



THE WATER
INSTITUTE

QUANTIFYING SPATIAL AND TEMPORAL UNCERTAINTY IN LOUISIANA'S COASTAL CARBON

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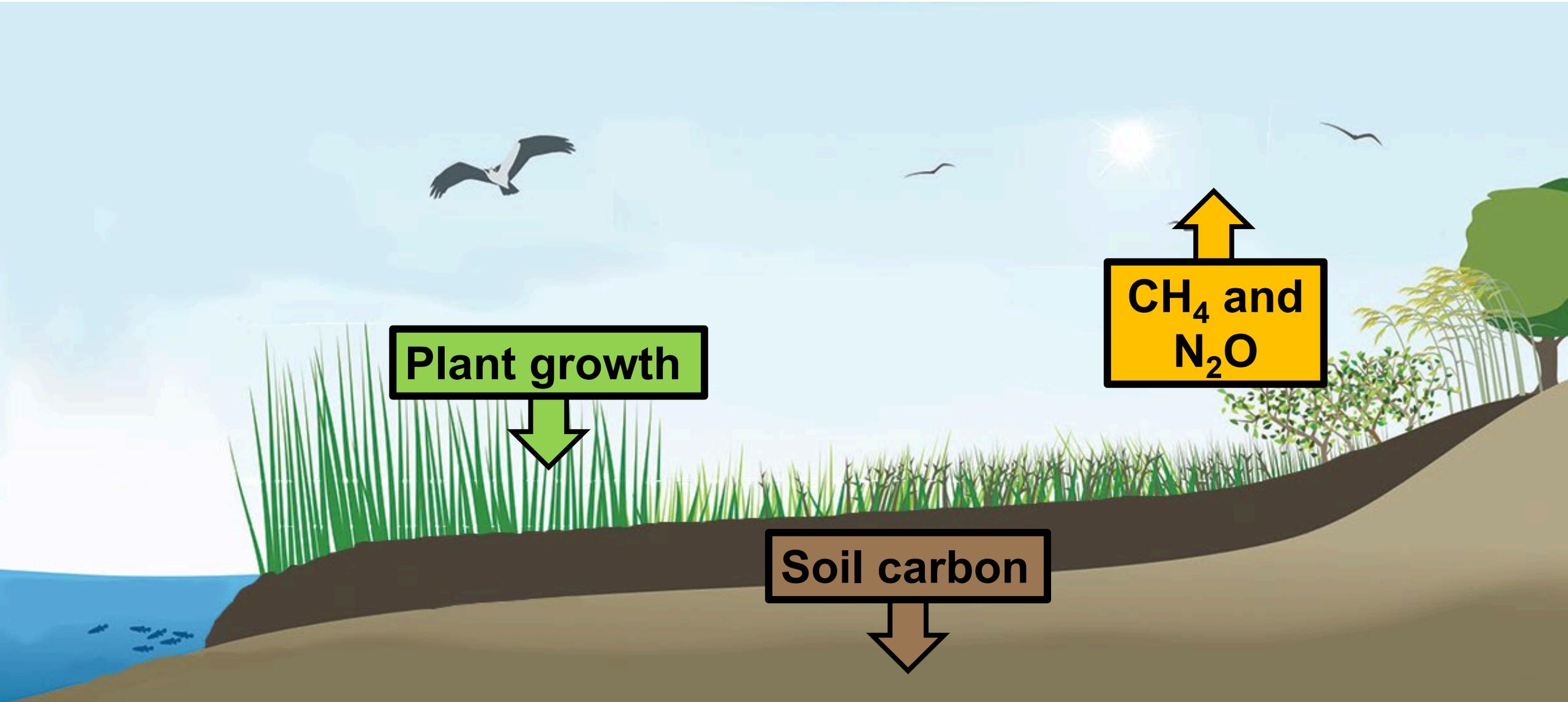


The 14th International Symposium on

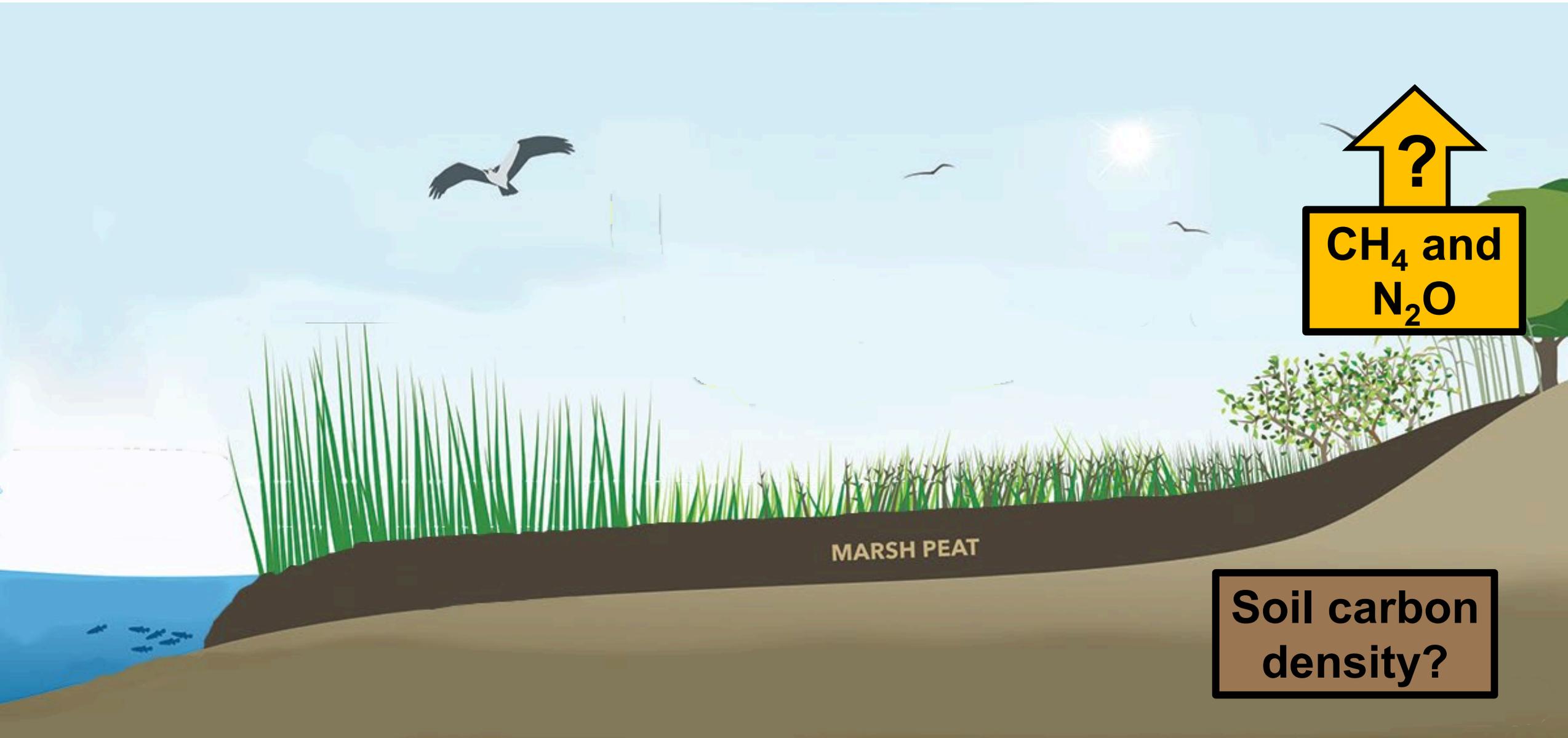
**BIOGEOCHEMISTRY OF
WETLANDS & AQUATIC SYSTEMS**

June 5, 2025

Quantifying Net Carbon Flux



Current unknowns under a changing landscape



?

CH₄ and
N₂O

Soil carbon
density?

Current Assumptions and Uncertainties



How much CO₂ is captured each year by plants?



ANPP: Aboveground net primary productivity

Varies over space and time

species composition

soil nutrients

temperature

precipitation

hurricanes/storms

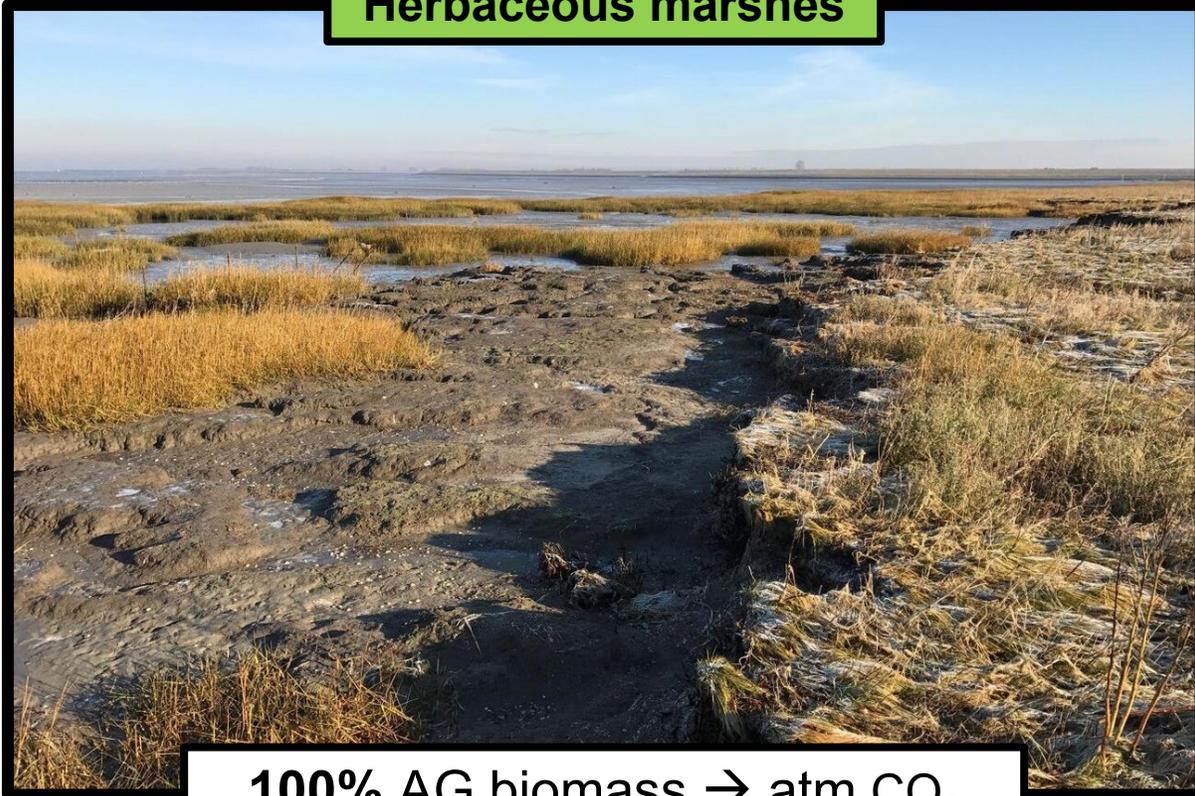
freeze events



What happens to plant biomass?

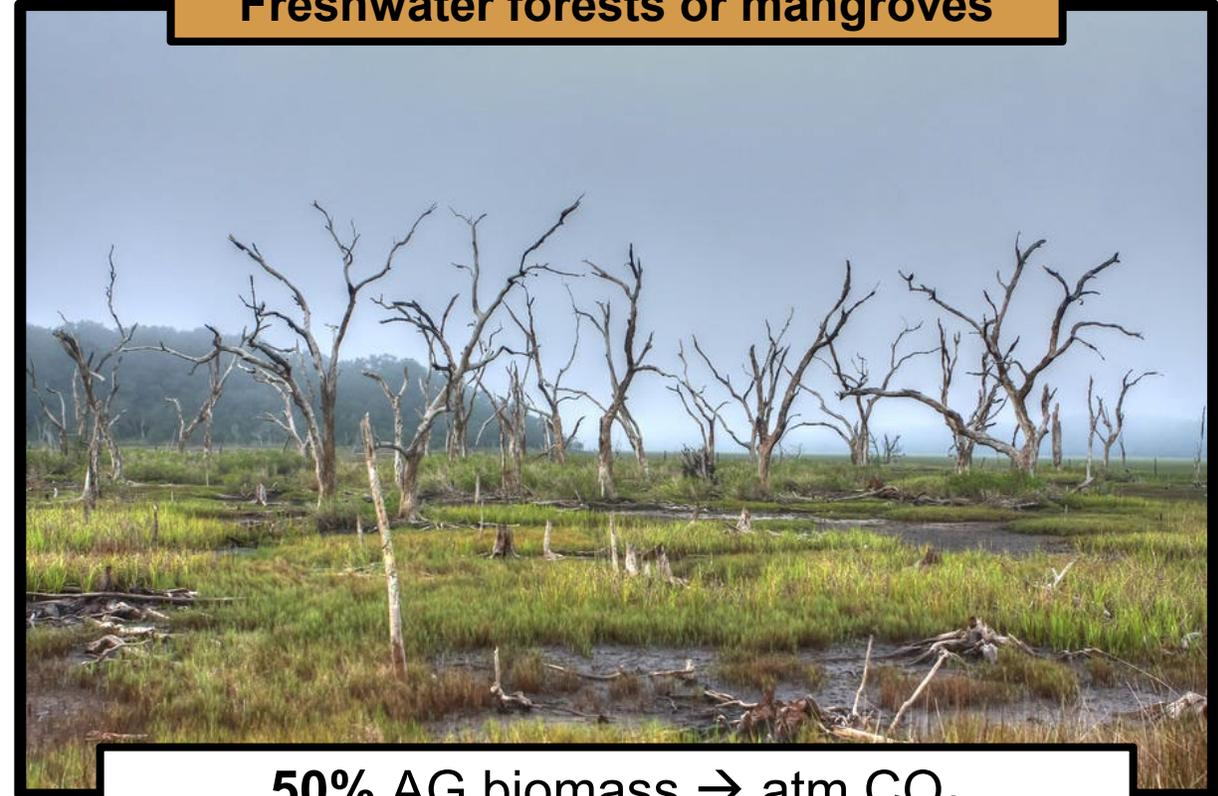
After conversion to open water, all the aboveground biomass is assumed to die.

Herbaceous marshes



100% AG biomass \rightarrow atm CO₂

Freshwater forests or mangroves



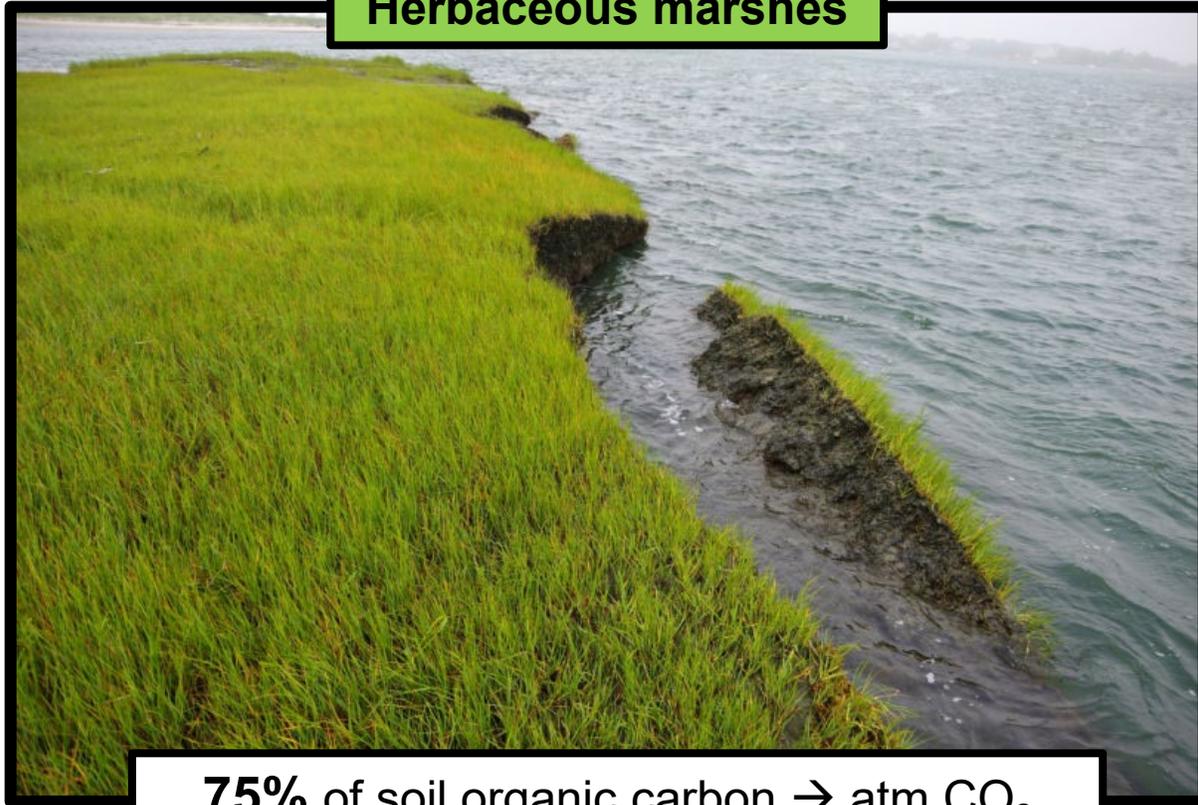
50% AG biomass \rightarrow atm CO₂



What is the fate of stored soil carbon stocks?

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

Herbaceous marshes



75% of soil organic carbon → atm CO₂

Freshwater forests or mangroves



50% of soil organic carbon → atm CO₂



How much soil carbon is being eroded?



Assumption

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

Baustian et al. 2021



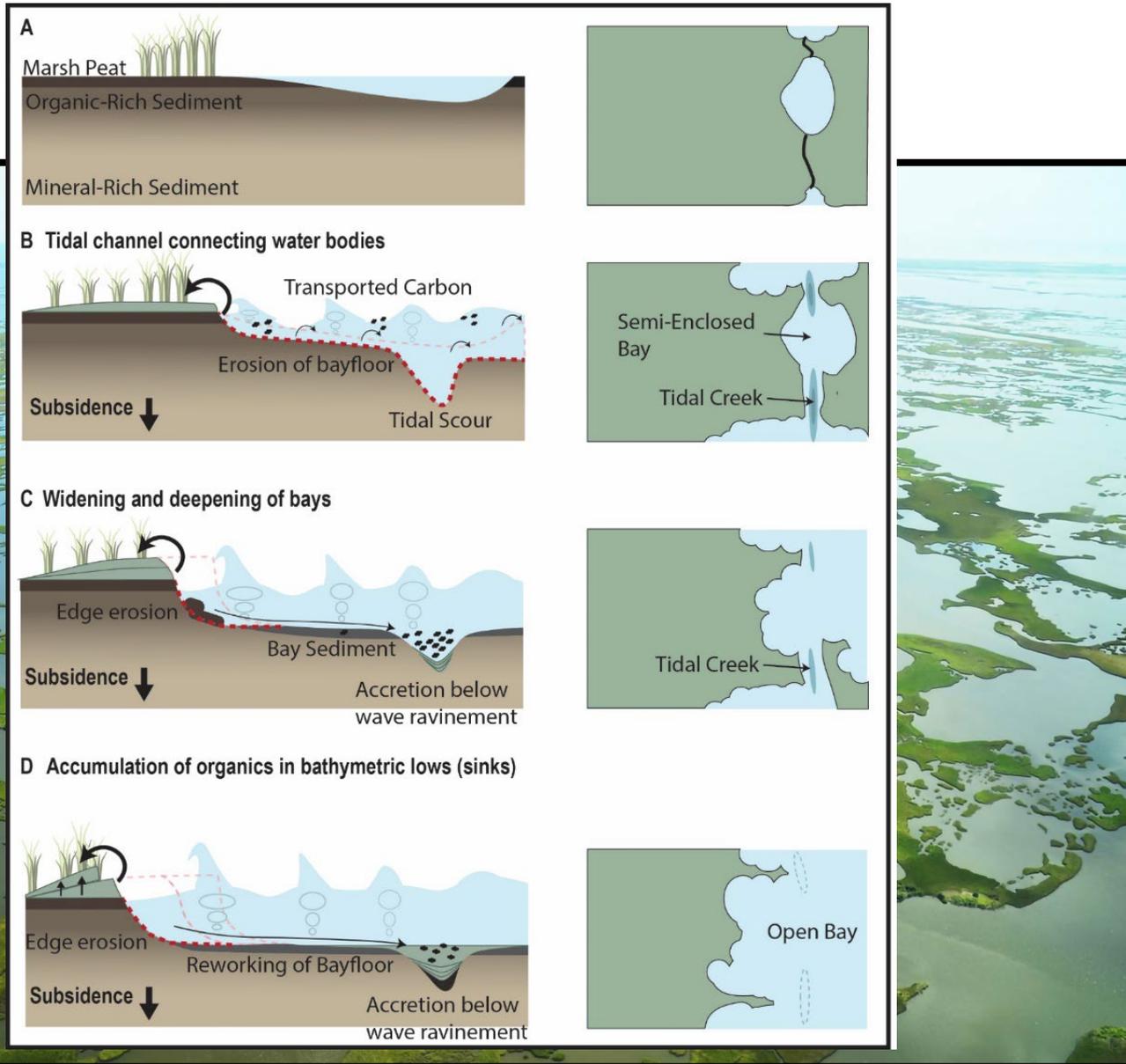
Uncertainty in methane emissions



Habitat	CH ₄ and N ₂ O flux (tons CO ₂ e 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 CO₂e ha⁻¹ per year.

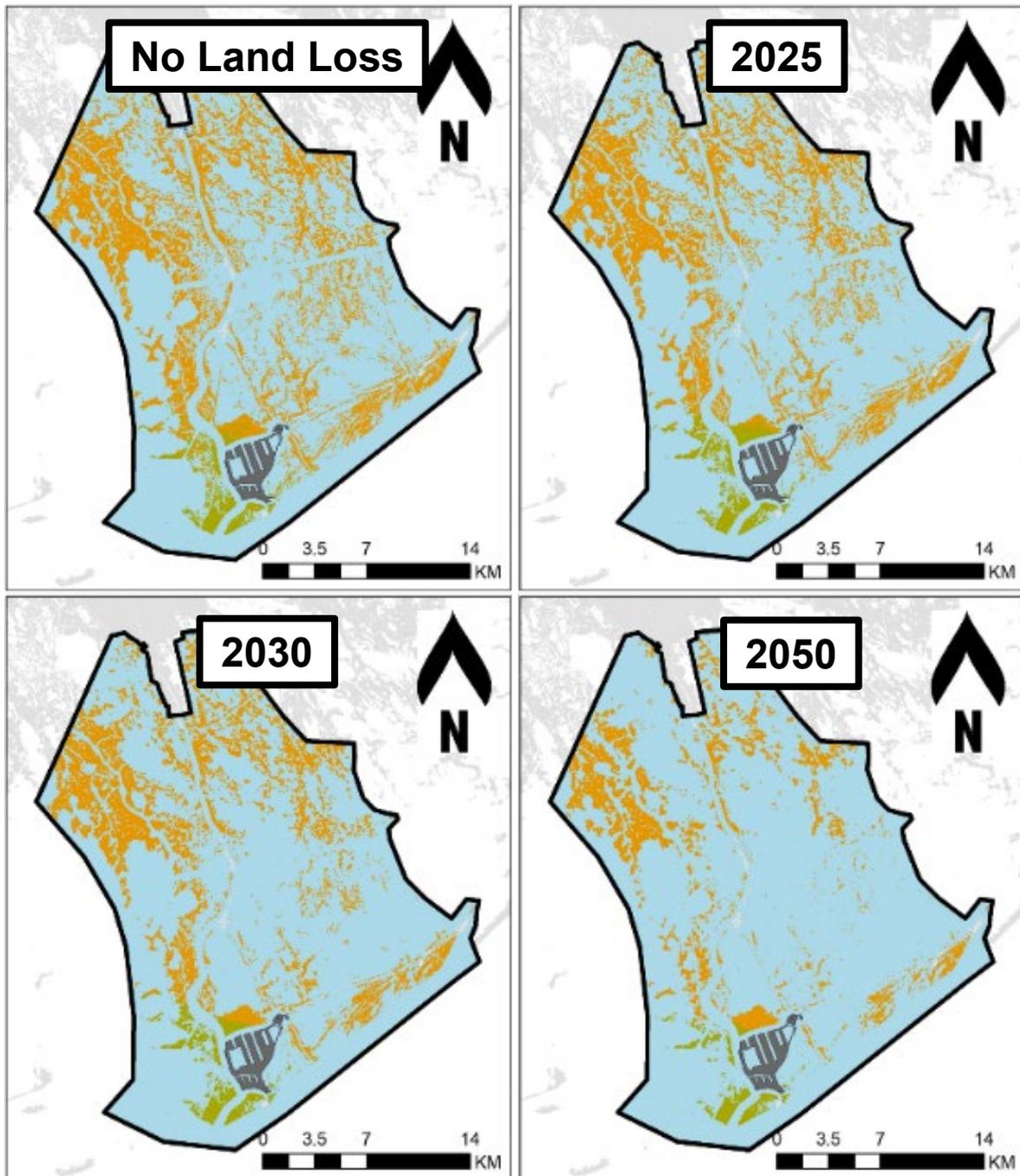
Not all open water areas are the same.

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



Modeling Coastal Carbon Flux

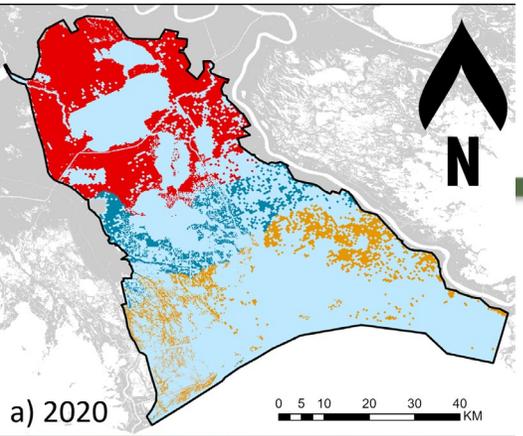




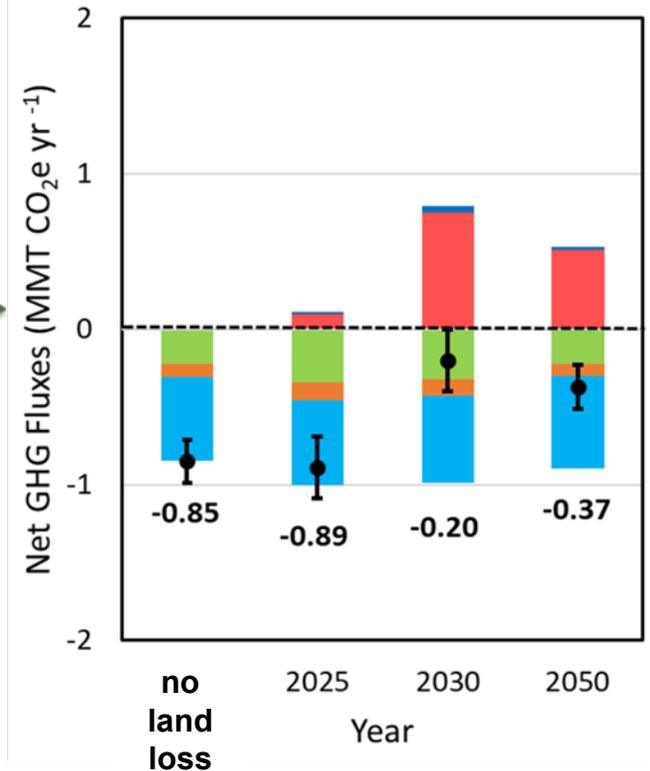
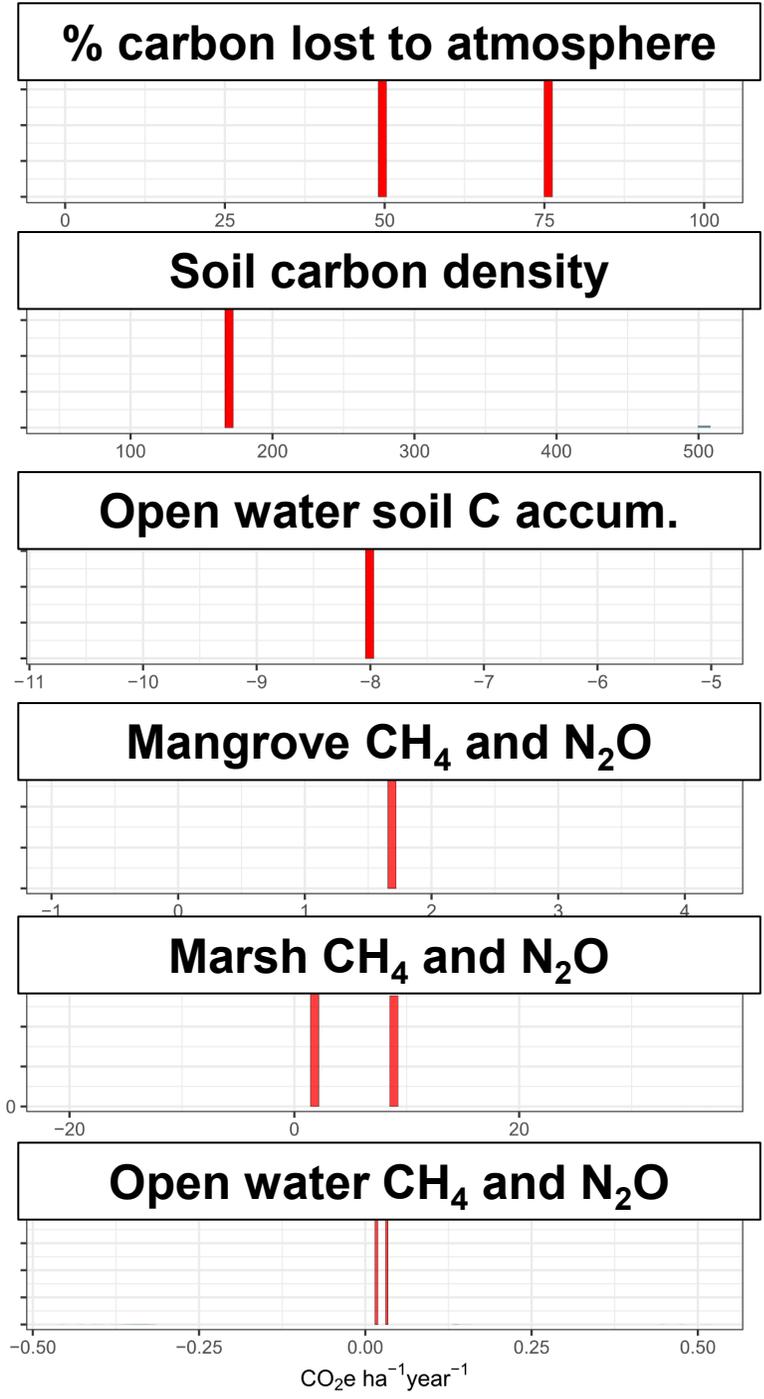
Landscape and Habitat Changes

- 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???

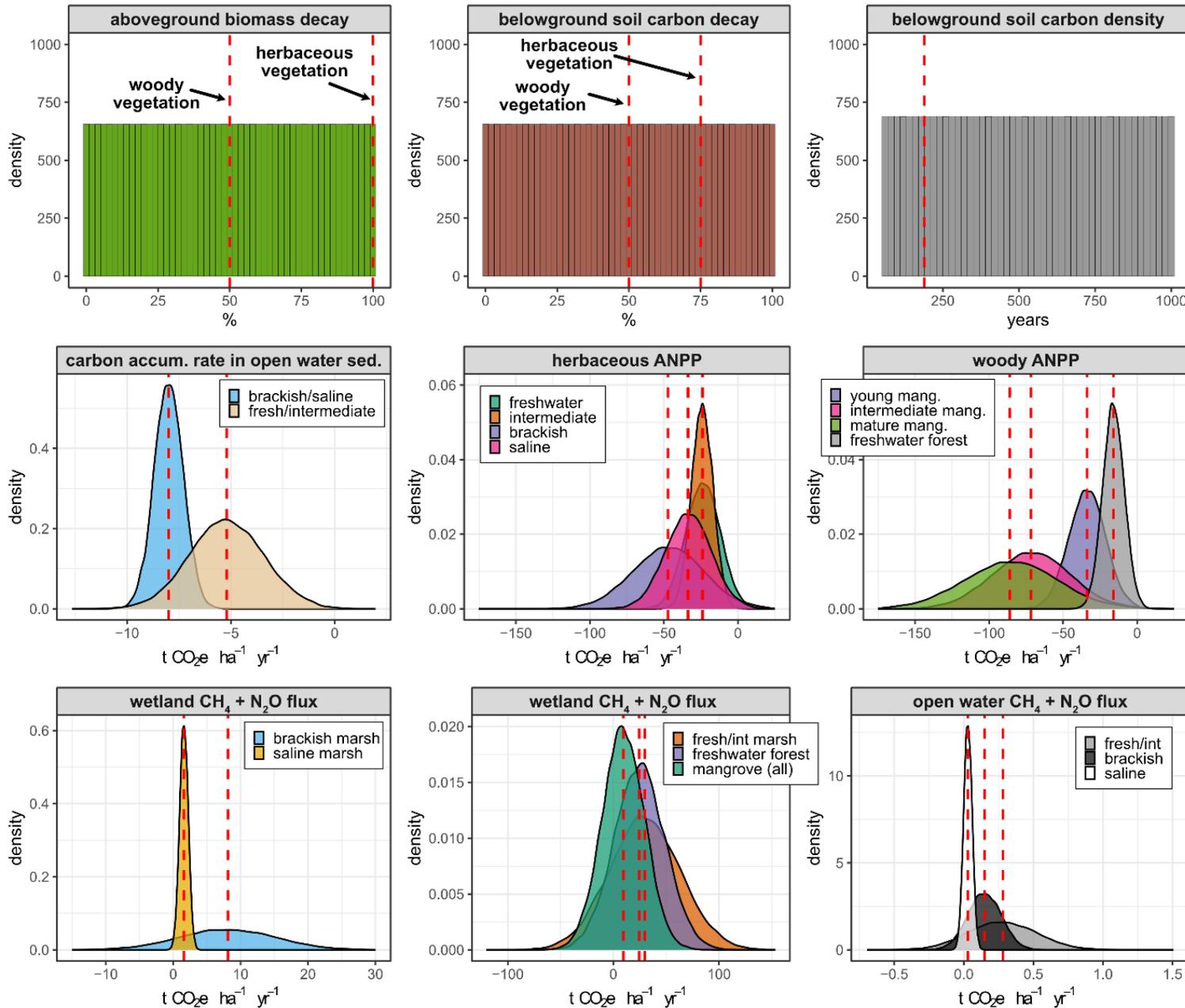


- Converted Habitats (Brackish + Saline Marsh to Open Water)
- Existing Marsh Habitats (Brackish + Saline)
- Existing Mangrove Forest Habitats
- Existing Open Water Habitats
- Net

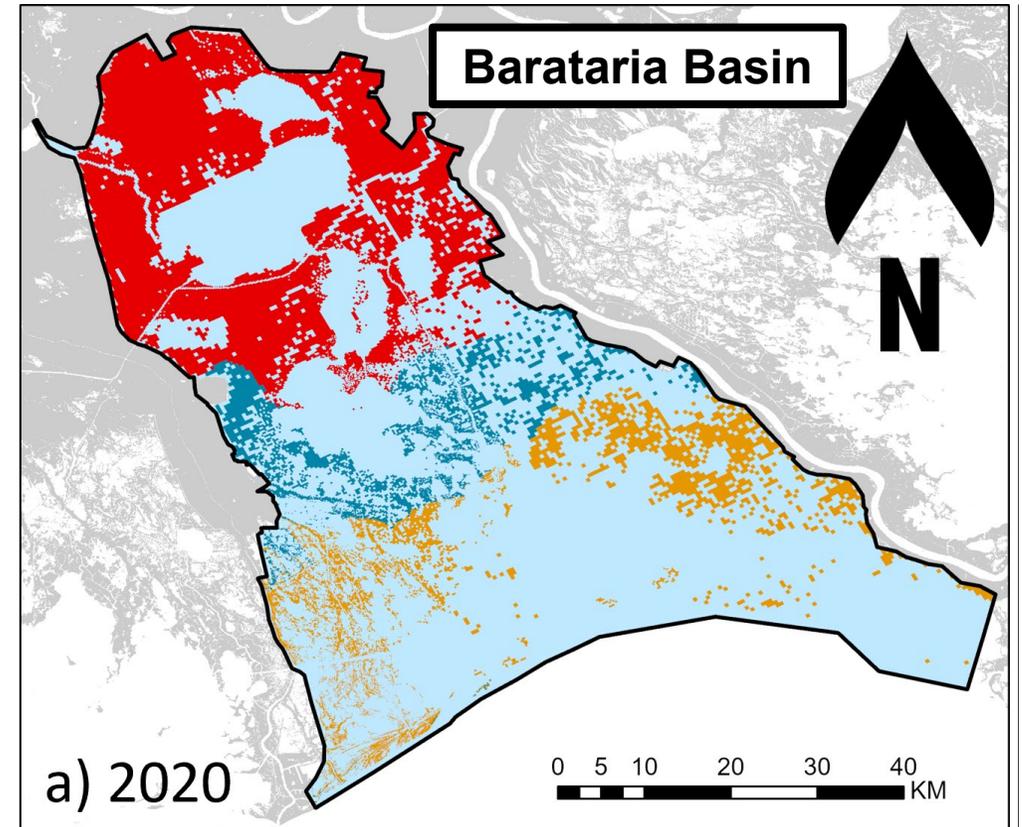
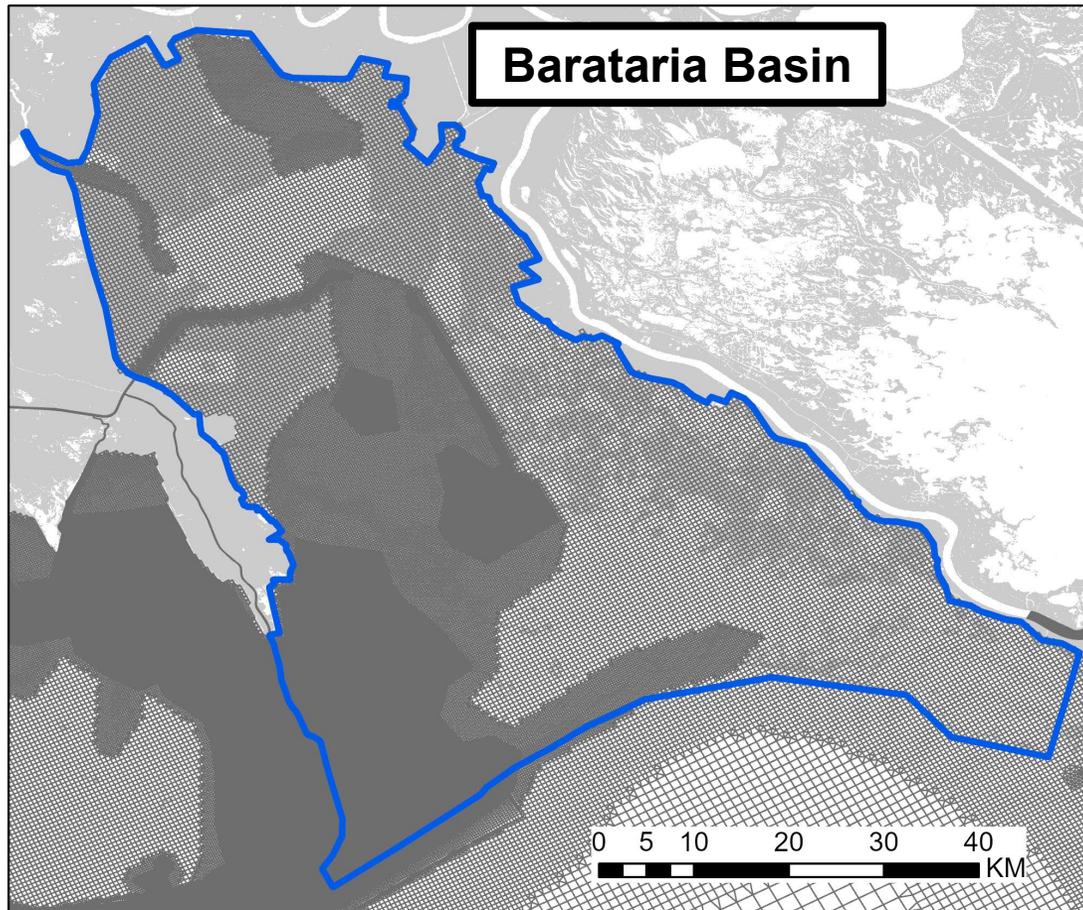


Net carbon flux using minimal assumptions

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?



 Study Area
 Model Grid

Computationally expensive!

 studyArea
 Open Water
 Saline Marsh
 Brackish Marsh
 Intermediate + Fresh Marsh
 Mangrove Forest

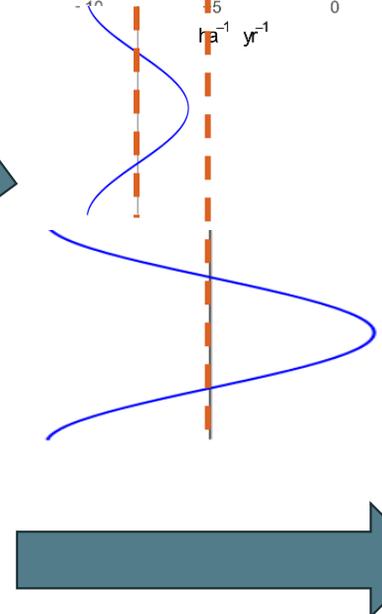
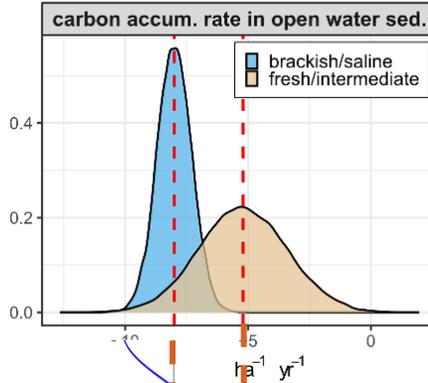
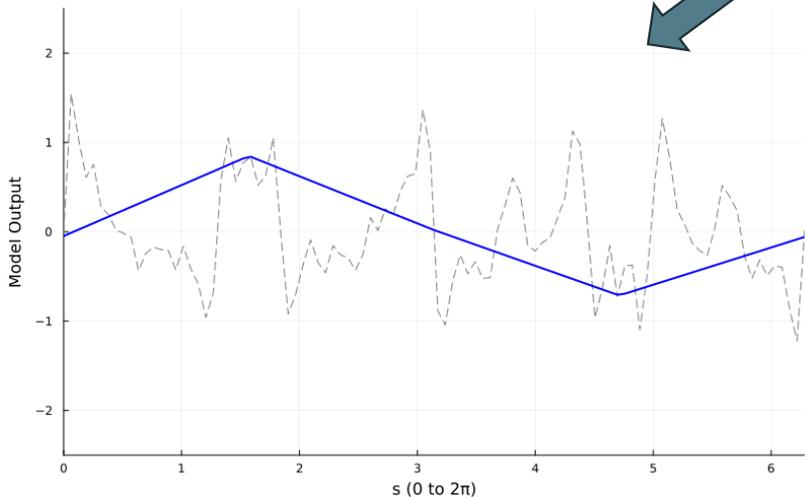


Extended Fourier Amplitude Sensitivity Test (eFAST)

Step 1: Create periodic search curves for each parameter.

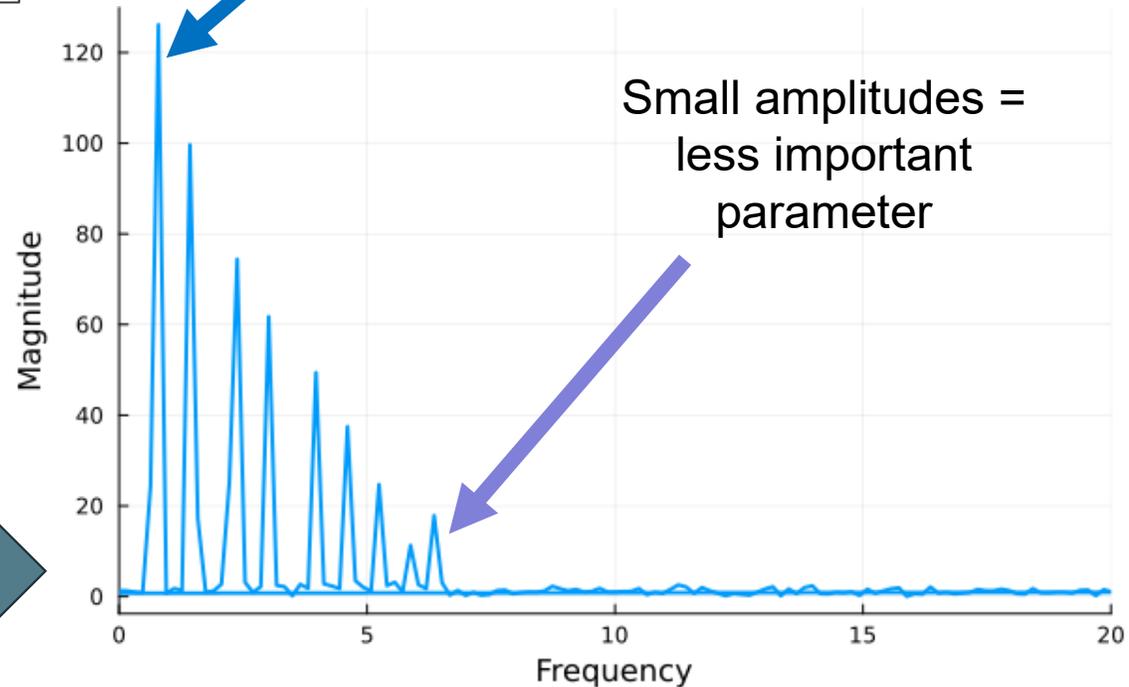
$$x_i = F_i^{-1} \left(\frac{1}{2} + \frac{1}{\pi} \arcsin(\sin(\omega_i s)) \right), \quad -\pi \leq s \leq \pi,$$

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

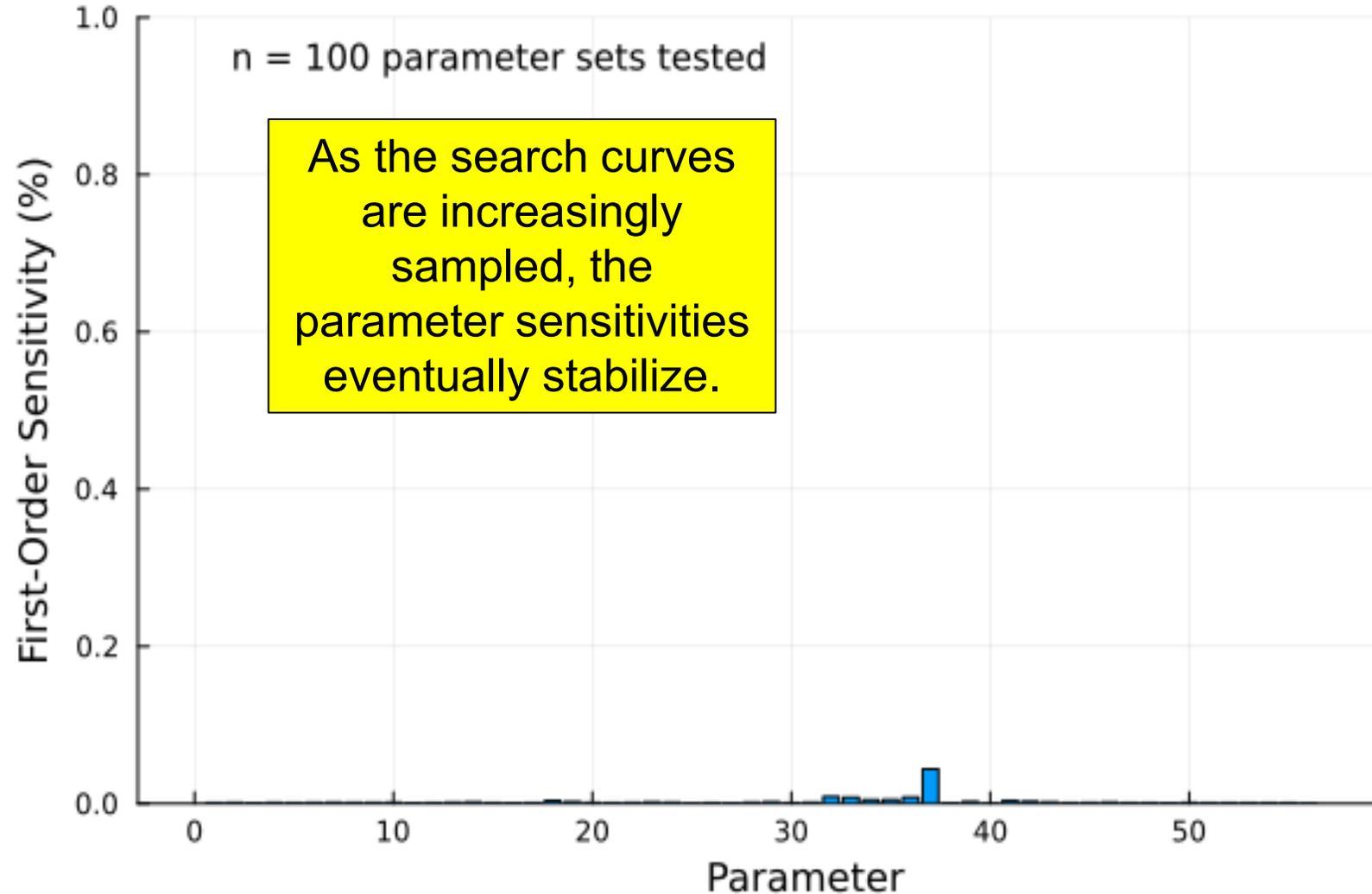
Small amplitudes = less important parameter



Step 3: 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

120,000 module iterations

julia ≈ 1.9 hours

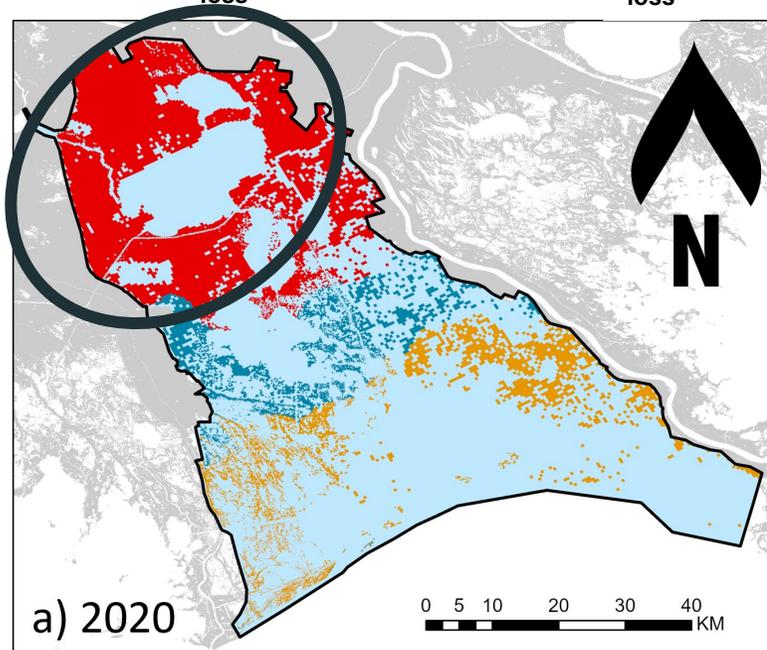
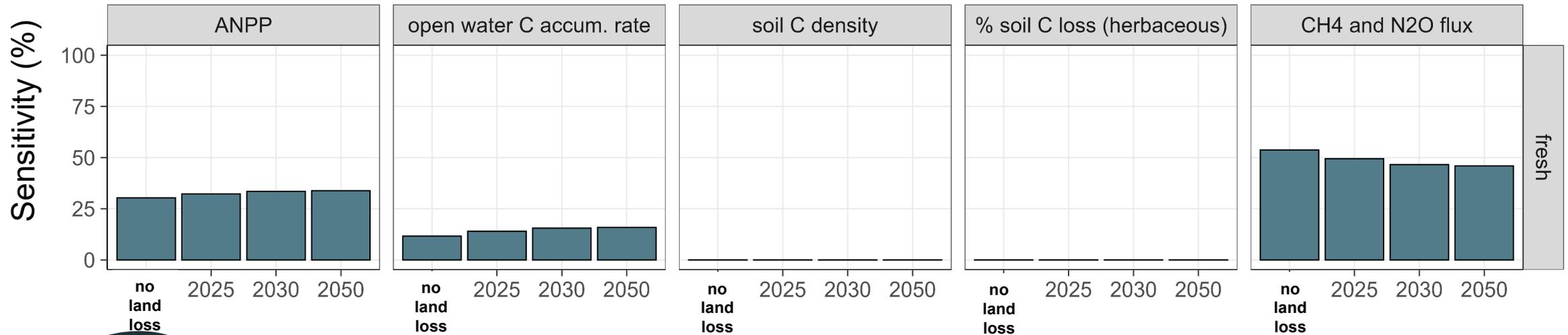
R ≈ 30 to 45 days



Python



Sensitivity Analysis (eFAST method): Barataria Basin



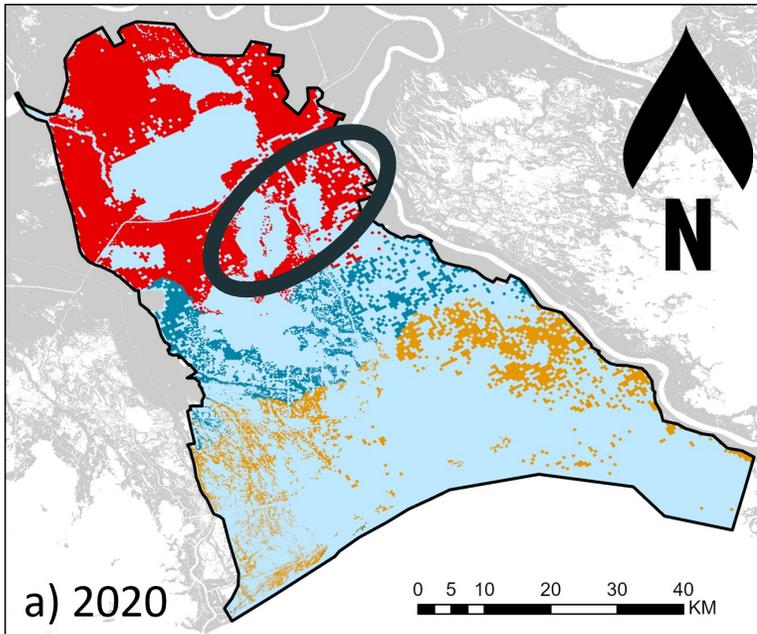
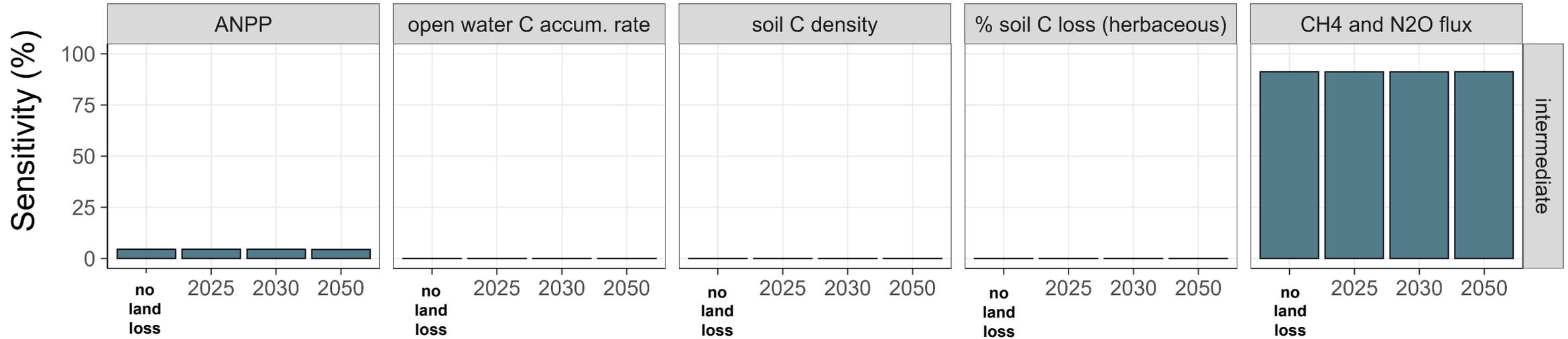
Freshwater Marsh

Two approximately equal opportunities to improve carbon flux estimates:

1. Improved spatial and temporal measurements of methane + N₂O emissions
2. Improving accurate maps of vegetation distribution and growth would also be beneficial.



Sensitivity Analysis (eFAST method): Barataria Basin



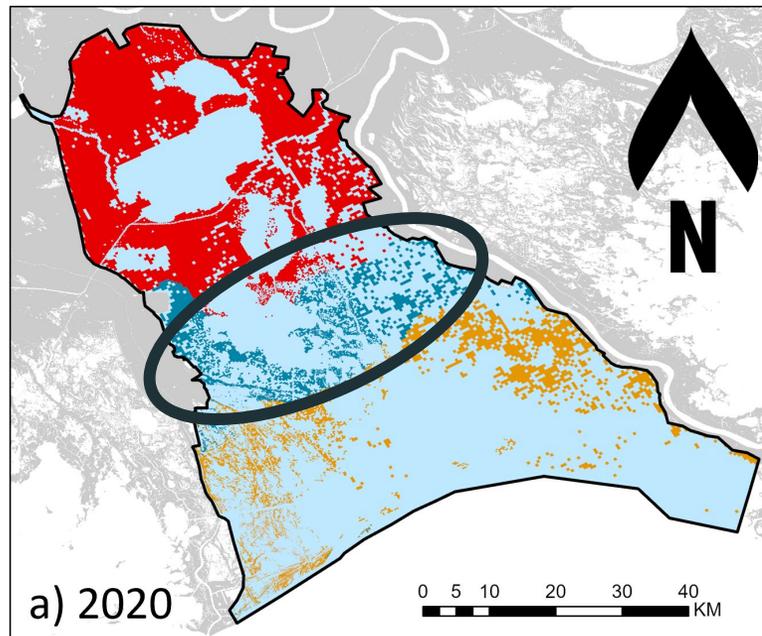
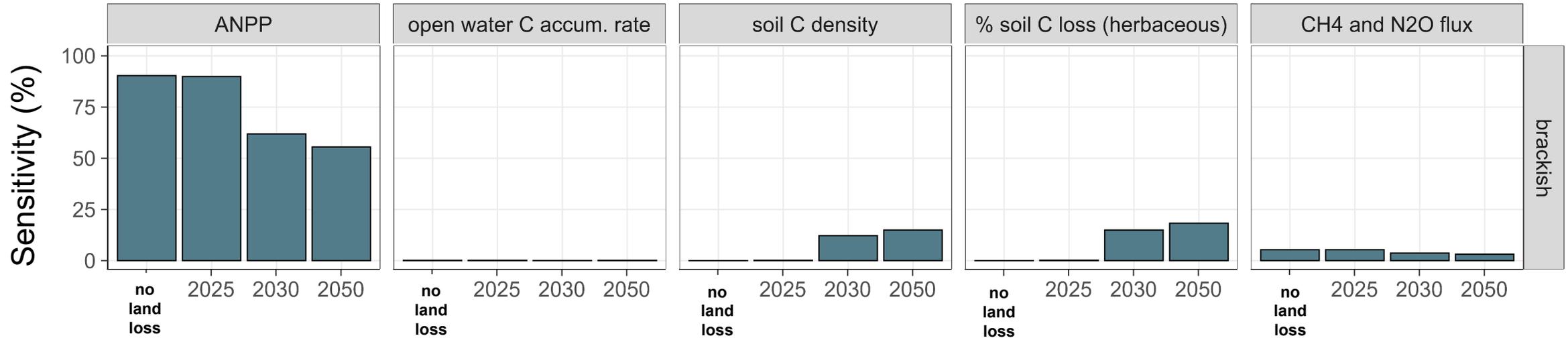
- Intermediate + Fresh Marsh
- Brackish Marsh
- Saline Marsh
- Mangrove Forest
- Open Water
- studyArea

Intermediate Marsh

Methane and N₂O emissions uncertainties are overwhelmingly dominant.



Sensitivity Analysis (eFAST method): Barataria Basin

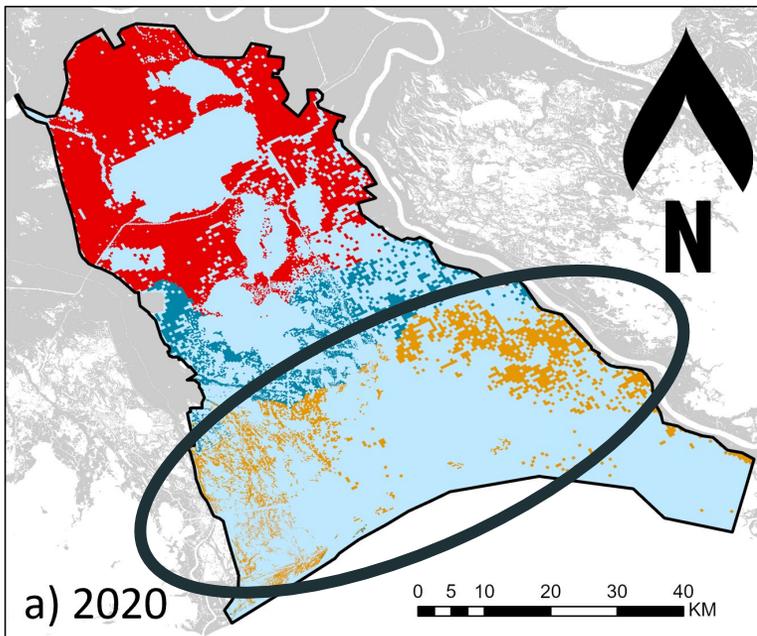
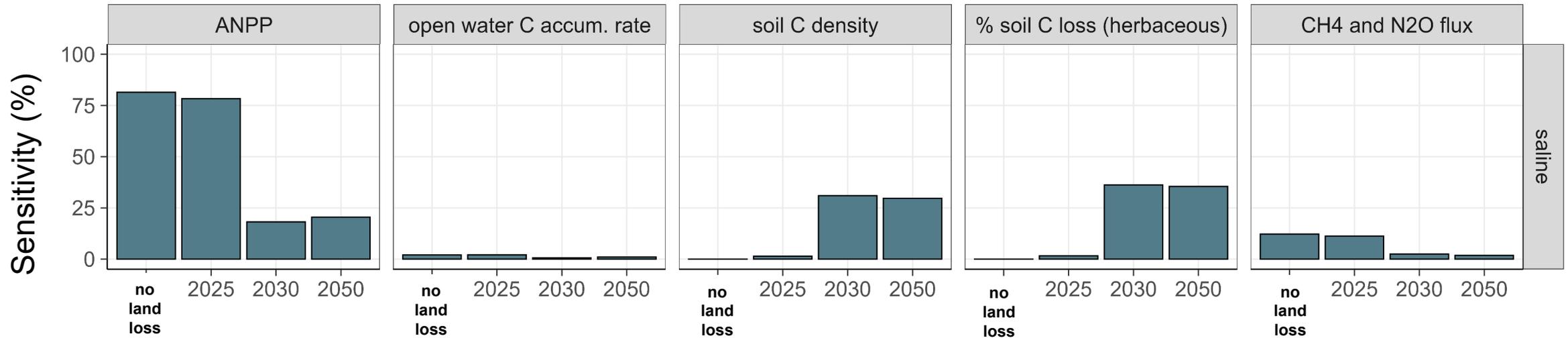


Brackish Marsh

- 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.





VCS Methodology

VM0033

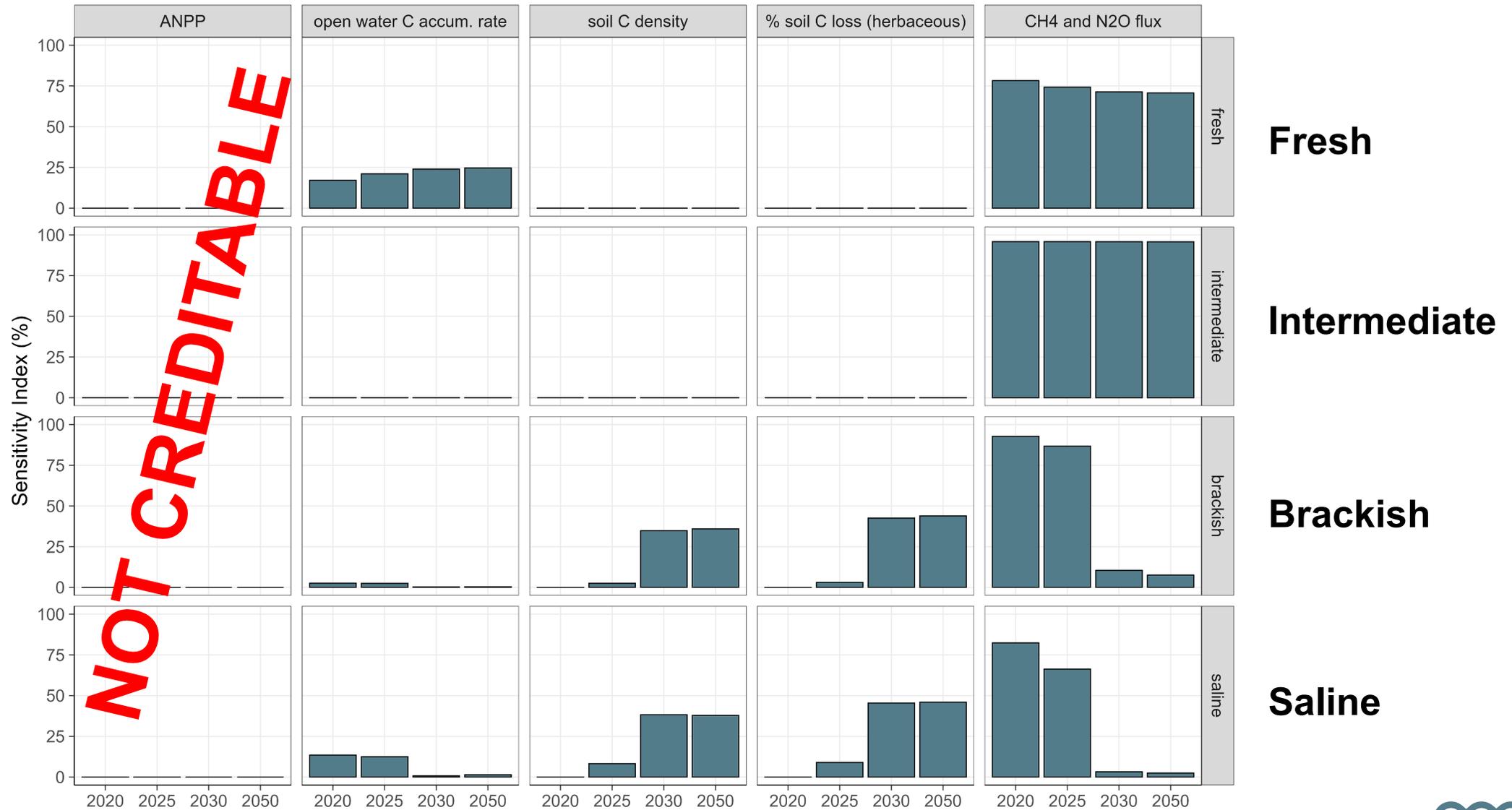
METHODOLOGY FOR TIDAL WETLAND
AND SEAGRASS RESTORATION

**Current carbon offset
methodologies applicable in
Louisiana include aboveground
biomass in carbon stock
assessments**

What if this wasn't permitted?



What if aboveground biomass isn't creditable?





TAKE AWAYS

Uncertainty Varies: The importance of different sources of blue carbon uncertainty (e.g., vegetation productivity, CH₄ emissions, soil carbon loss) significantly changes based on wetland type, salinity, the spatial and temporal scale of your project, and what you are permitted to credit.

Key Uncertainties Shift: Short-term net carbon flux estimates are most impacted by uncertainties in annual plant productivity (ANPP) and CH₄ 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.





THANK YOU

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