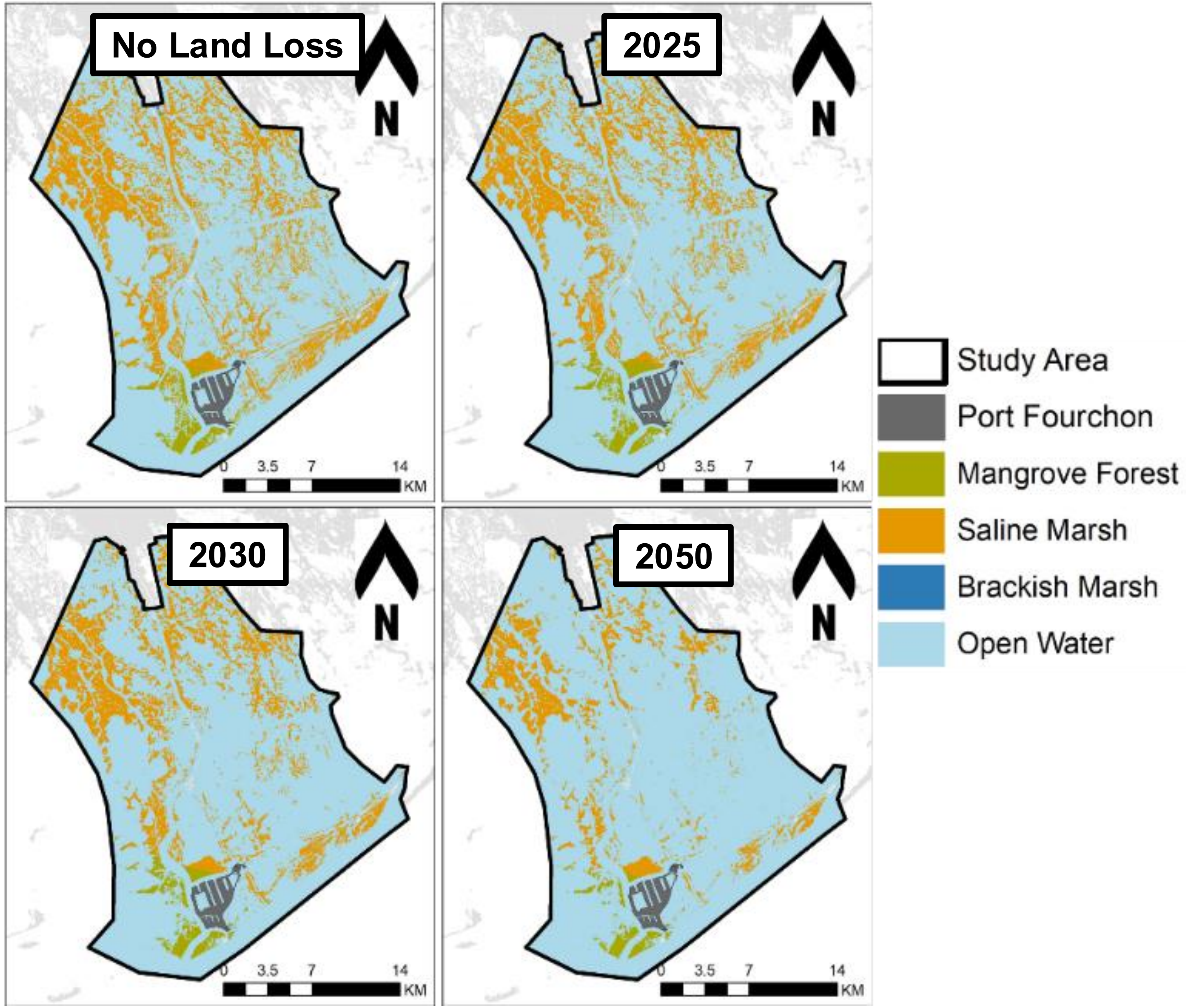


On average, open water habitats accumulate
8.0 ± 0.7
tons CO_2e ha^{-1} per year.

Not all open water areas are the same.

Open bays, semi-enclosed bays, tidal creeks, paleo-distributary channels

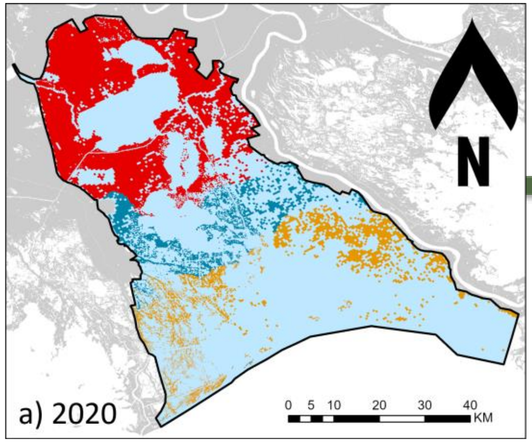
Modeling Coastal Carbon Flux

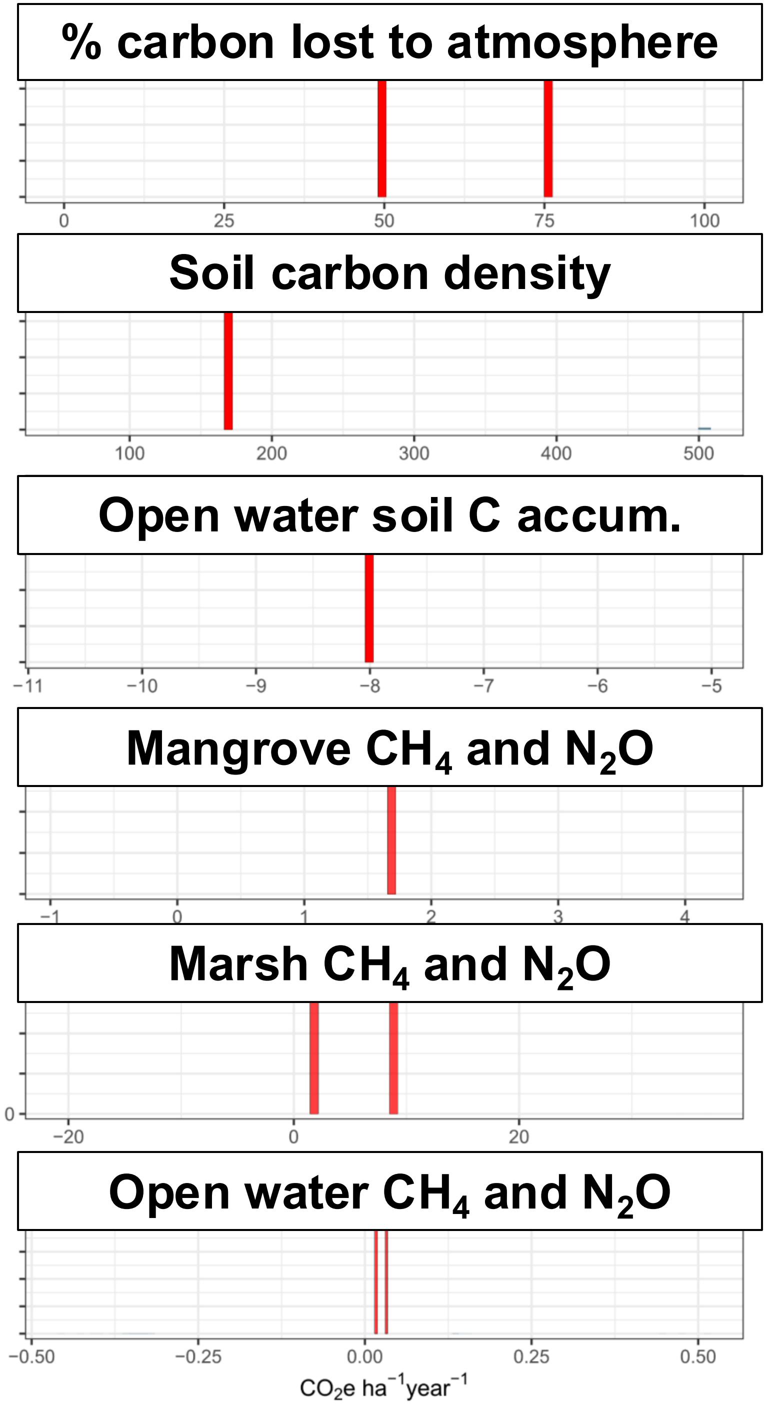


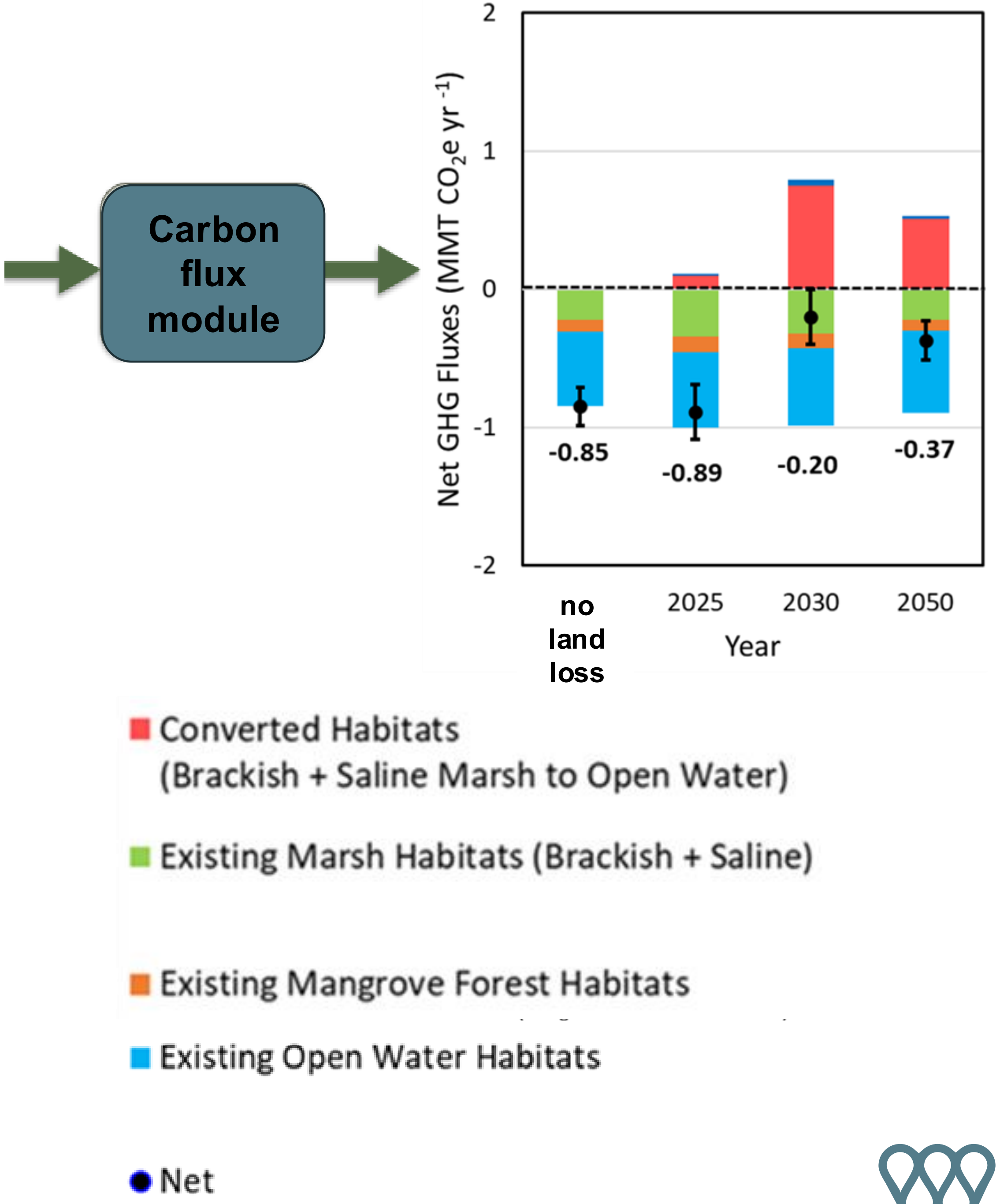
Landscape and Habitat Changes

- Delft3D-FM with coupled hydrodynamic, morphology, and waves models
- Vegetation predicted with LAVegMod.PF
- Assumed RSLR: 0.25m by 2025 (Scenario S07-RCP 4.5)
- Subsidence rates derived from LACMP 2023
- 27 synthetic tropic storm events

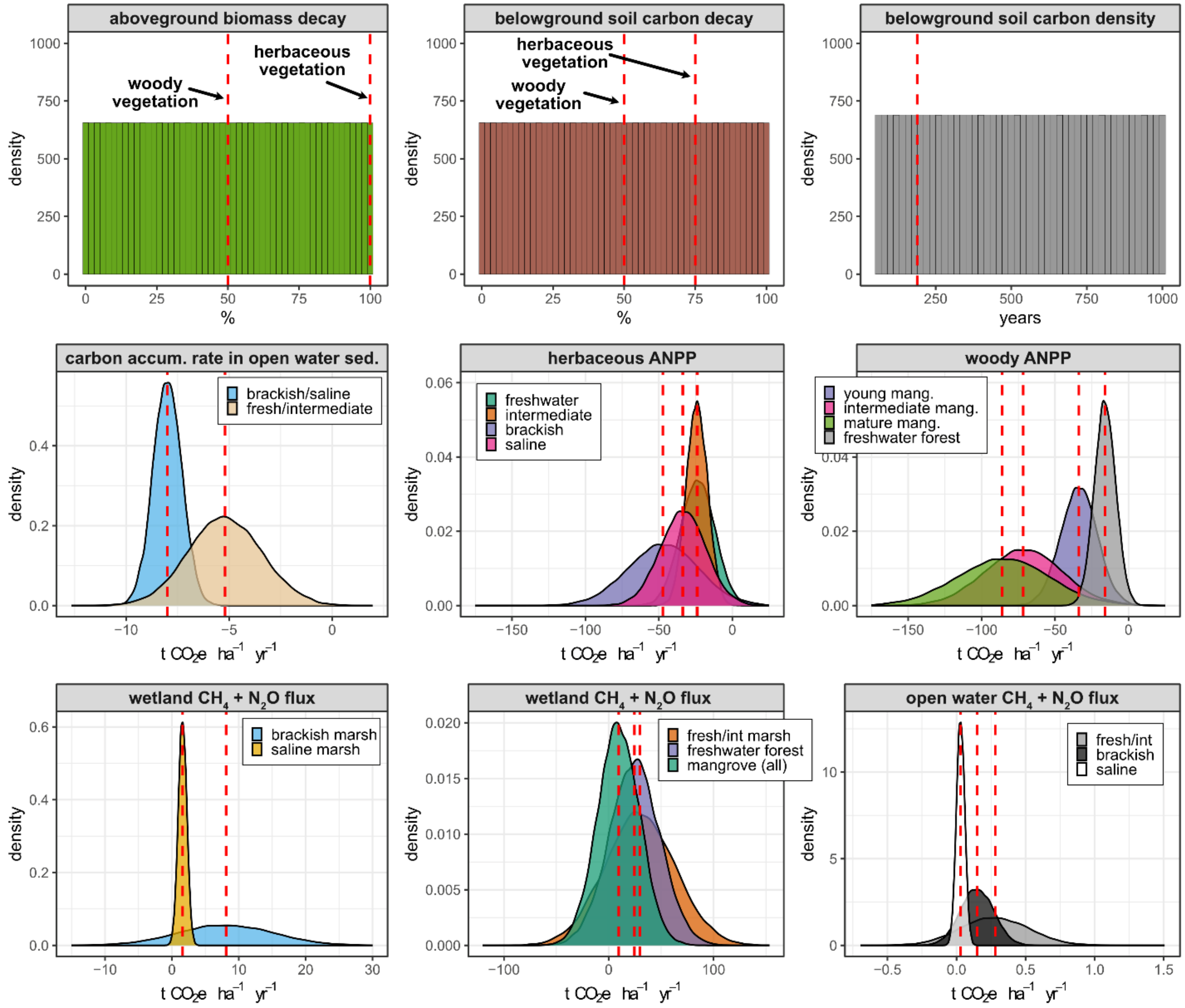
Net carbon flux using current assumptions







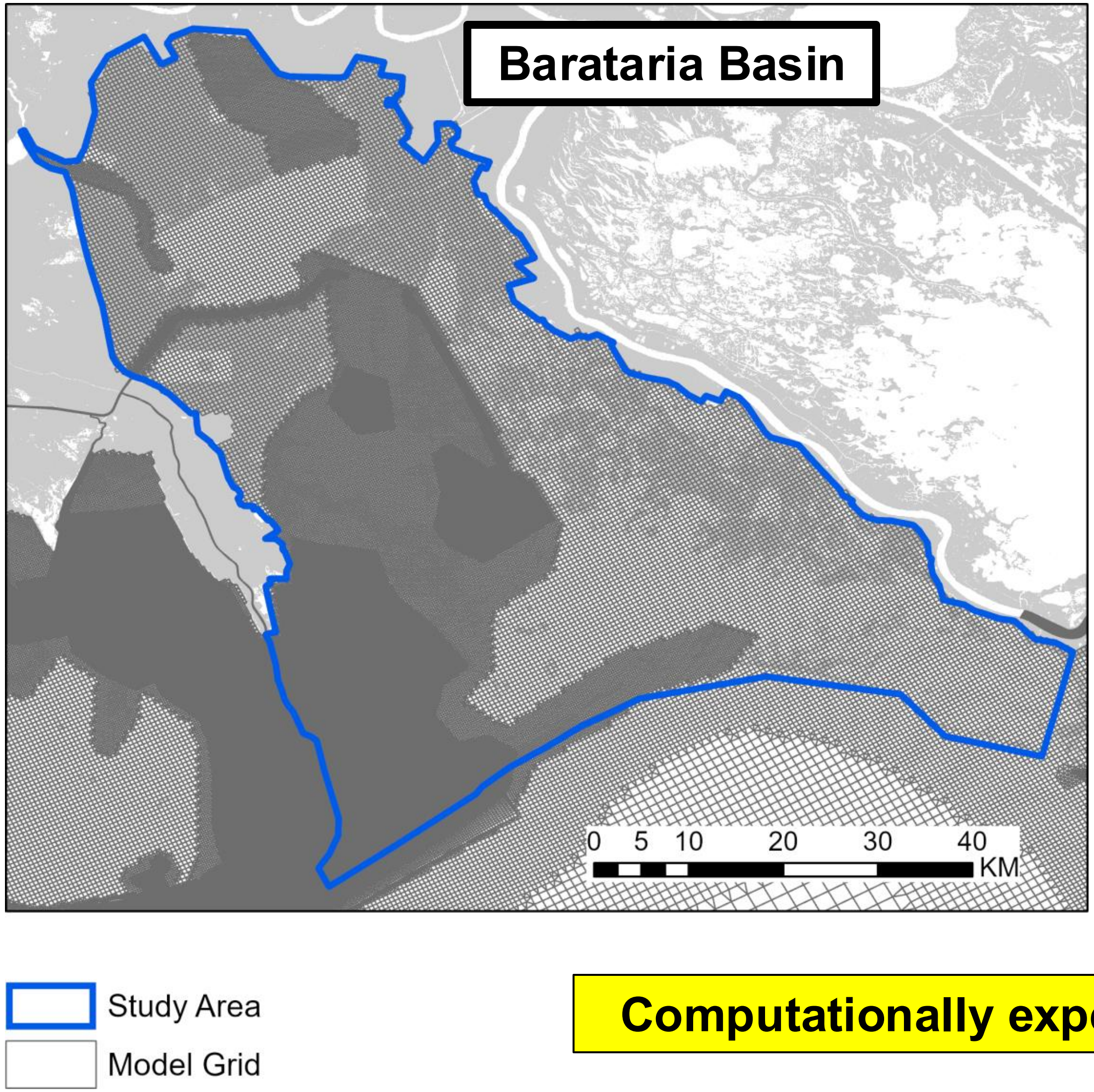
Which areas of uncertainty—*if reduced*—would yield the highest return in developing a viable blue carbon market???



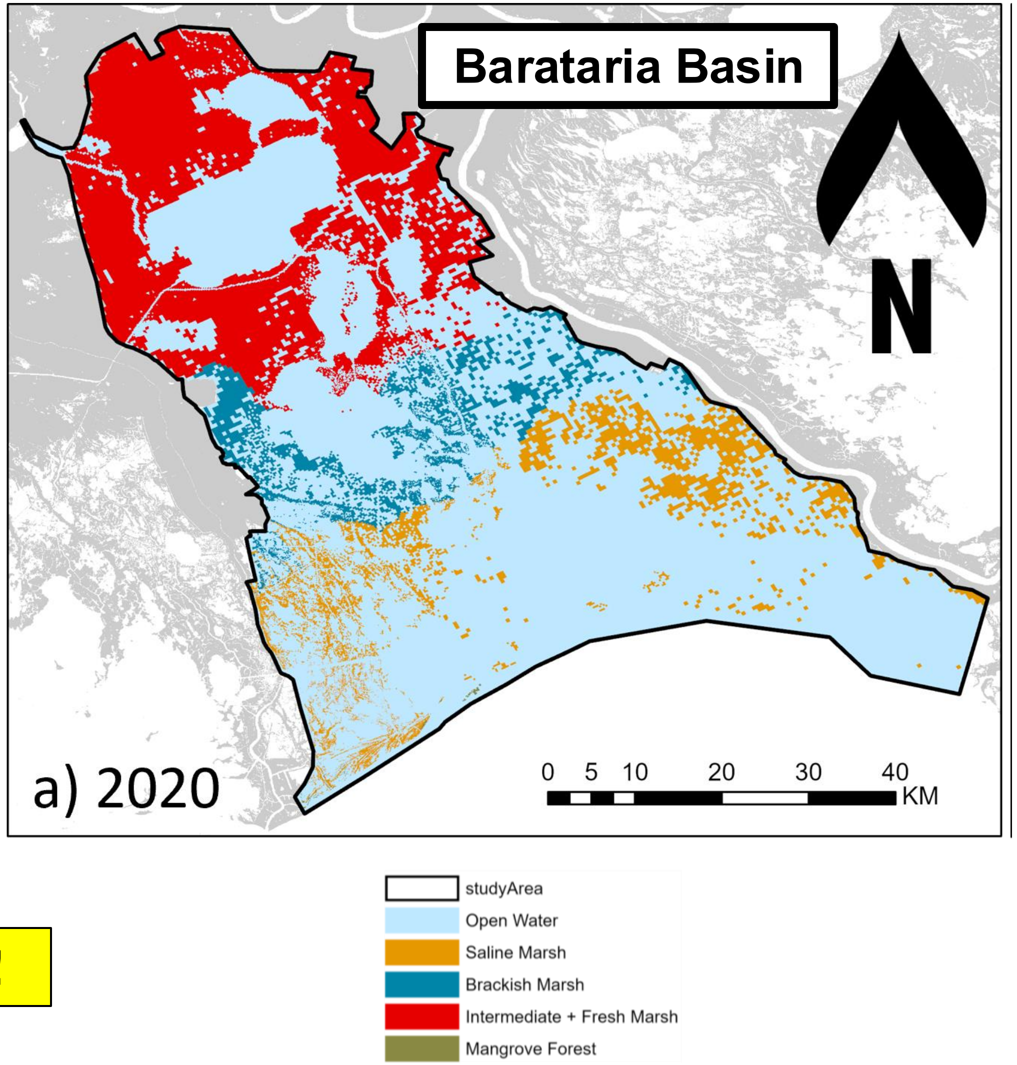
Net carbon flux using minimal assumptions

Instead of using a single, assumed value for each parameter (i.e. the average flux per habitat), we will allow each parameter to take any value within a distribution or range.

How do we calculate thousands of parameter possibilities across tens of thousands of grid cells?



Computationally expensive!

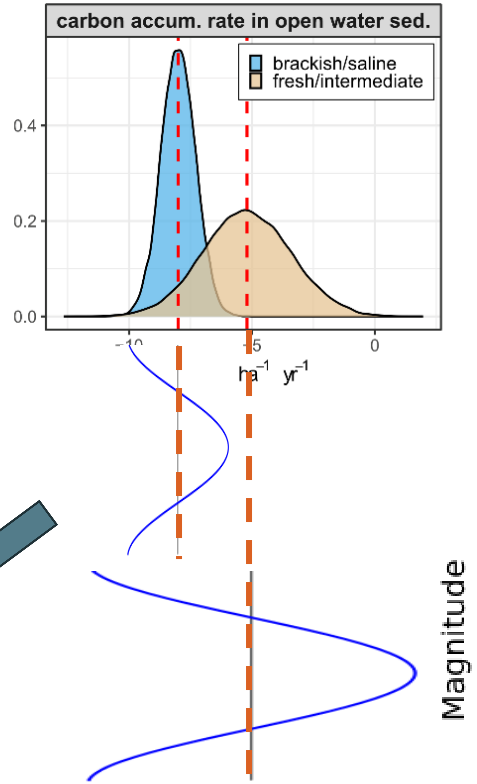


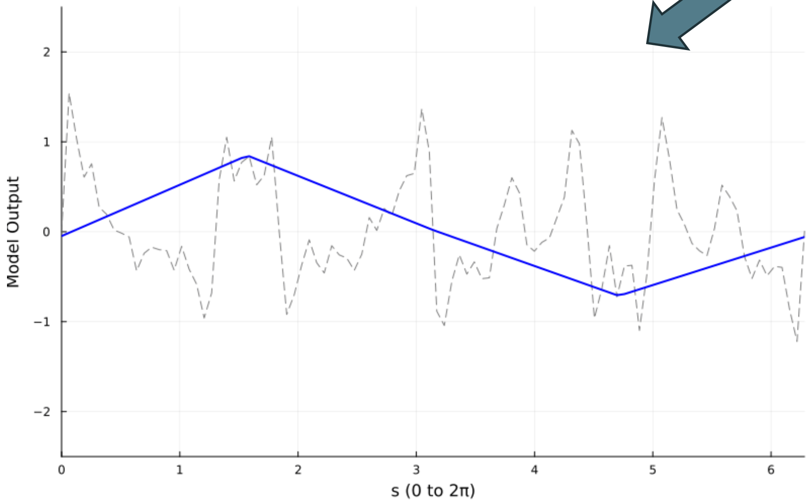
Extended Fourier Amplitude Sensitivity Test (eFAST)

Step 1: Create periodic search curves for each parameter.

$$x_i = F_i^{-1}\left(\frac{1}{2}+\frac{1}{\pi}\arcsin(\sin(\omega_i s))\right), \quad -\pi \leqslant s \leqslant \pi,$$

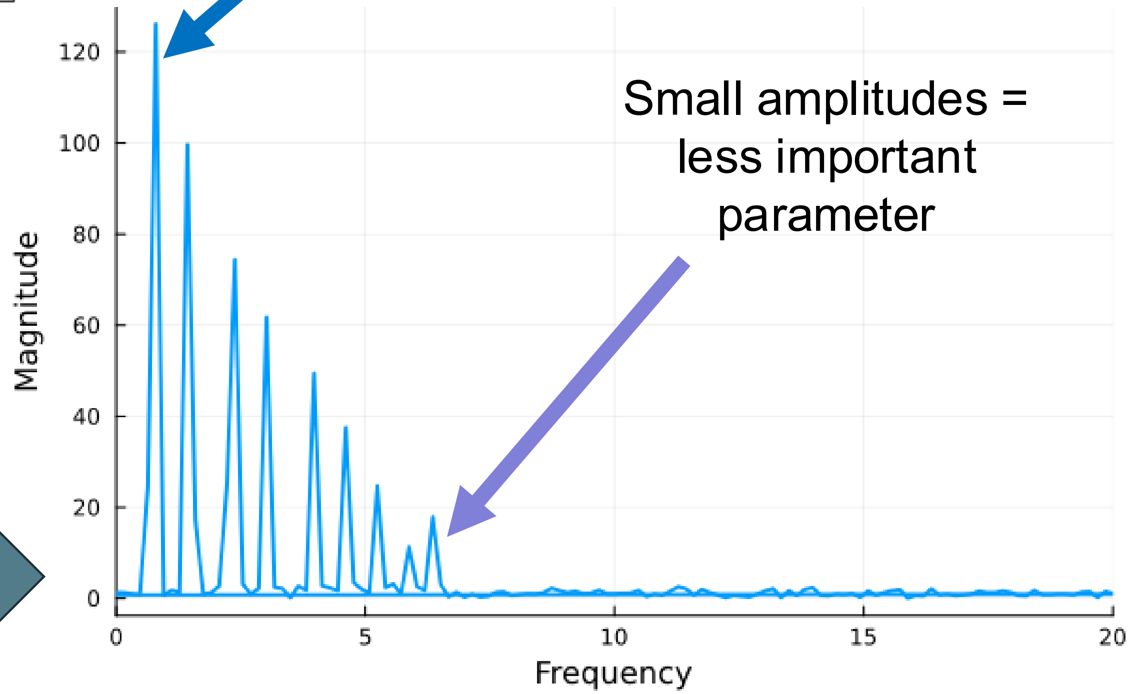
Step 2: The carbon flux calculation, which had ***dozens*** of parameters, now has ***one*** parameter (*s*). Carbon flux can now be repeatedly calculated across thousands of input possibilities ***efficiently***.





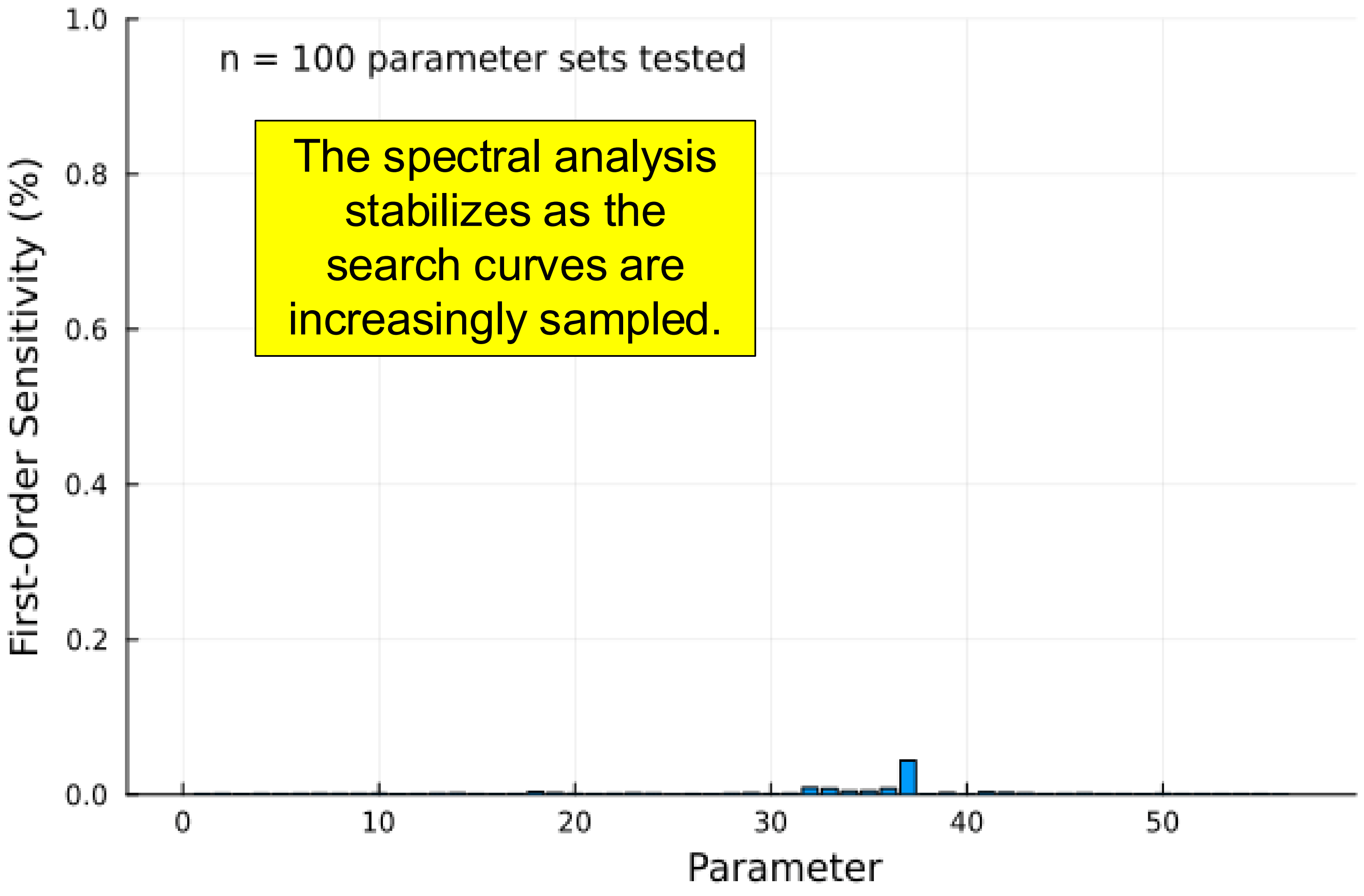
Large amplitudes = Important parameter

Small amplitudes = less important parameter



Step 3: Spectral analysis (Fourier decomposition)

Extended Fourier Amplitude Sensitivity Test (eFAST)



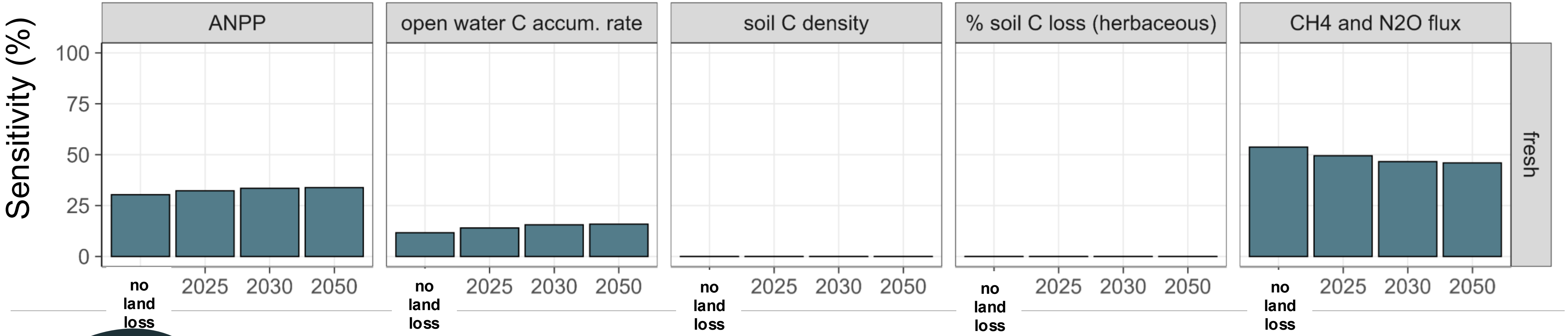
Adopting modern languages such as Julia offers the potential for a dramatic increase in speed over more traditional options like R or Python

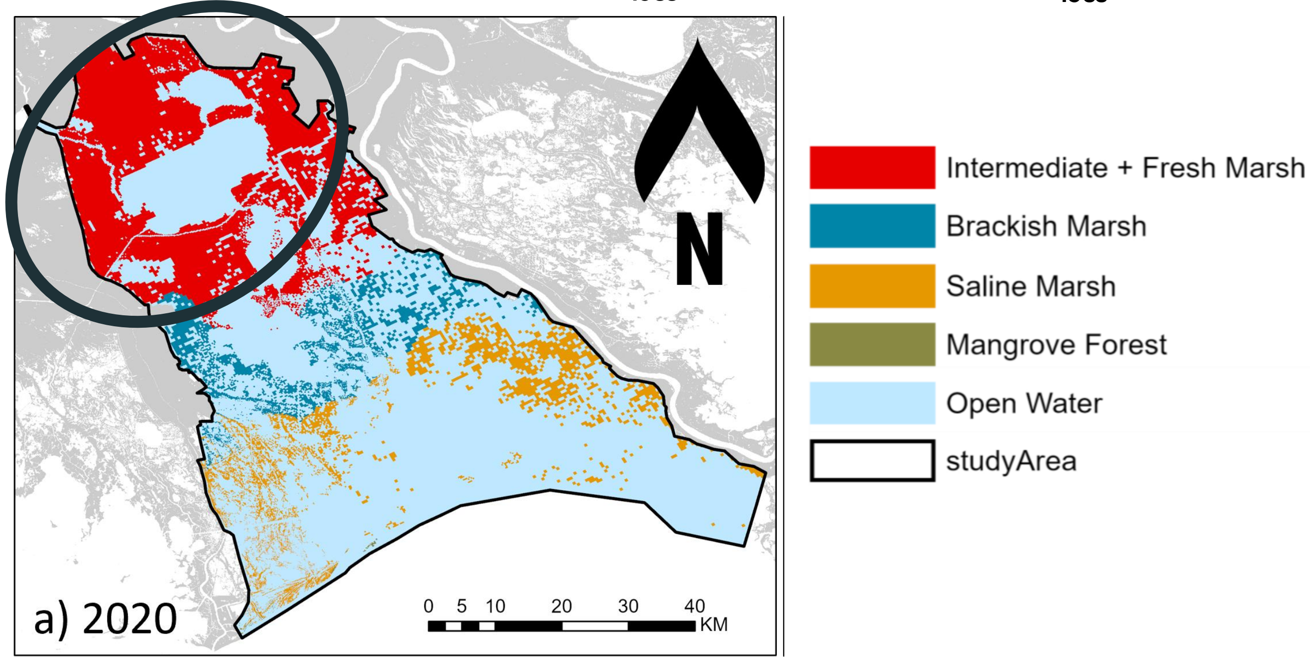
<u>120,000 module iterations</u>

julia **≈ 1.9 hours**

R / Python **≈ 30 to 45 days**

Sensitivity Analysis (eFAST method): Barataria Basin



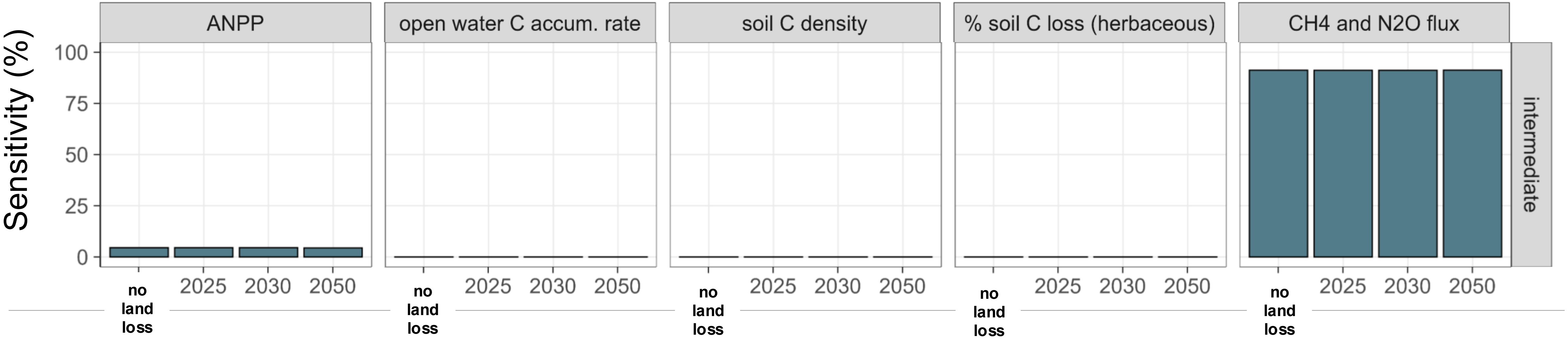


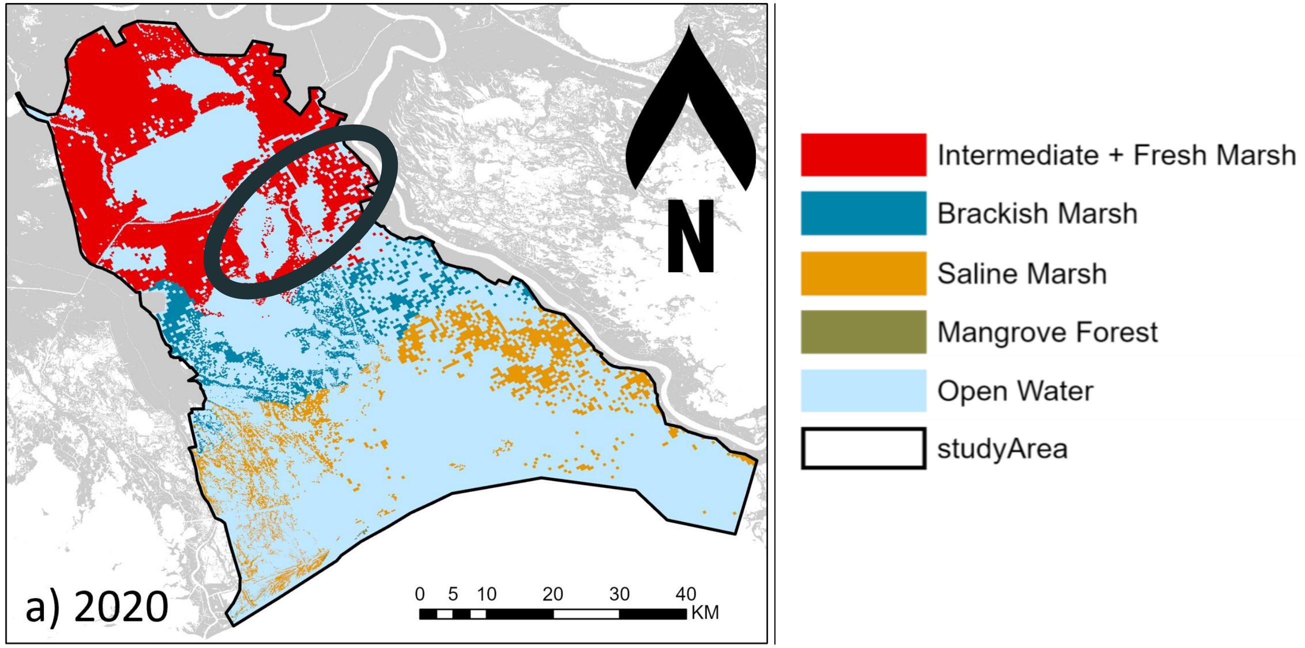
Freshwater Marsh

Two approximately equal opportunities to improve carbon flux estimates:

1. Improved spatial and temporal measurements of methane + N_2O emissions
2. Improving accurate maps of vegetation distribution and growth would also be beneficial.

Sensitivity Analysis (eFAST method): Barataria Basin

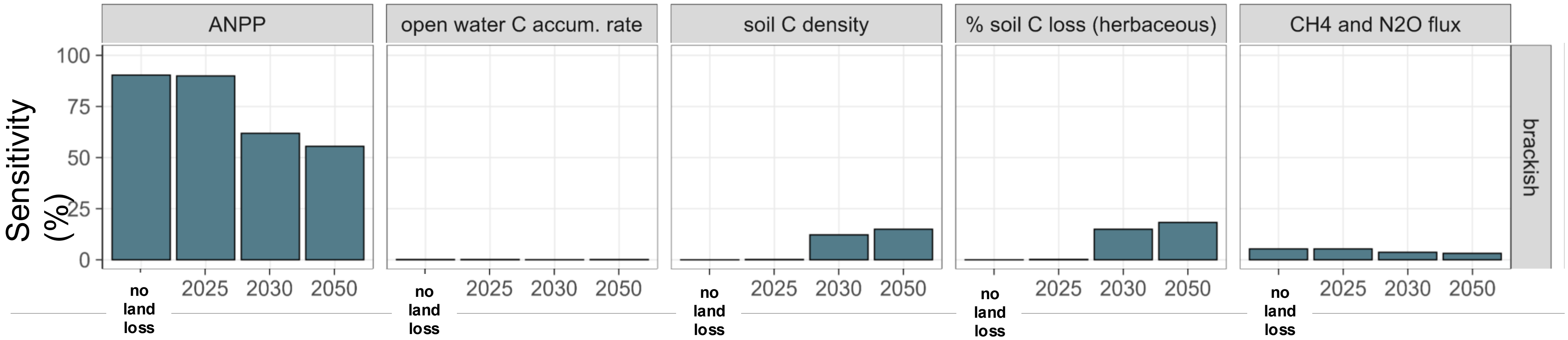


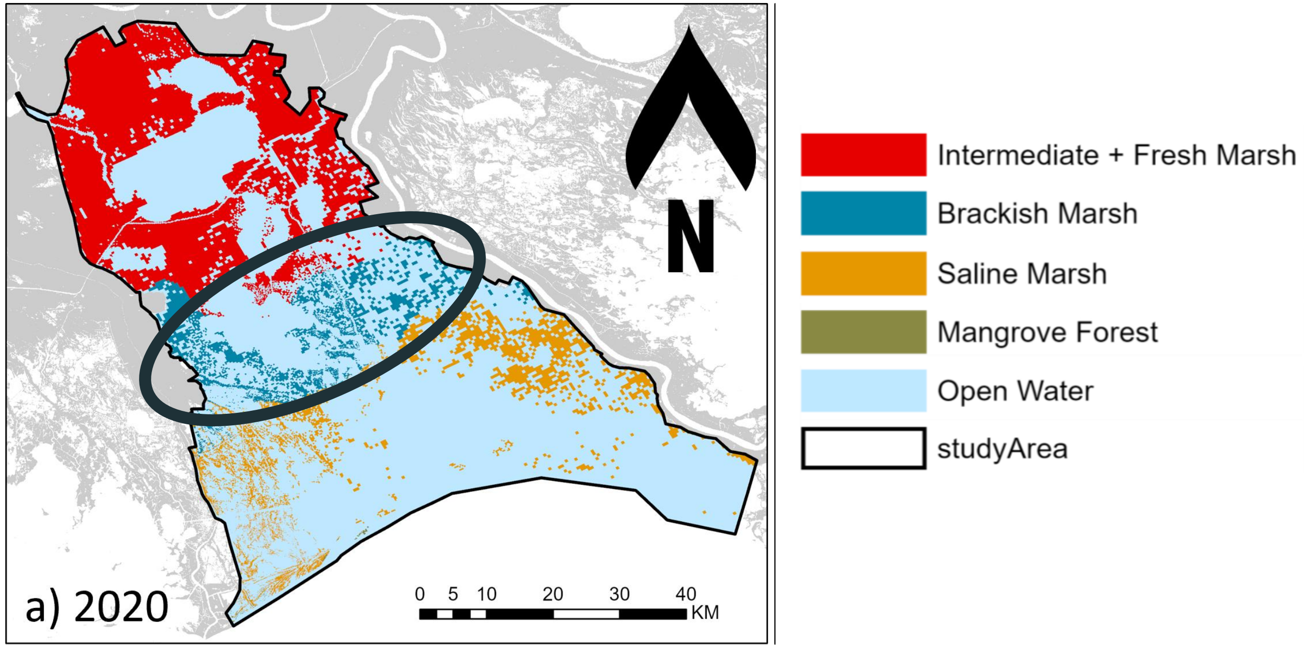


Intermediate Marsh

Methane and N_2O emissions uncertainties are overwhelmingly dominant.

Sensitivity Analysis (eFAST method): Barataria Basin

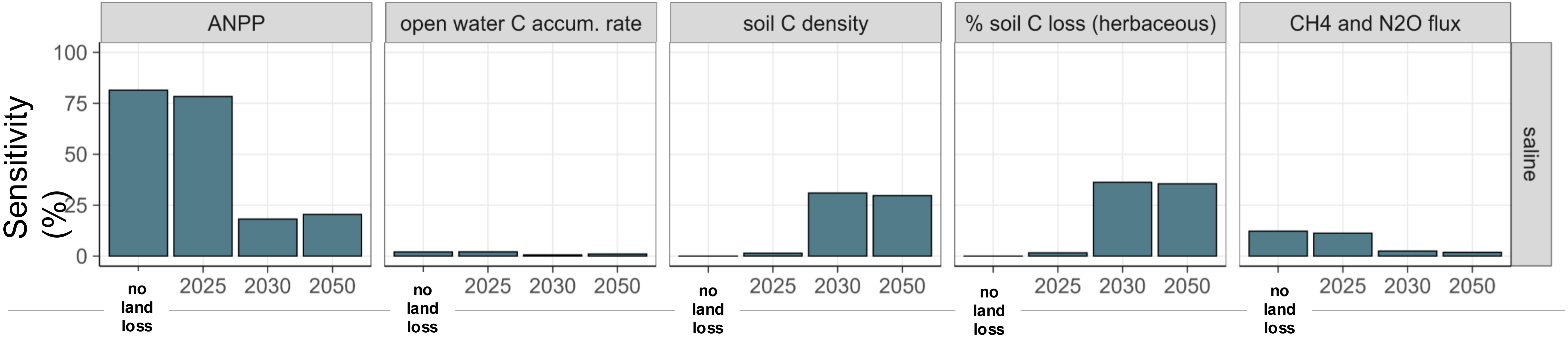


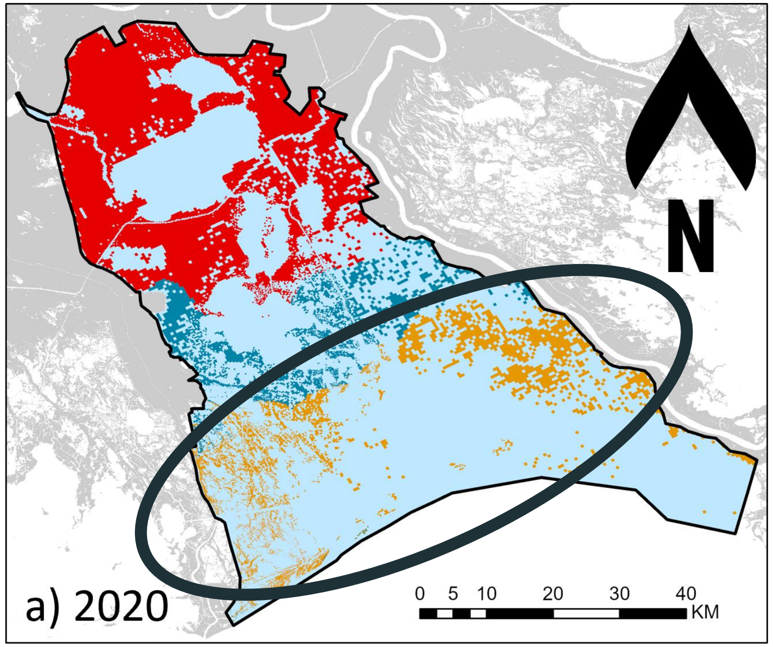


Brackish Marsh

- ANPP uncertainty is dominant, especially near term.
- Land loss uncertainties begin to creep in over time.
- Importance of methane uncertainties fall off dramatically

Sensitivity Analysis (eFAST method): Barataria Basin





Saline Marsh and Mangroves

- ANPP uncertainty also dominant over short timeframes.
- Land loss drivers become dominant over long timeframes.
- Near-term, methane uncertainties are important, but not dominant. Drop off over time.

TAKE AWAYS

Uncertainty Varies: The importance of different sources of blue carbon uncertainty (e.g., vegetation productivity, CH_4 emissions, soil carbon loss) significantly changes based on wetland type, salinity, and the spatial and temporal scale of your project.

Key Uncertainties Shift: Short-term net carbon flux estimates are most impacted by uncertainties in annual plant productivity (ANPP) and CH_4 emissions. Over decades, however, uncertainty around carbon released from coastal land loss becomes dominant.

Strategic Research Needs: To make blue carbon projects viable, especially in dynamic wetlands, research must focus on high-resolution vegetation mapping, better quantifying methane/nitrous oxide variability, and improving models for soil carbon changes during land loss.

Targeted Efforts Maximize Impact: Addressing all uncertainties isn't always practical; Blue carbon research and monitoring should be focused to where it will most effectively reduce uncertainty.

THE WATER INSTITUTE

THANK YOU

Shawn Doyle

sdoyle@thewaterinstitute.org

STATE OF THE COAST

Baton Rouge
1110 RIVER ROAD SOUTH, SUITE 200
BATON ROUGE, LA 70802

WWW.THEWATERINSTITUTE.ORG
@THEH2OINSTITUTE

New Orleans
2021 LAKESHORE DRIVE, SUITE 310
NEW ORLEANS, LA 70122