Global Review of Salt Marsh Change and Carbon Emissions

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Presentation Outline

- Why salt marshes?
- Remote sensing for understanding global change
- Global Salt marsh change and carbon emissions
- New spatial data products
  - Case Study - Chesapeake Bay
- New technology and data synthesis
  - Case Study – South Africa

Coastal wetland importance

Biodiversity
Carbon sequestration
Nursey habitat
Water quality (denitrification and filtering of pollutants)
Wave attenuation
Approximately 193,845 and 28,917 (USD 2007) per hectare benefit of salt marsh and seagrass respectively (Davidson et al. 2019).

Carbon

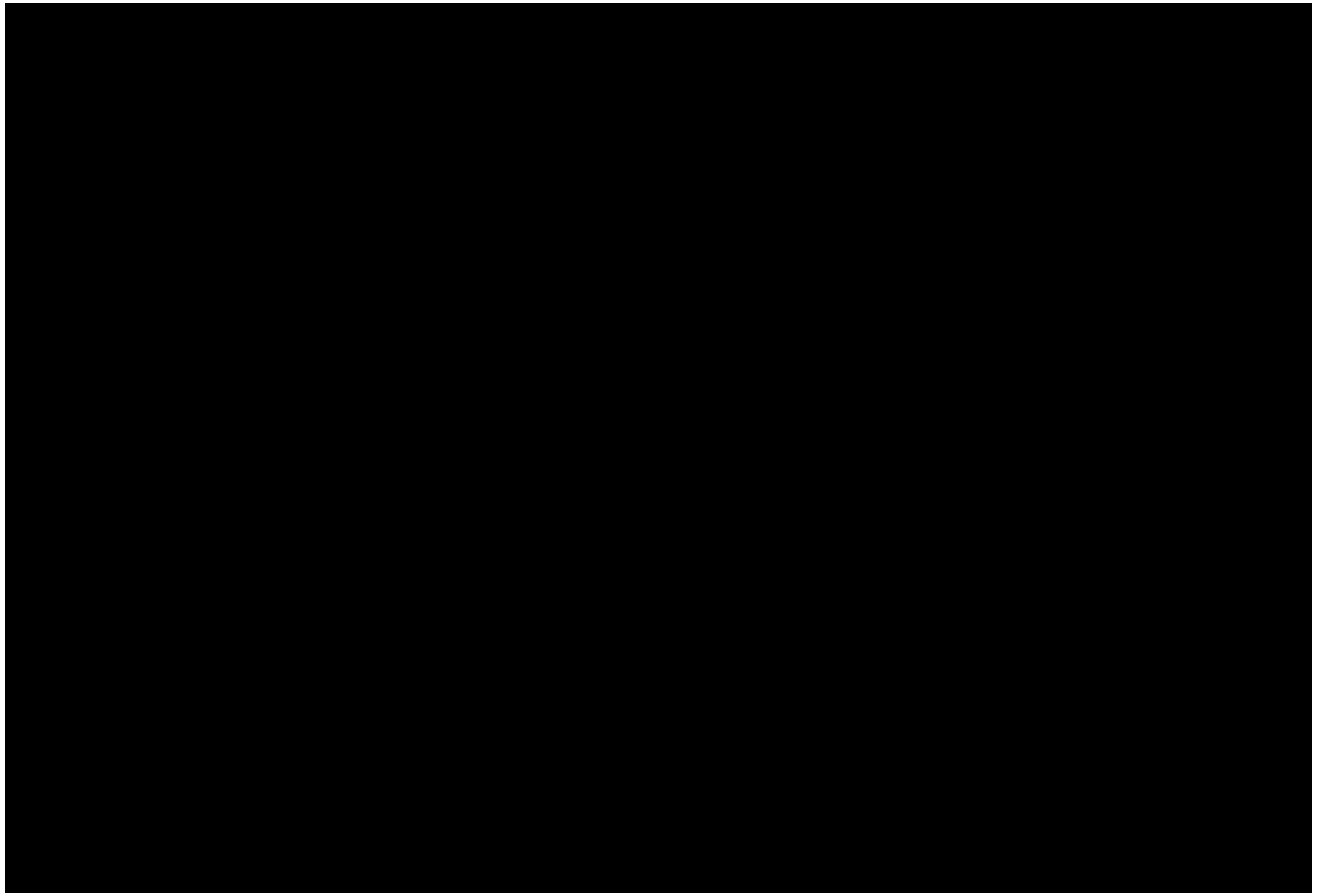
- Blue carbon – salt marsh, mangroves, and seagrass
- Vast amount of carbon stored in their soils
- Tidal marsh are estimated to have 1.44 Pg C of carbon in the 1 m (Maxwell et al. 2024)

Loss drivers

- Eutrophication (Deegan *et al*. 2012)
- Climate change
  - Mangrove expansion (Saintilan *et al*. 2014; Armitage *et al*. 2015)
  - Sea level rise (Watson *et al*. 2017)
- Herbivory (Holdredge *et al*. 2009; Crotty et al. 2020)

Wetland conversion

- Wetland conversion to farmland, aquaculture, or other land use



Types of salt marsh loss

Edge Erosion

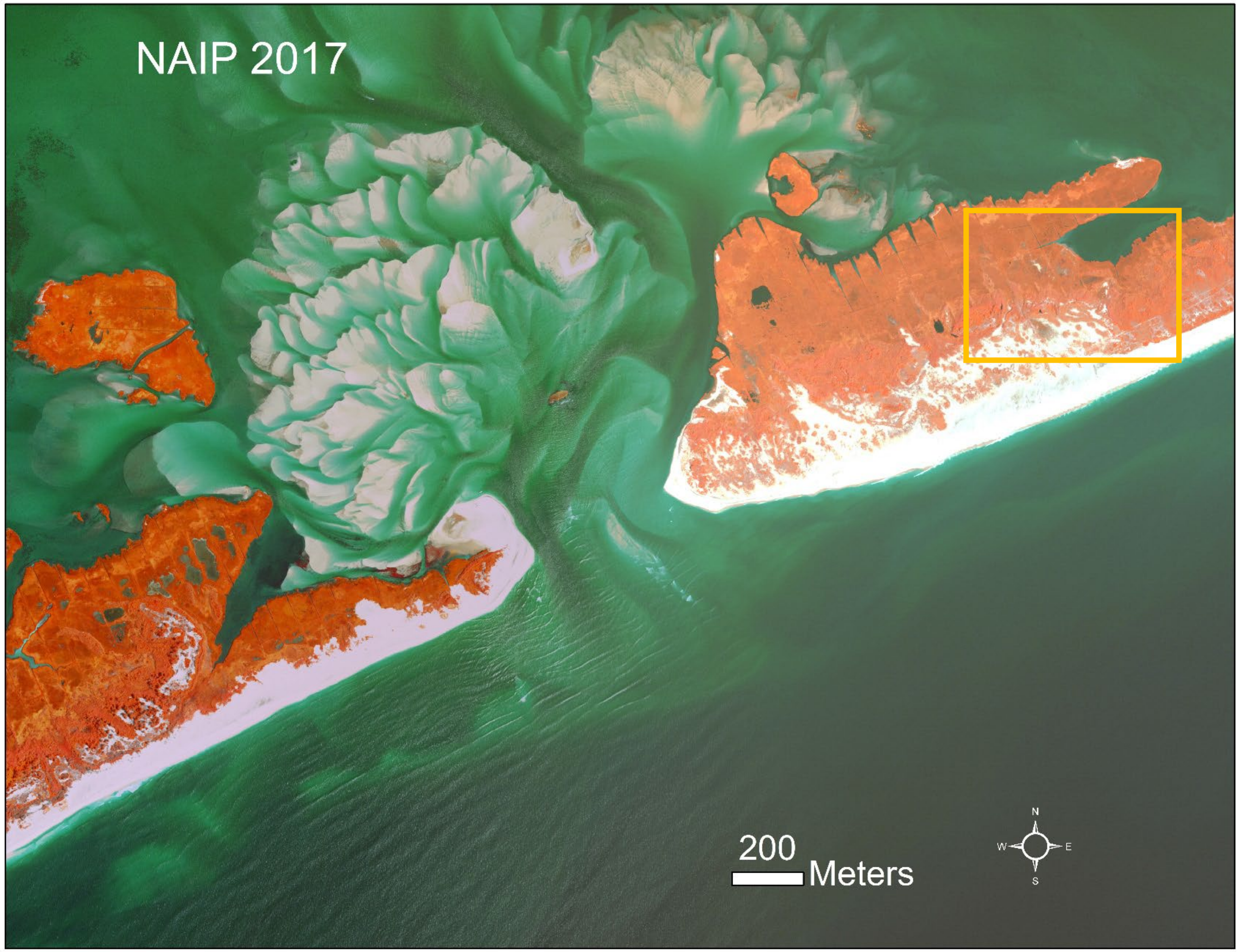
Tidal channel change

Salt marsh interior

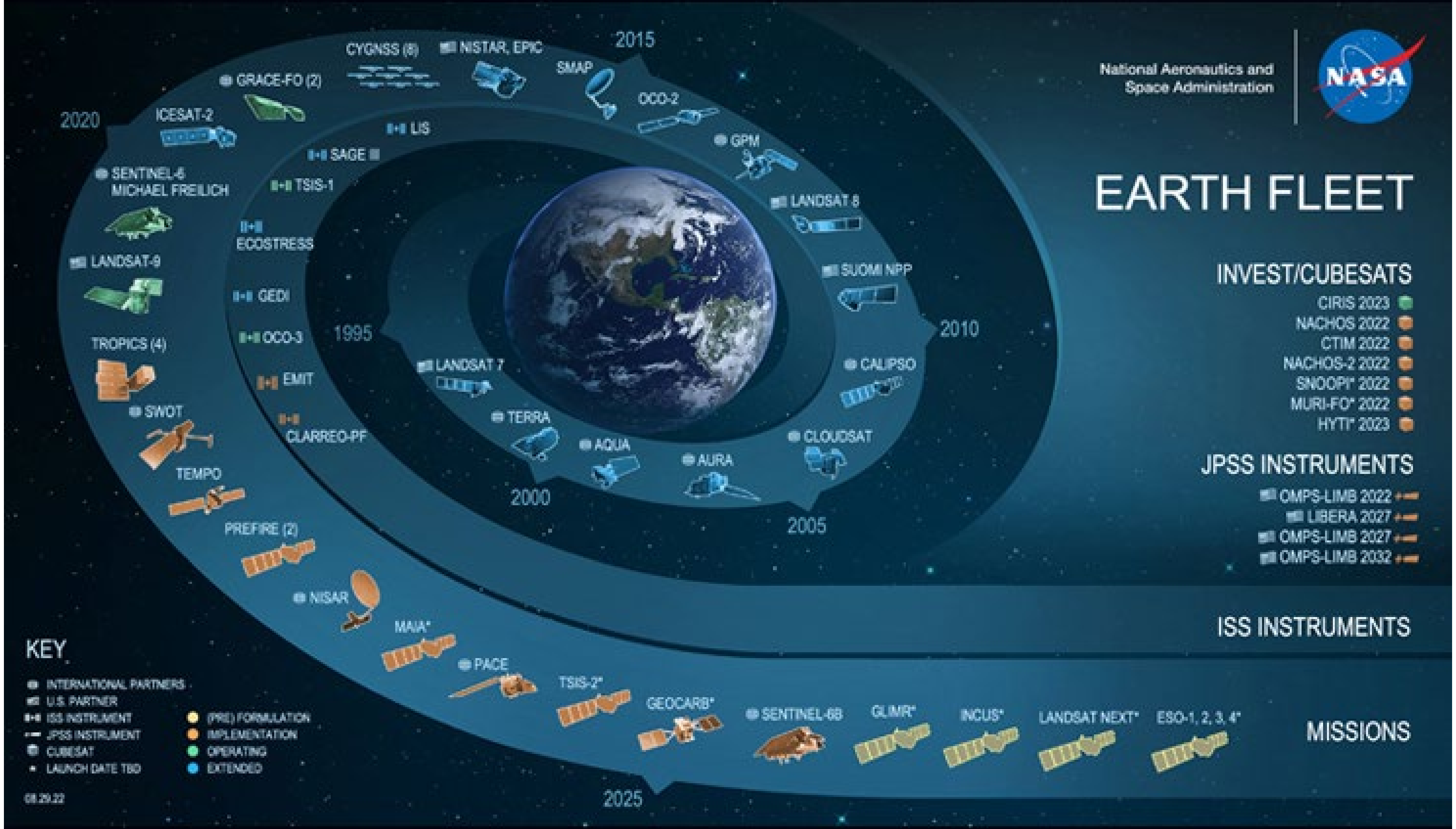
Types of salt marsh loss

Tidal connections

Overwash



Remote Sensing



https://science.nasa.gov/earth-science

Monitoring with Landsat

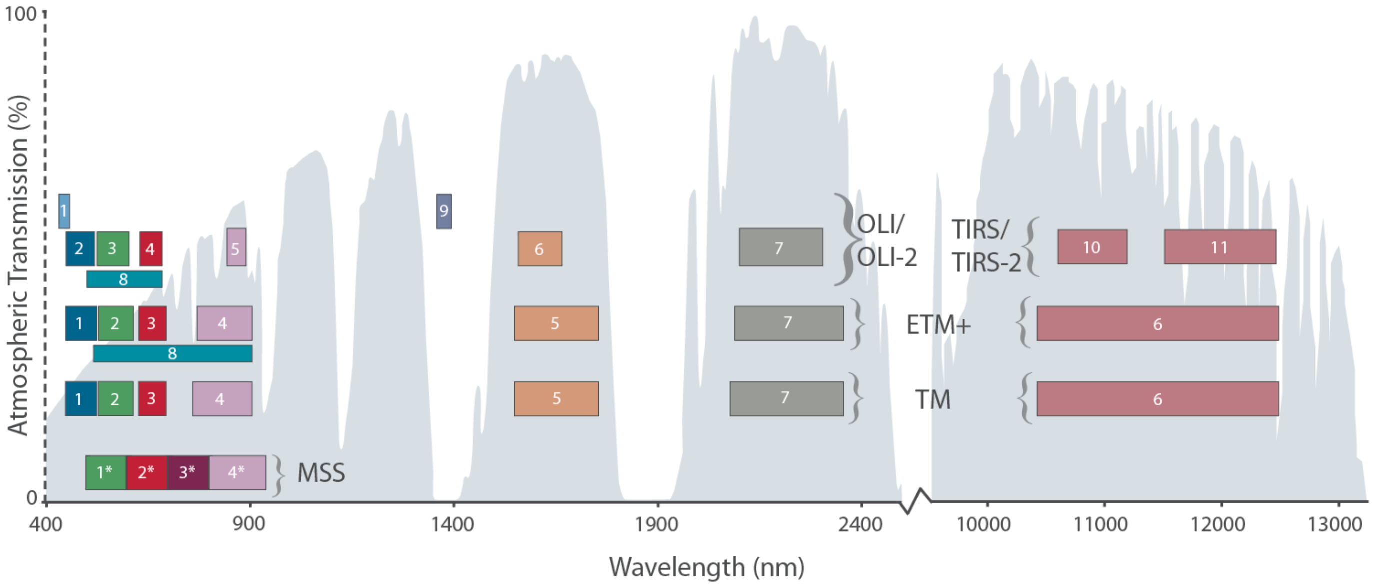
Spatial resolution: 30 m

Temporal resolution: 16 days

Time period: 1984-Current

Spectral resolution: bands vary by sensor but remain consistent enough to facilitate comparisons between sensor.

Longest continuous earth observing satellite archive



https://landsat.gsfc.nasa.gov/article/the-intervening-atmosphere-tracing-the-provenance-of-a-favorite-landsat-infographic/

Global Salt marsh change and carbon emissions

Science questions

- Where are salt marshes being lost and gained?
- What are the carbon emissions from salt marsh ecosystems over the last two decades?
- How much of the salt marsh losses then recover?

Methodology

- Extent – Mcowen map (Mcowen et al. 2017) and National Wetland Inventory (U. S. Fish and Wildlife Service. 2021)
- Mapped loss, gain, and recovery from 2000-2019 with Landsat archive data and an anomaly approach.
- Calculated carbon emissions for countries and watersheds.

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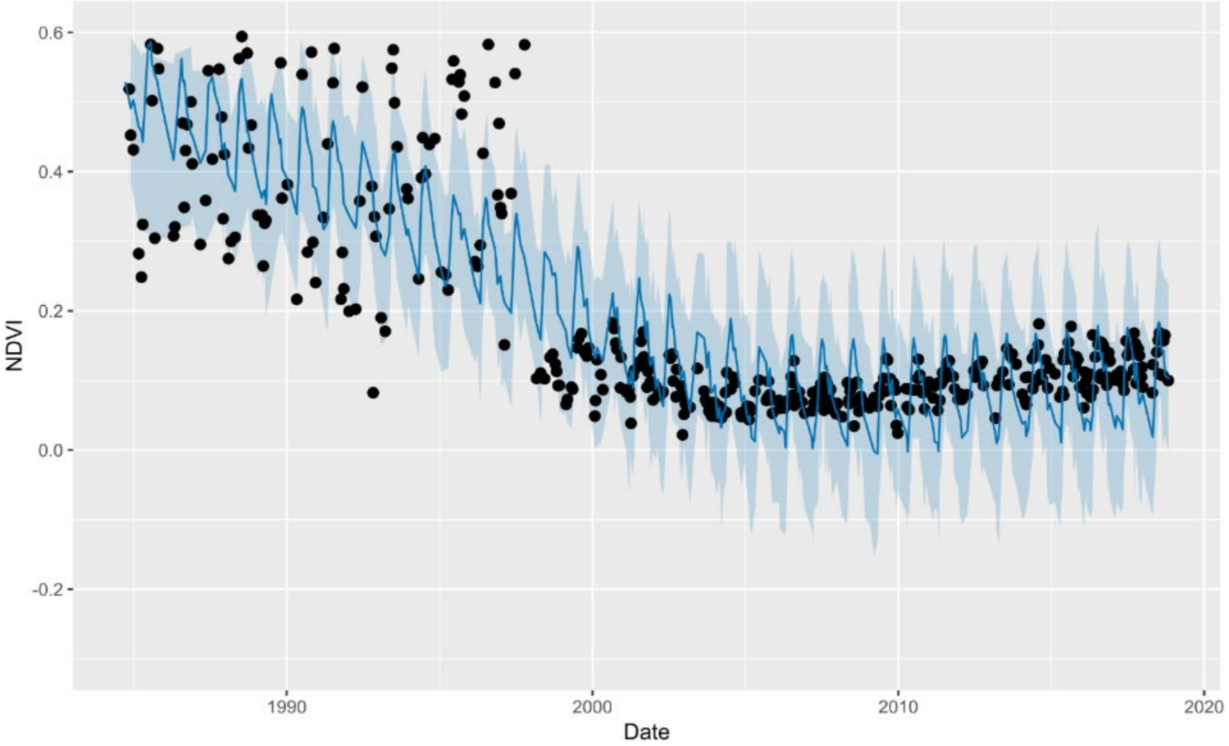
Global hotspots of salt marsh change and carbon emissions

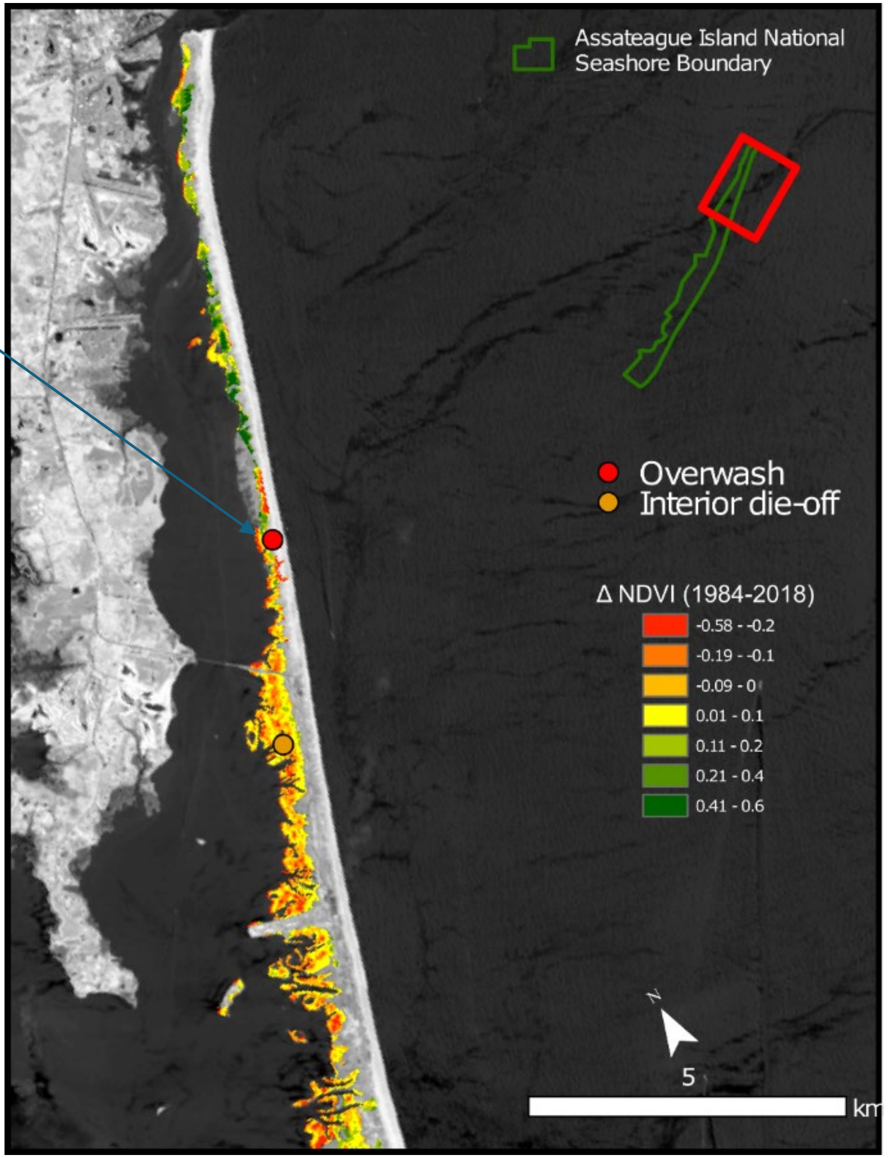
Anthony D. Campbell, Lola Fatoyinbo, Liza Goldberg & David Lagomasino

Assateague NDVI (1984-2018)

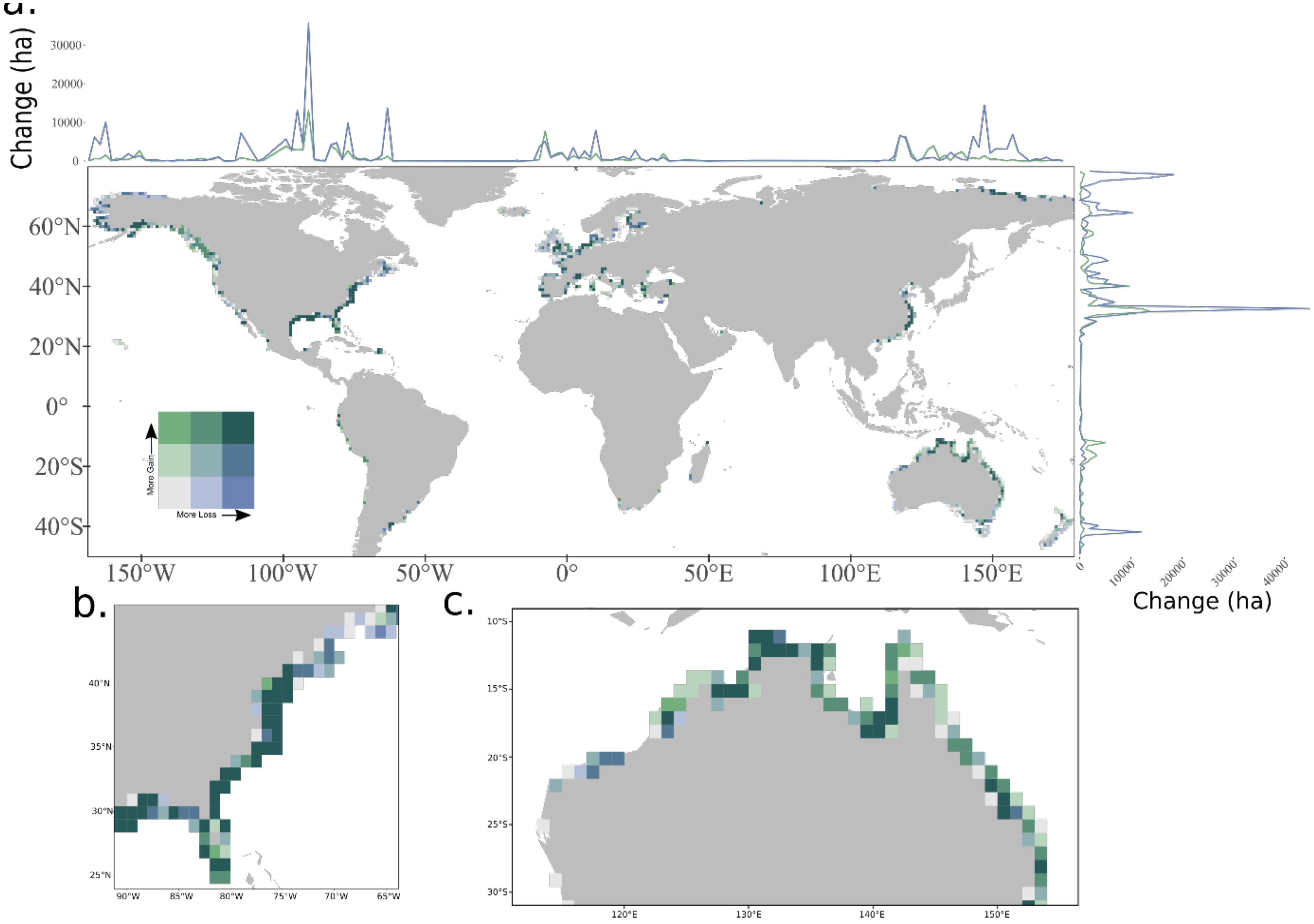
- Types of loss
  - Overwash

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

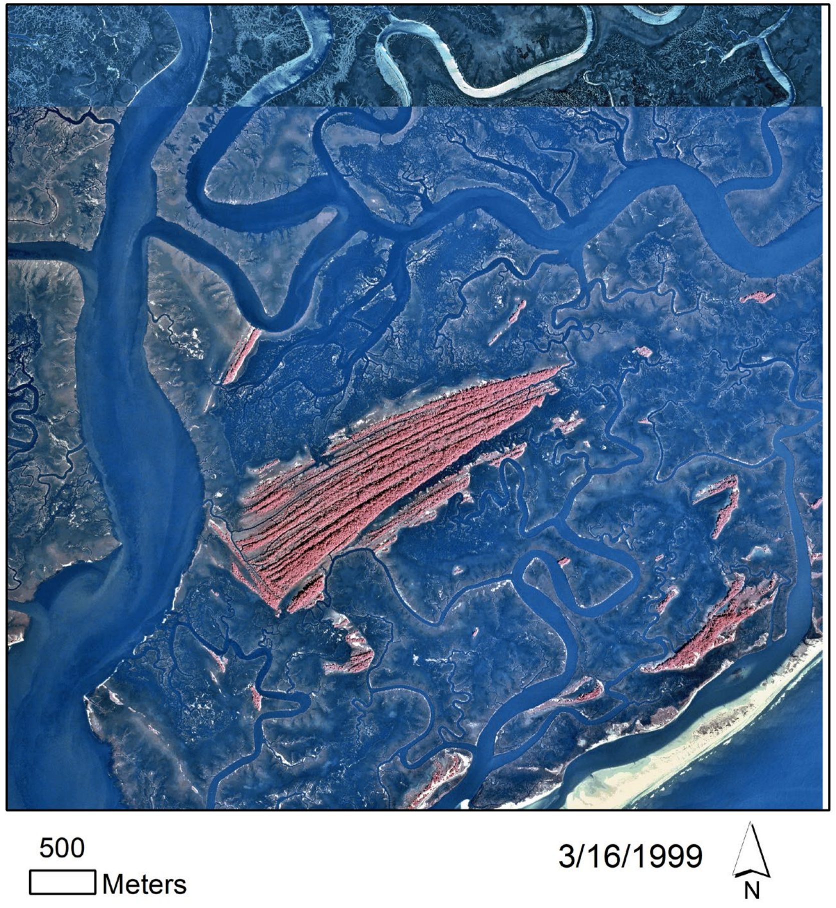




Global salt marsh change

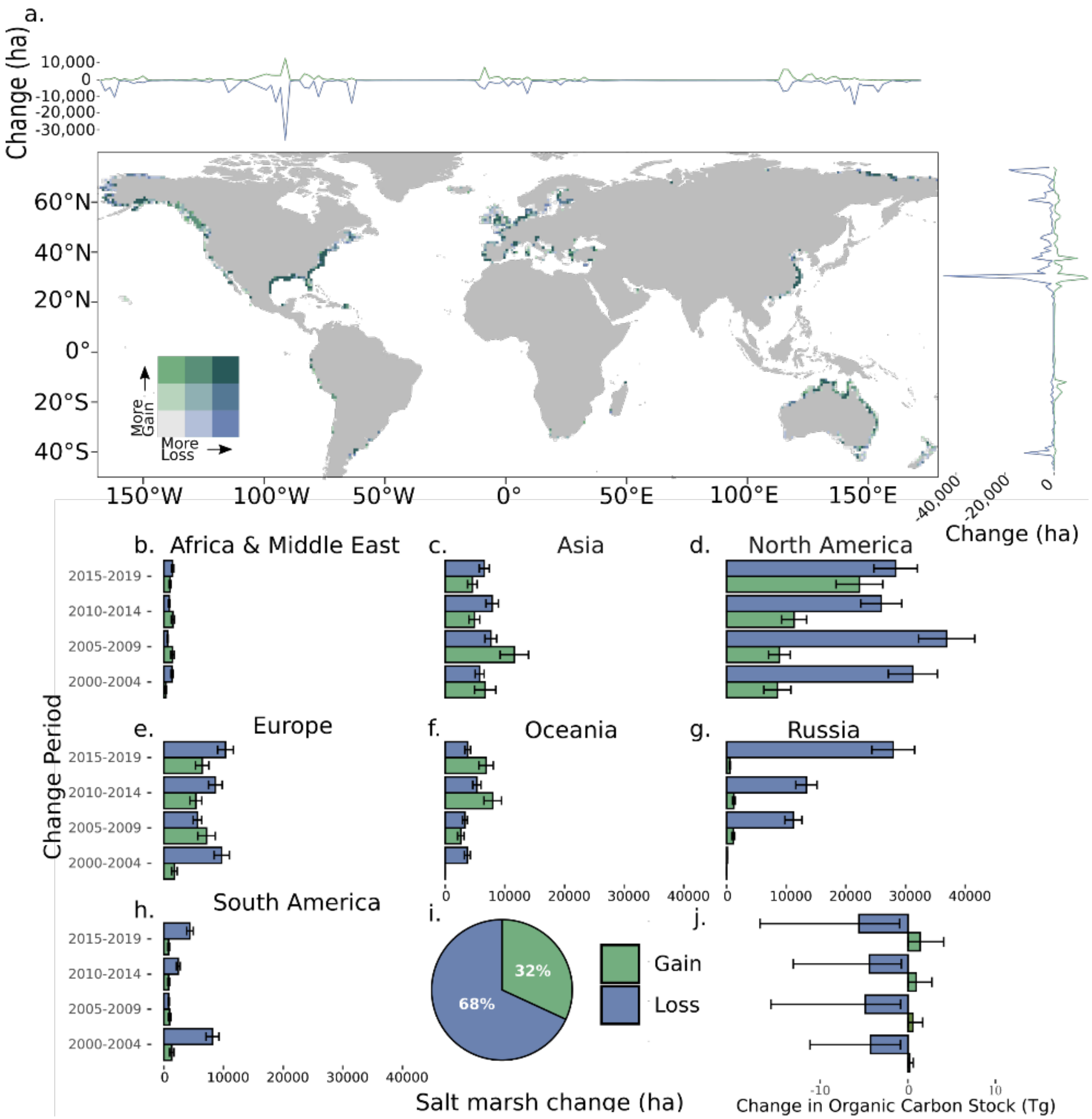


Local change example in Georgia, USA



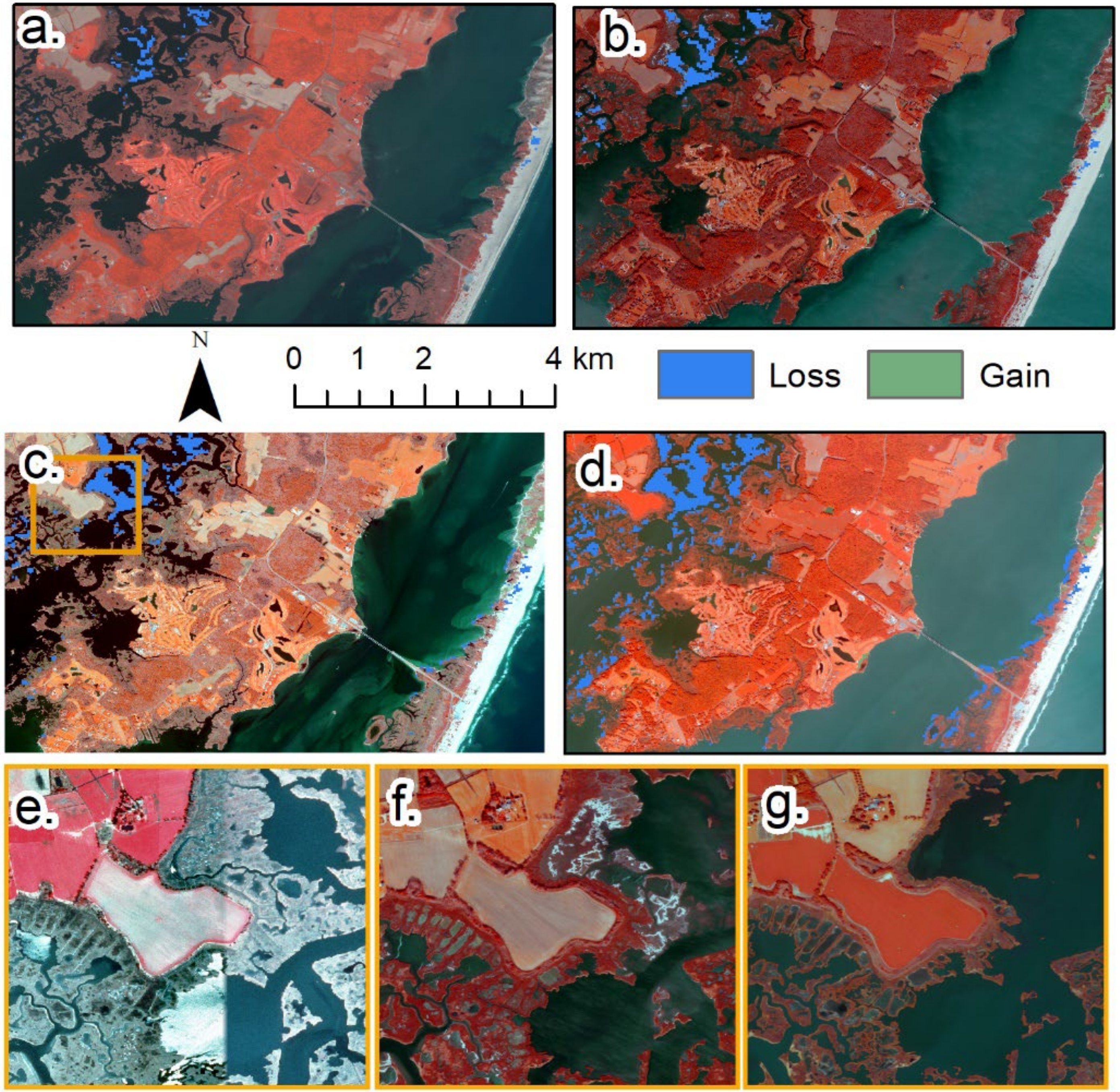
Change and carbon emissions

- From 2000-2019, there was a global net salt marsh loss of -1,452.84 km^2 (-733.1 to -2172.07 km^2).
- Globally, 4.7% of all salt marsh losses had recovered by 2019, with most of the recovery occurring in areas lost between 2005-2009



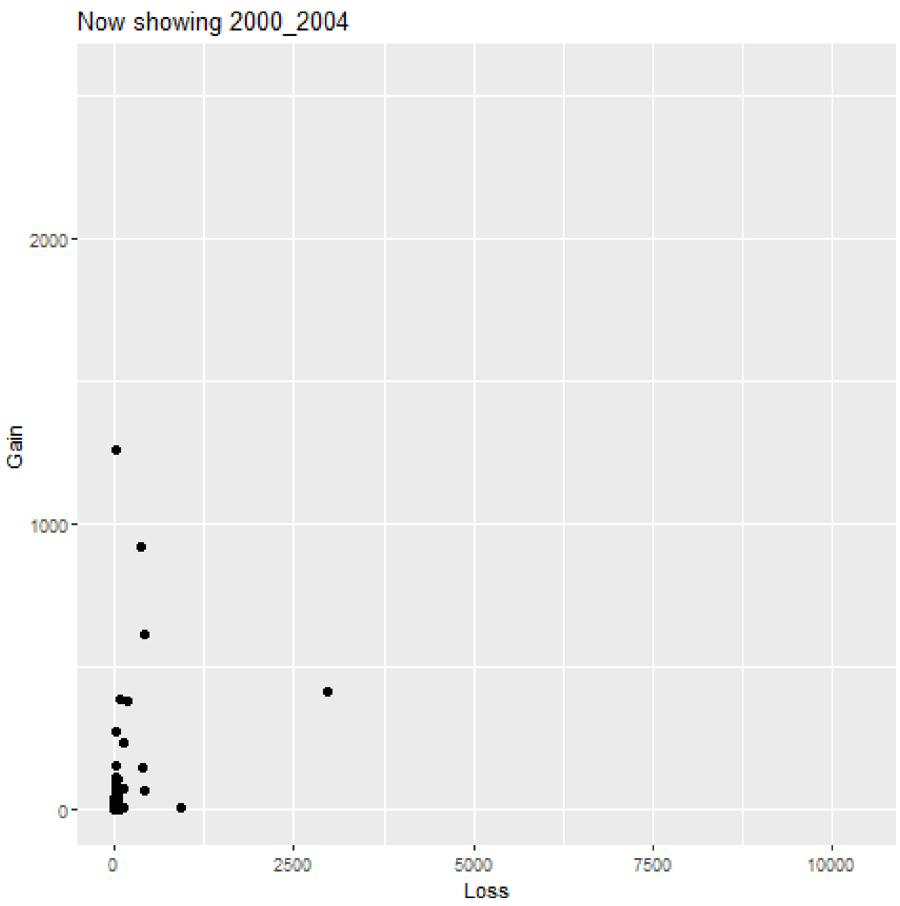
Long term change

Loss driven by interior drowning (f.)
Loss in yearly epochs (a-d)
Prior to loss (e.)



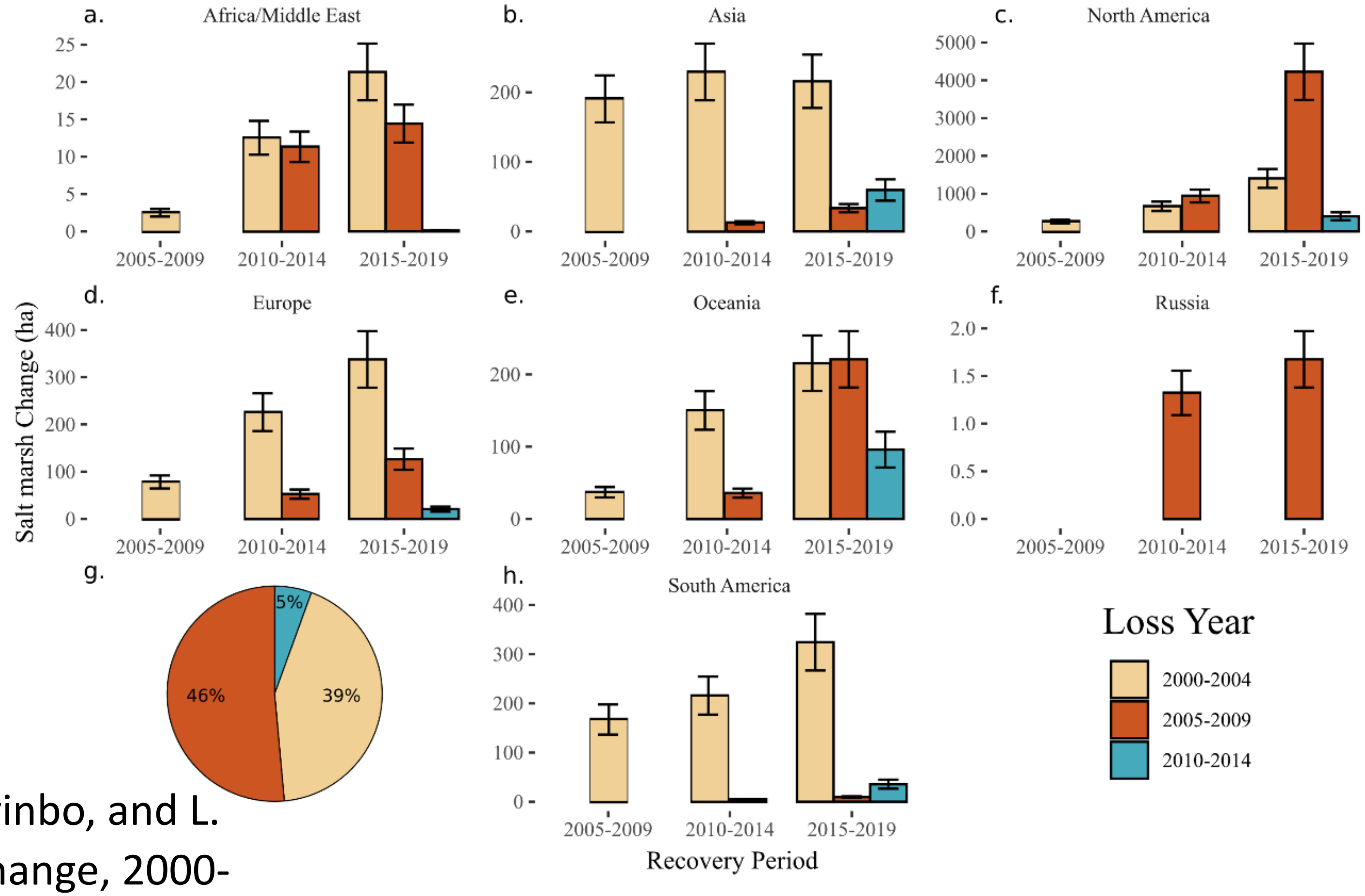
CONUS loss and gain by watershed

- A few watersheds and the 2005-2009 period drove change within the CONUS
- Both loss and gain varied across the time period
- No clear trend at the regional or watershed level



Salt marsh recovery

- Recovery is an important change process with certain types of loss more likely to recover
- Salt marsh recovery following storm related losses –
    - Loss from 2005-2009 had the greatest recovery rate in the Gulf
    - Corresponding with (2005 and 2008)



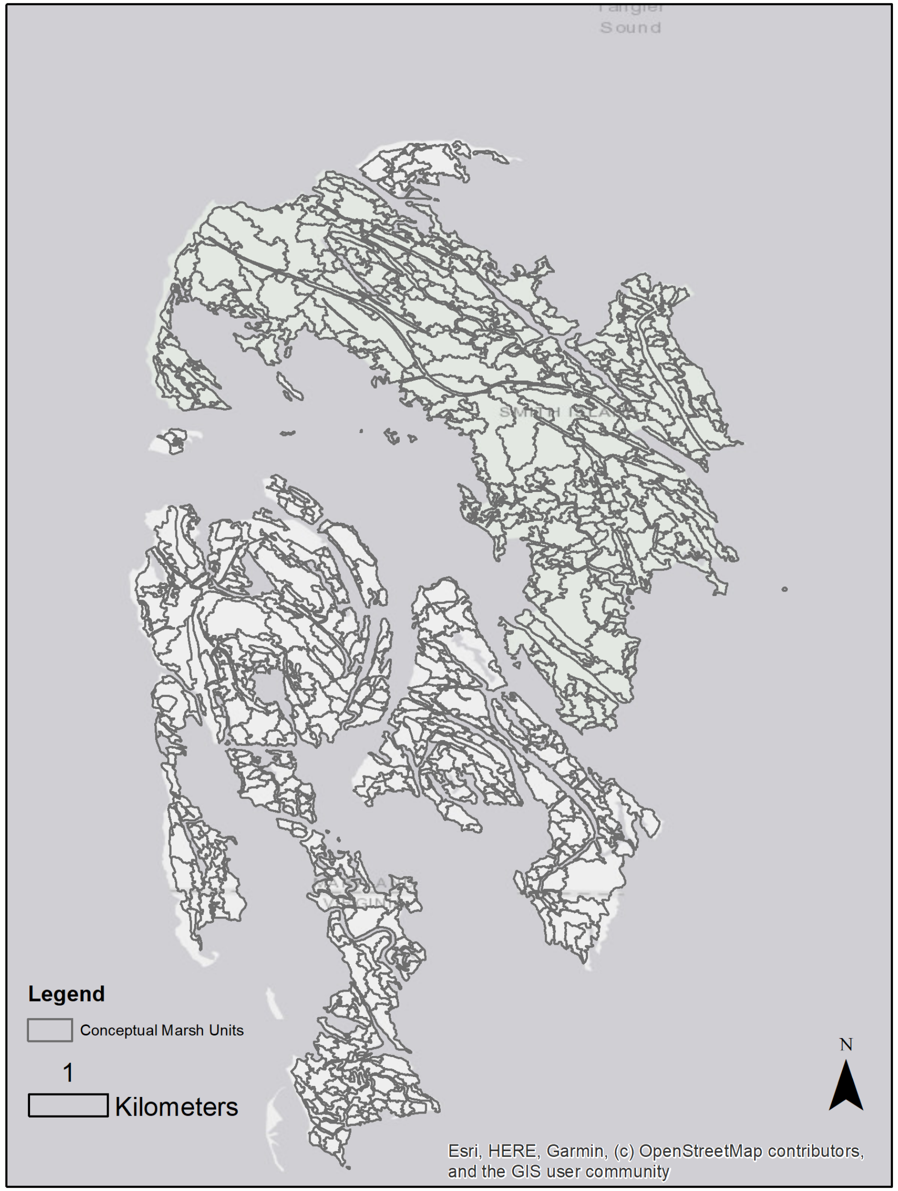
Data available: Campbell, A., T. Fatoyinbo, and L. Goldberg. 2022. Global Salt Marsh Change, 2000-2019. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2122

Chesapeake Bay – Case Study

- Spatial estimates of SOC (Maxwell et al. 2024)
- Lifespan of salt marshes (Ganju et al. 2024)
- Multiple yearly estimates of change
    - US National Land Cover Database (USGS, 2024)
        - 30 m
        - 1985-2024
        - Wetland classes: Woody Wetlands and Herbaceous
    - Global wetland layer (Zhang et al. 2023)
        - 30 m
        - 2000-2022
        - Wetland classes: permanent water, swamp, marsh, flooded flats, saline, mangrove forest, salt marshes, and tidal flats

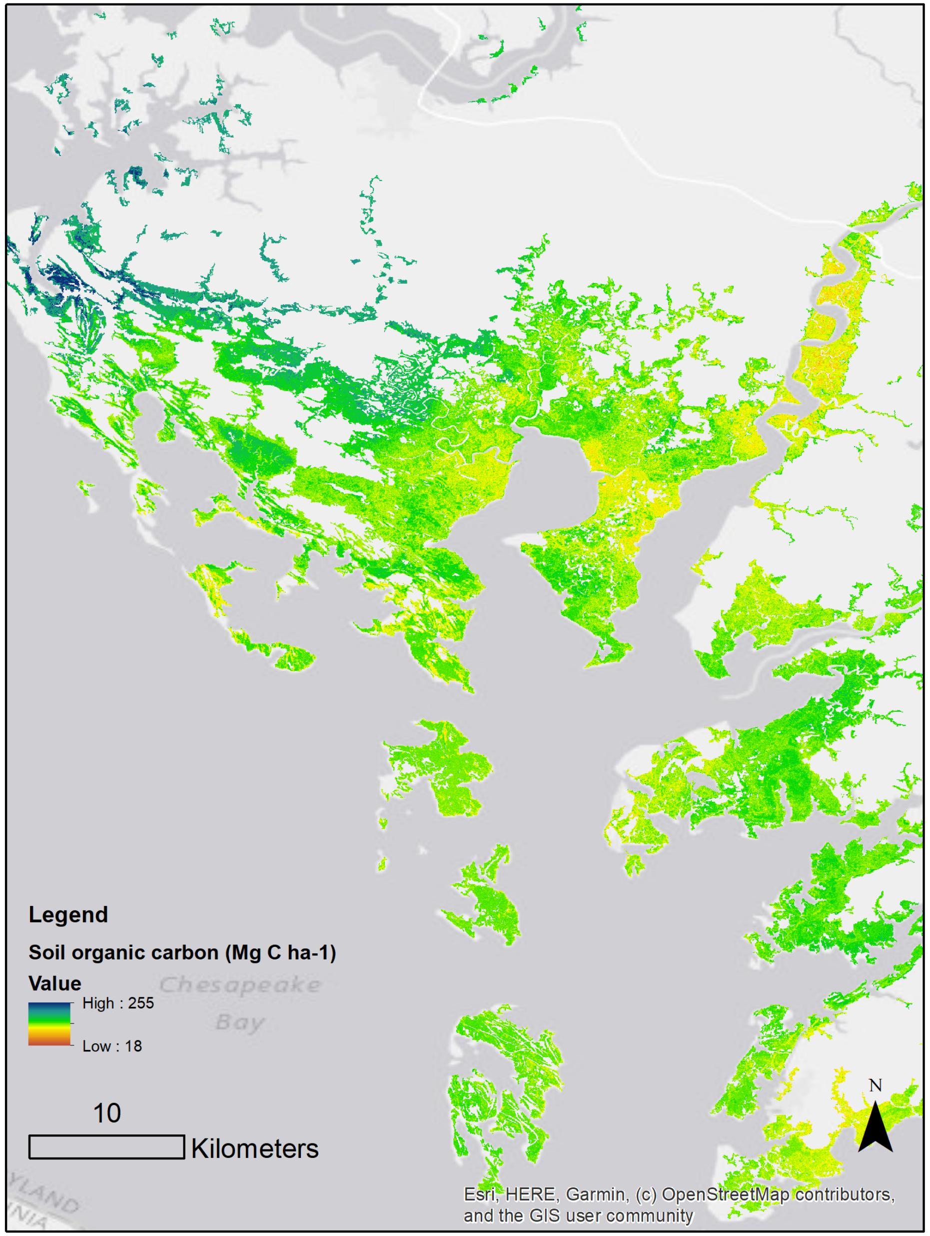
Conceptual Marsh Units

- Hydrological marsh units
- Lifespan calculated by Unvegetated Vegetated Ratio (UVVR) and modeled sediment supply
- Utilizing relationships developed with in situ data
- Lifespan by sea level rise scenario are also estimated.

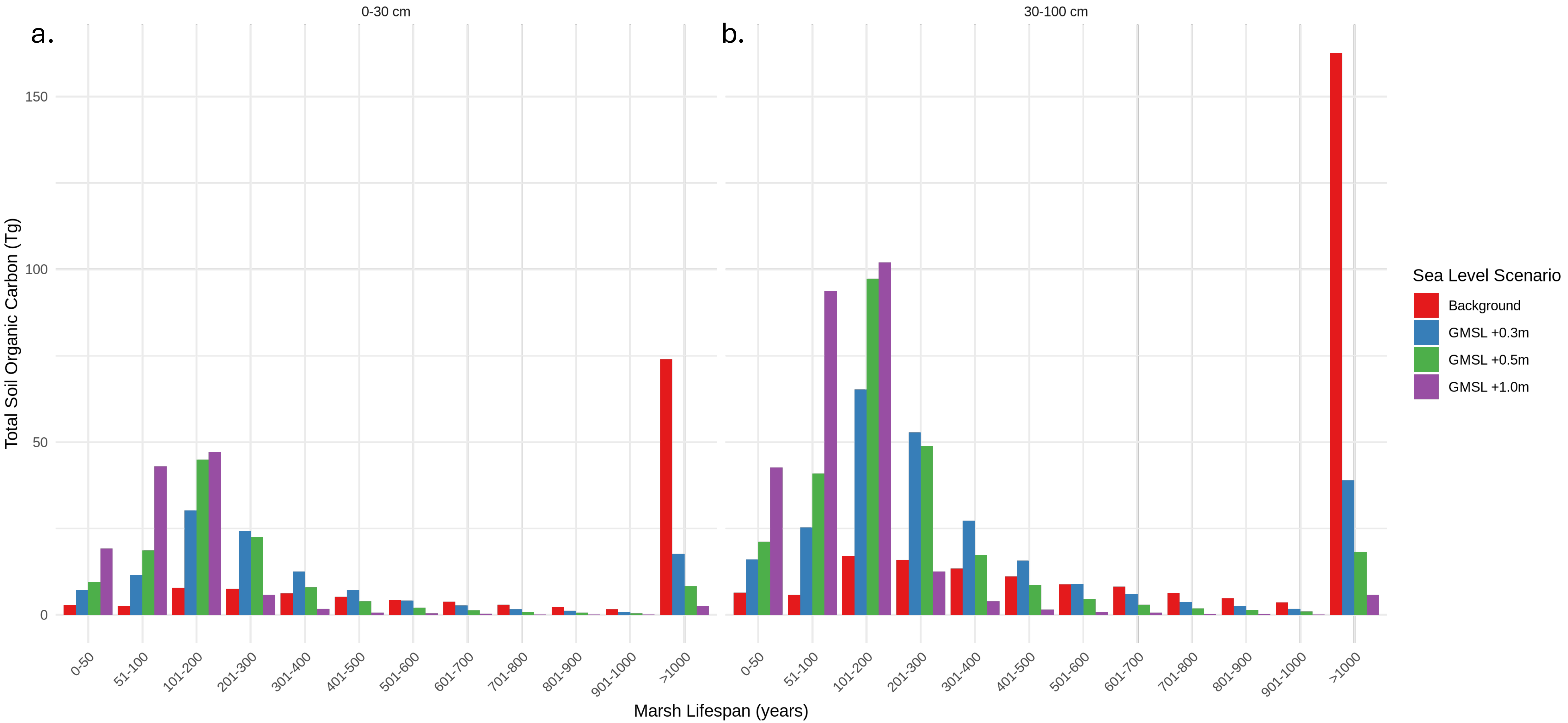


Soil organic carbon

- Spatial prediction of tidal marsh soil organic carbon.
  - 10 m spatial resolution
  - Predicted to the extent of global tidal marsh map (Worthington et al. 2024).
- Does not predict values in regions of high uncertainty



Soil organic carbon by lifespan



Remote sensing data products

- Multiple yearly estimates of change
  - US National Land Cover Database (USGS, 2024)
    - 30 m
    - 1985-2024
    - Wetland classes: Woody Wetlands and Herbaceous
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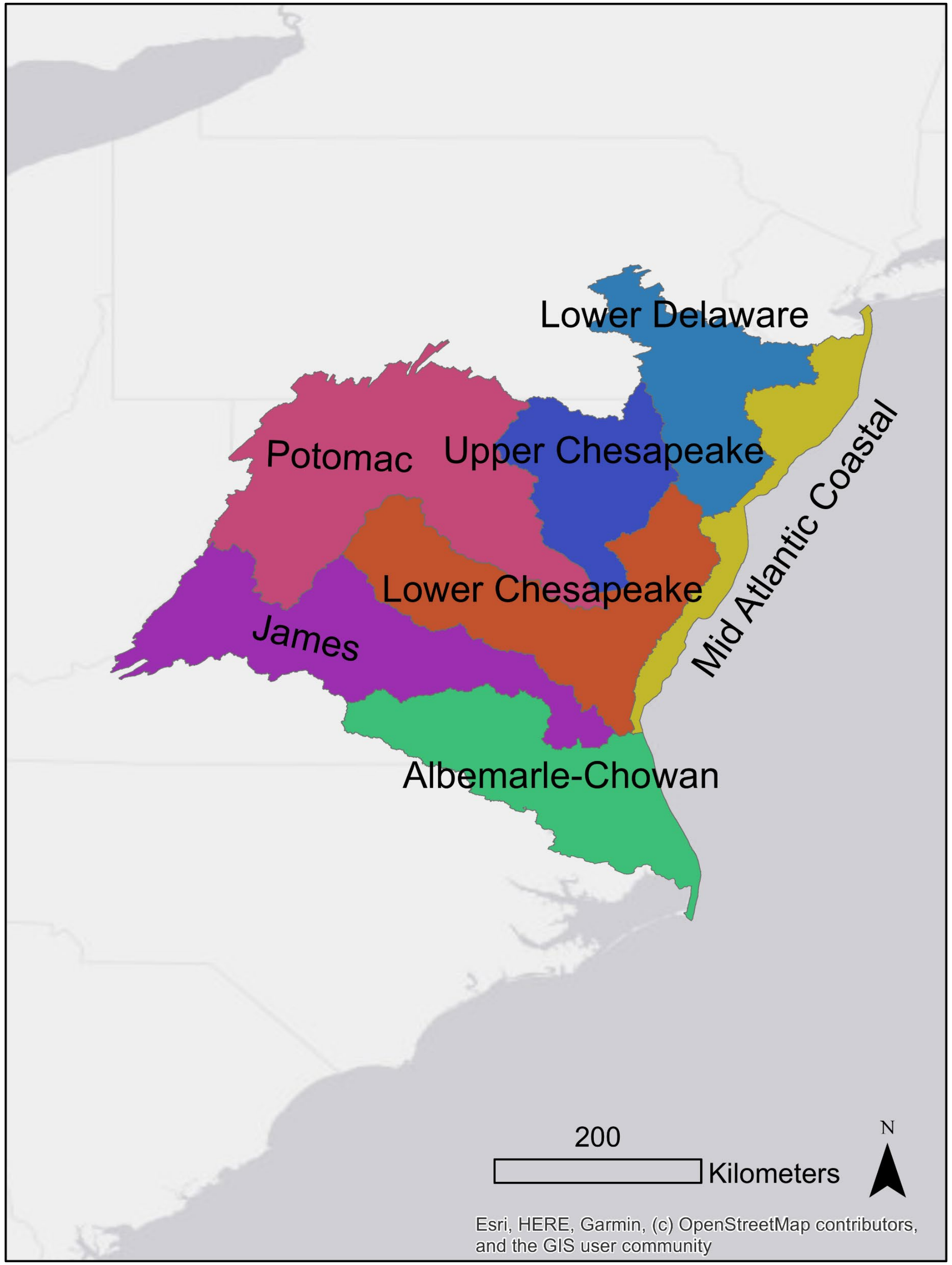
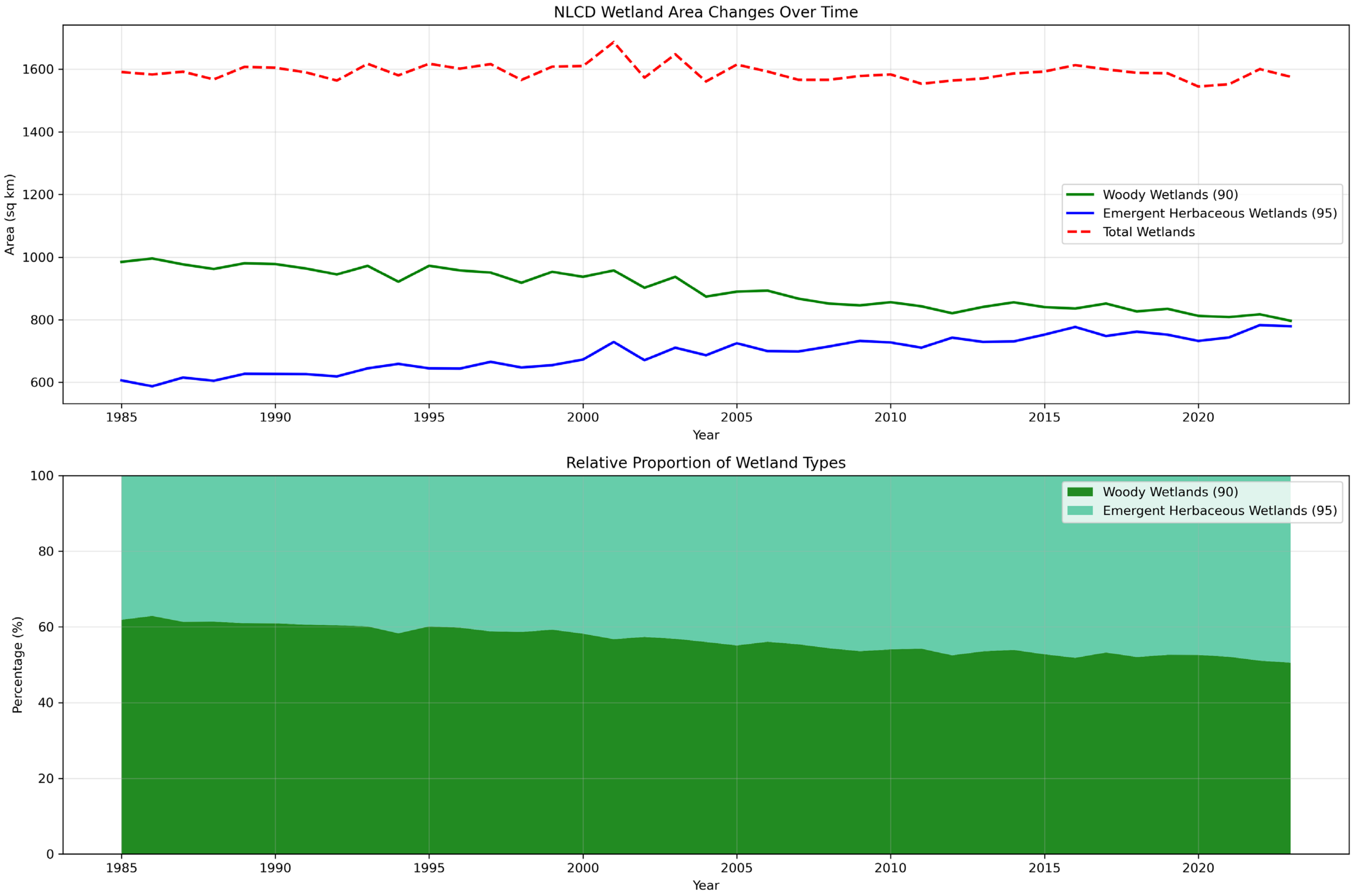
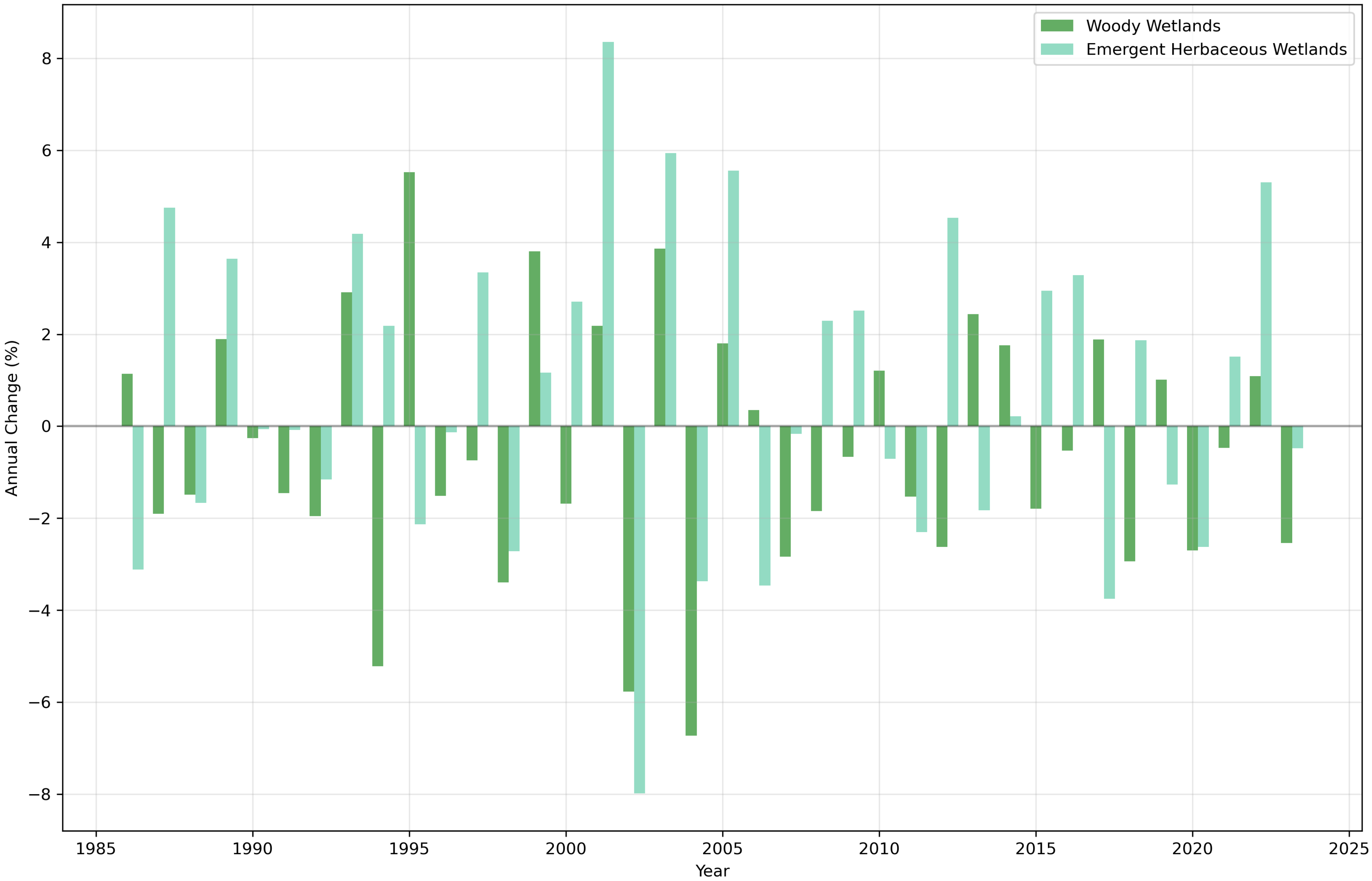


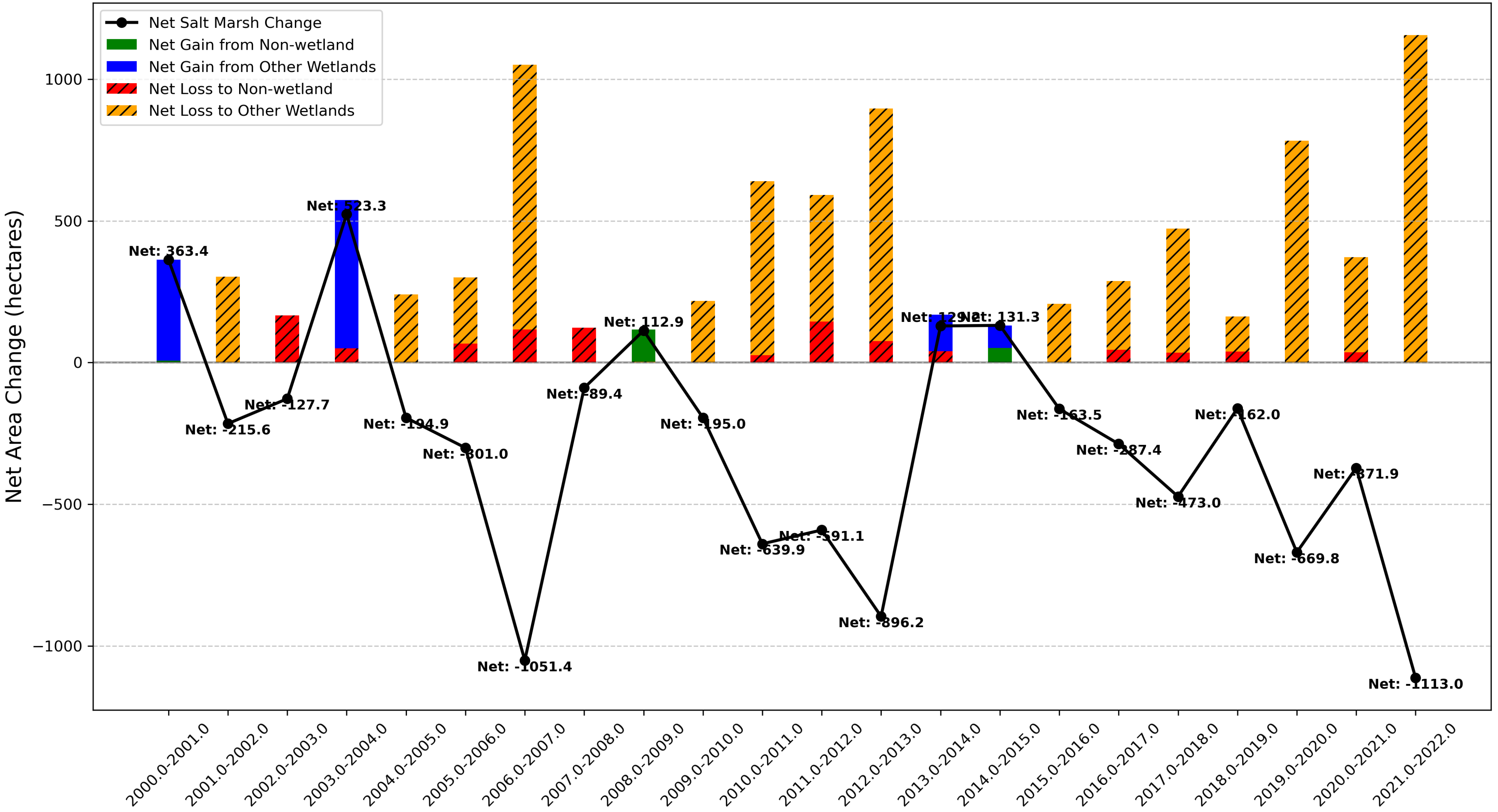
Mid-Atlantic – NLCD wetland change trends



Mid-Atlantic – Annual % change of wetland classes



Salt marsh



Net Salt Marsh Change
Net Gain from Non-wetland
Net Gain from Other Wetlands
Net Loss to Non-wetland
Net Loss to Other Wetlands
Net Area Change (hectares)
1000
500
0
−500
−1000
Net: 363.4
Net: -215.6
Net: -127.7
Net: 523.3
Net: -194.9
Net: -301.0
Net: -1051.4
Net: -89.4
Net: 112.9
Net: -195.0
Net: -639.9
Net: -591.1
Net: -896.2
Net: 129.2
Net: 131.3
Net: -163.5
Net: -287.4
Net: -473.0
Net: -162.0
Net: -669.8
Net: -371.9
Net: -1113.0
2000.0-2001.0
2001.0-2002.0
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2005.0-2006.0
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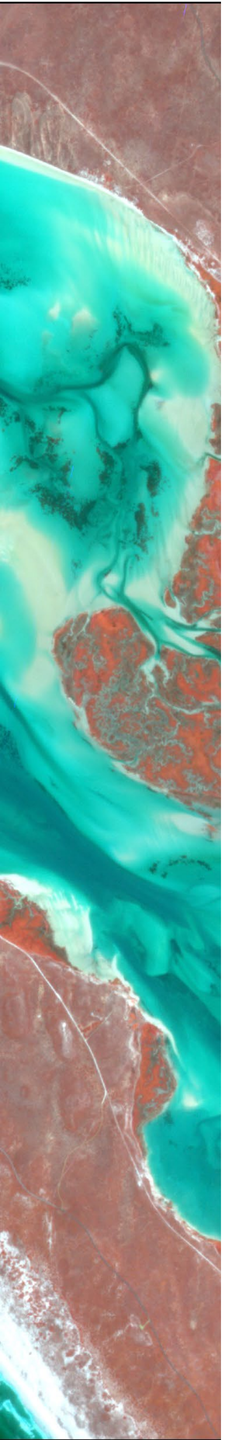
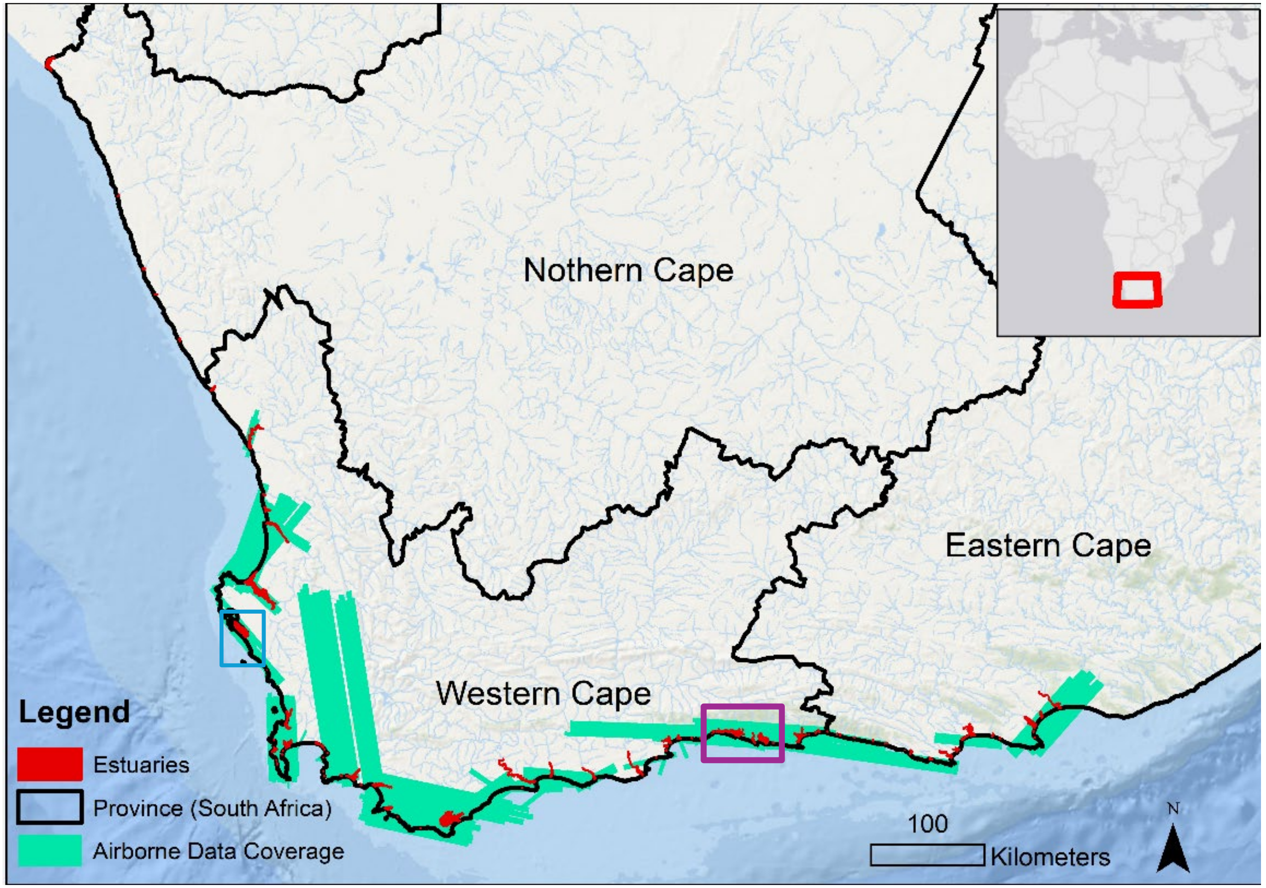
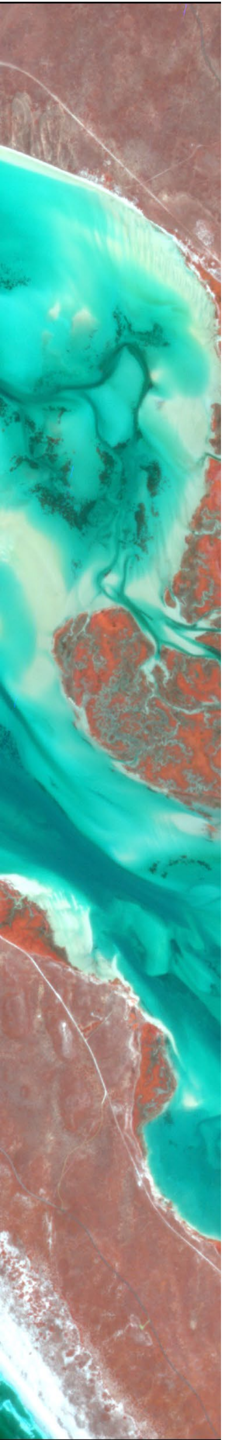
2021.0-2022.0



Case Study 2: South Africa

- Biodiversity-Remote sensing for Estuarine and Coastal Habitat research(BioREaCH)is focused on understanding the biodiversity of coastal wetlands across the Greater Cape Floristic Region of South Africa using imaging spectroscopy, LiDAR, and multispectral satellite data.
- Recent efforts by collaborators to map change across these coastal wetlands in South Africa
  - Landsat and Sentinel-1 and 2 overpredicted both seagrass and salt marsh habitats (Van Deventer et al. 2025)

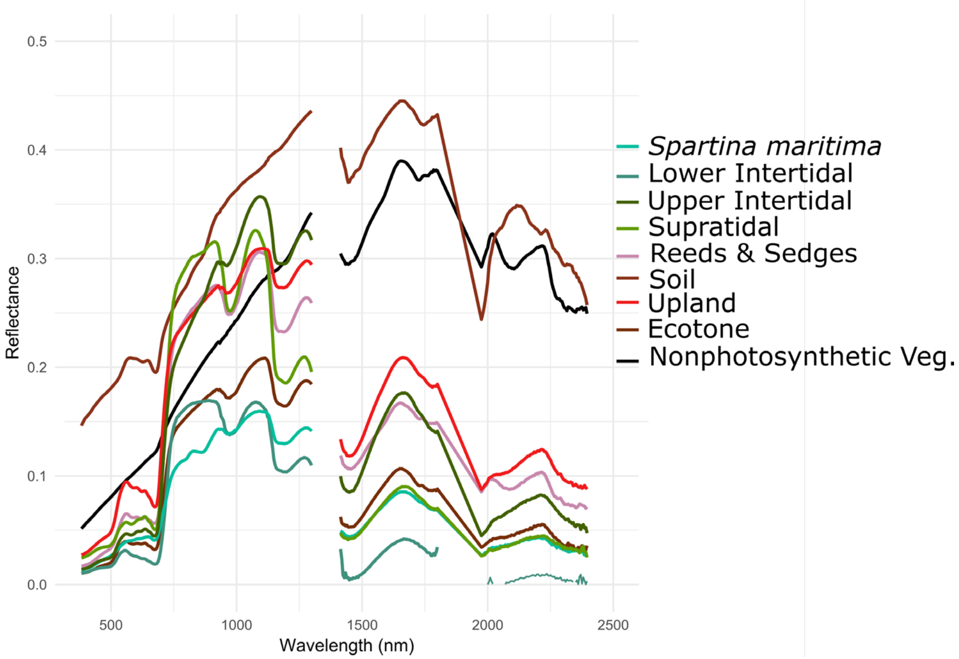


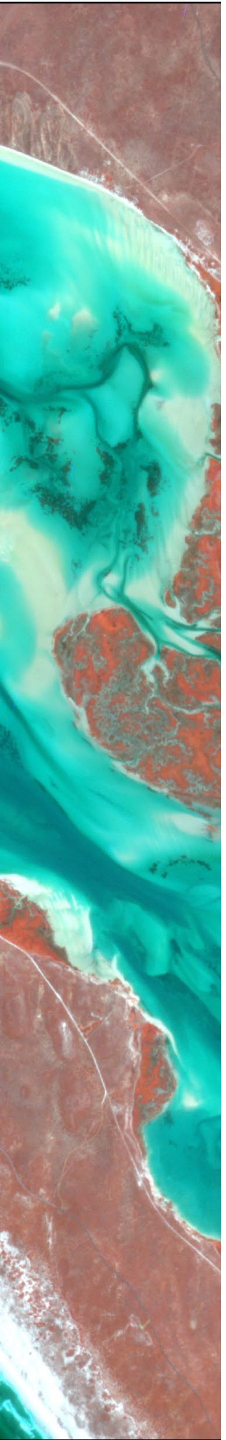


Spectral libraries

- We used three hundred and ten in situ ASD FieldSpec measurements to create our spectral library
- Develop a spectral library and apply to airborne data for plant functional community classification

1. Broad
   Water, Wetland, Upland, Soil
2. Tidal marsh community
   Water, Supratidal marsh, Upper intertidal marsh, Intertidal marsh, Upland, Reeds and Sedges, Soil



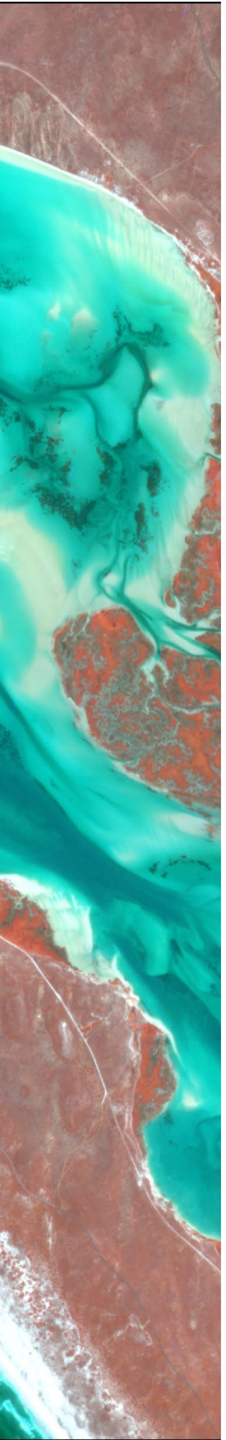


MESMA

Multiple Endmember Spectral Mixture Analysis (MESMA; Ochoa et al. 2025) was used to apply the spectral signatures to AVIRIS-NG data collected during the BioSCape campaign.

MESMA assumes each pixel is composed of a combination of pure spectra or endmembers.

In our study, the spectral library is composed of pure spectra collected in the field in Langebaan Lagoon coincident with airborne image acquisitions.

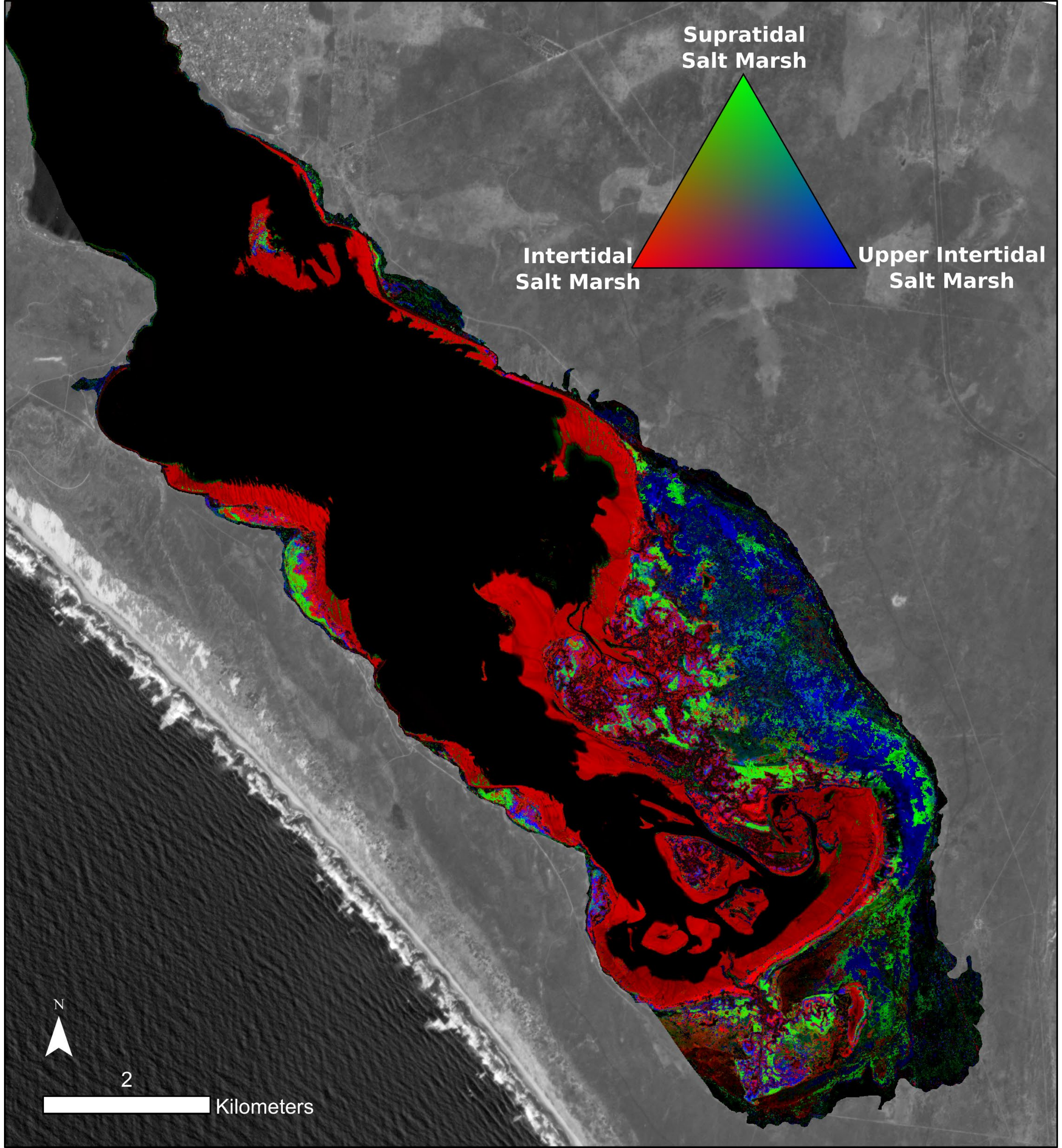


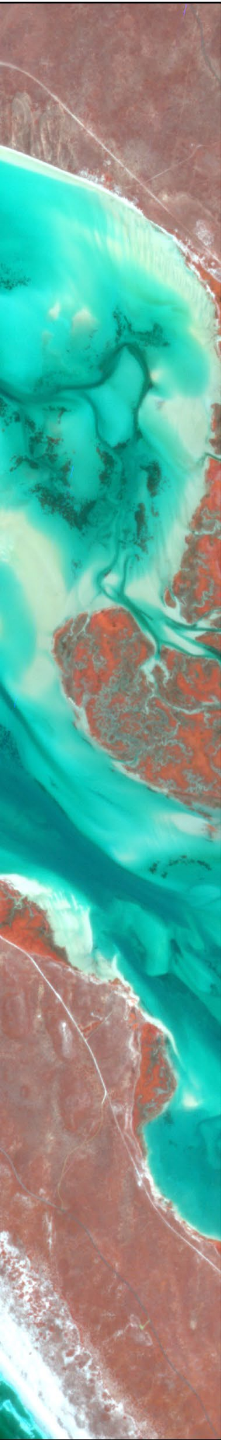
MESMA-Results

Langebaan Lagoon – 10/29/2023 (0.077 m above MSL)

Salt marsh habitats

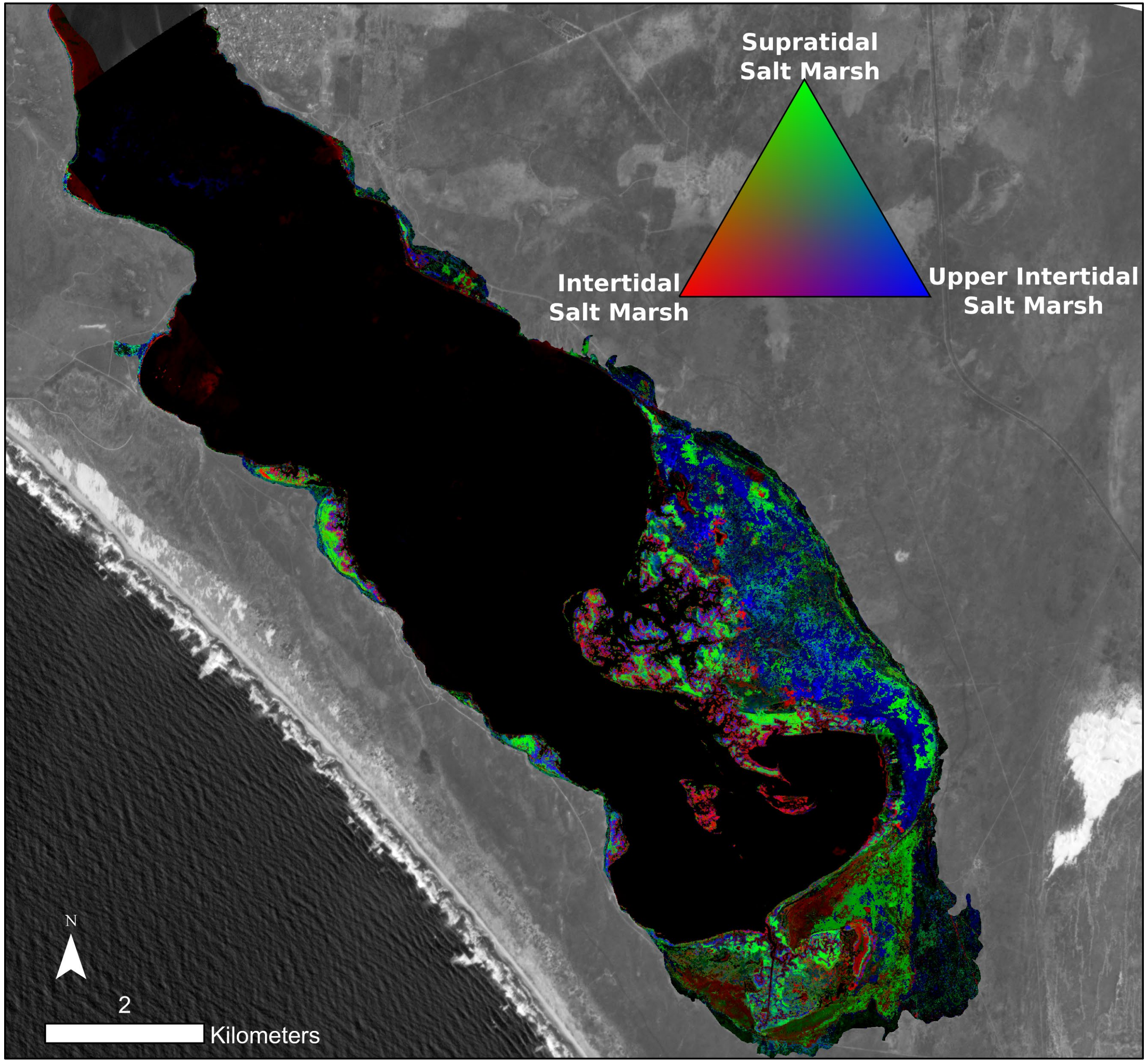
- Intertidal is over predicted





MESMA-Results

Langebaan Lagoon – 10/26/2023 (0.708 m above MSL)
Salt marsh habitats
- Intertidal extent reduced due to higher water levels and no submerged spectra in the spectral library



Conclusions

- Remote sensing is rapidly becoming indispensable for carbon monitoring of these ecosystems
- US has multiple algorithms and approaches to mapping coastal wetland extent at 30 m
  - Global Wetland Layer, NLCD, DECODED (Yang et al. 2022), CCDC+ (Di Vittorio et al. 2024)
- Despite relying on the same underlying remote sensing data the outcomes are very different depending on the methods, thematic resolution, and scope
- Remote sensing advances will address many of the limitations of current sensors

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