Analyzing wetland change along the Louisiana Coast during a period of rapid sea-level rise

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OVERVIEW

The Louisiana Coast has faced rapid sea-level rise (>10 mm/yr) since 2010 (Dangendorf et al., 2023), which can affect ecosystems along the coast and thus their functions to communities as barriers and mitigators of flood risks. According to Li et al. (2024), 87% of the wetland sites in the CRMS project (which monitors parameters like water level (RWL) and surface elevation change (SEC) along the Louisiana coast) cannot keep up with such rising water levels. That study analyzes the rates of RWL and SEC, however vegetation may respond differently. This project compares the vegetative health in terms of greenness via NDVI (as measured from Landsat and Sentinel-2 imagery) of select CRMS sites based on the degree of drowning (measured by elevation deficit, ED) and tidal range experienced from 2000 to 2020. Here, we take a closer look at 2 sites on Marsh Island and 1 site to the northeast.

NDVI: *vegetation index that measures vegetation health in terms of greenness*
Elevation Deficit (ED): *rate of relative water level (ΔRWL) minus rate of surface elevation change (ΔSEC)*

Table 1: *CRMS sites 504, 523, and 545 are paired such that 504 and 523 will demonstrate tide comparisons (a) and 545 and 523 demonstrate ED comparisons (b).*

a) Tidal Range Comparison

Site	Tidal Range	ED (degree of drowning)	
504	5 mm	4.5 mm/yr	No tide, low ED
523	220 mm	5 mm/yr	Tide, low ED

b) Elevation Deficit Comparison

Site	Tidal Range	ED (degree of drowning)	
545	220 mm	26 mm/yr	Tide, High ED
523	220 mm	5 mm/yr	Tide, Low ED

METHODS

- Sites are paired based on degree of drowning (ED) and tidal range (data from Li et al., 2024).
  - In the pair, either degree of drowning or tidal range is equivalent in value and the other varies.
- Calculate/analyze NDVI of Landsat & Sentinel-2 images via Google Earth Engine & ArcGIS.
- For Landsat imagery: only pixels containing ≥75% land are used (Couvillion, 2021 dataset applied as mask).
- For Sentinel-2 imagery: a threshold between water and land is manually determined to mask out water pixels.
- Sites are analyzed within a buffer radius of ~100 m.

Site	Marsh Class
504	Brackish
523	Brackish
545	Fresh

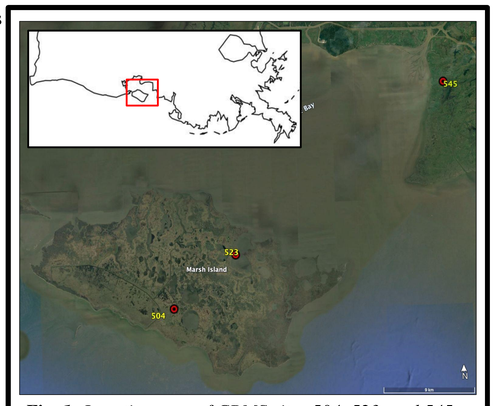

Fig. 1: *Location map of CRMS sites 504, 523, and 545 with an inset map of the greater Louisiana Coast.*

Fig. 3a-c: *Water level and surface elevation field data for each site. Low and high tide water levels are included. Data is compiled by and sites are classified by Li et al., (2024).*

Fig. 4a-c: *Percent coverage of vegetation species. Data is compiled from http://cims.coastal.louisiana.gov.*

Percent cover of vegetation species can vary greatly from year to year. Site 504 shows an increase in *Spartina patens* and a decrease in *Distichlis spicata (Fig. 4a)*. Site 523 shows a decrease in *Distichlis spicata (Fig. 4b)*. Site 545 shows an increase in *Ludwigia grandiflora* and a disappearance of *Cicuta maculata* and *Zizaniopsis miliacea* starting in 2019 & *Phragmites australis* starting in 2021 (Fig. 4c. Site 545's species disappearance occurs around the site's significant surface elevation drop (2019-2020) (Fig. 3c).

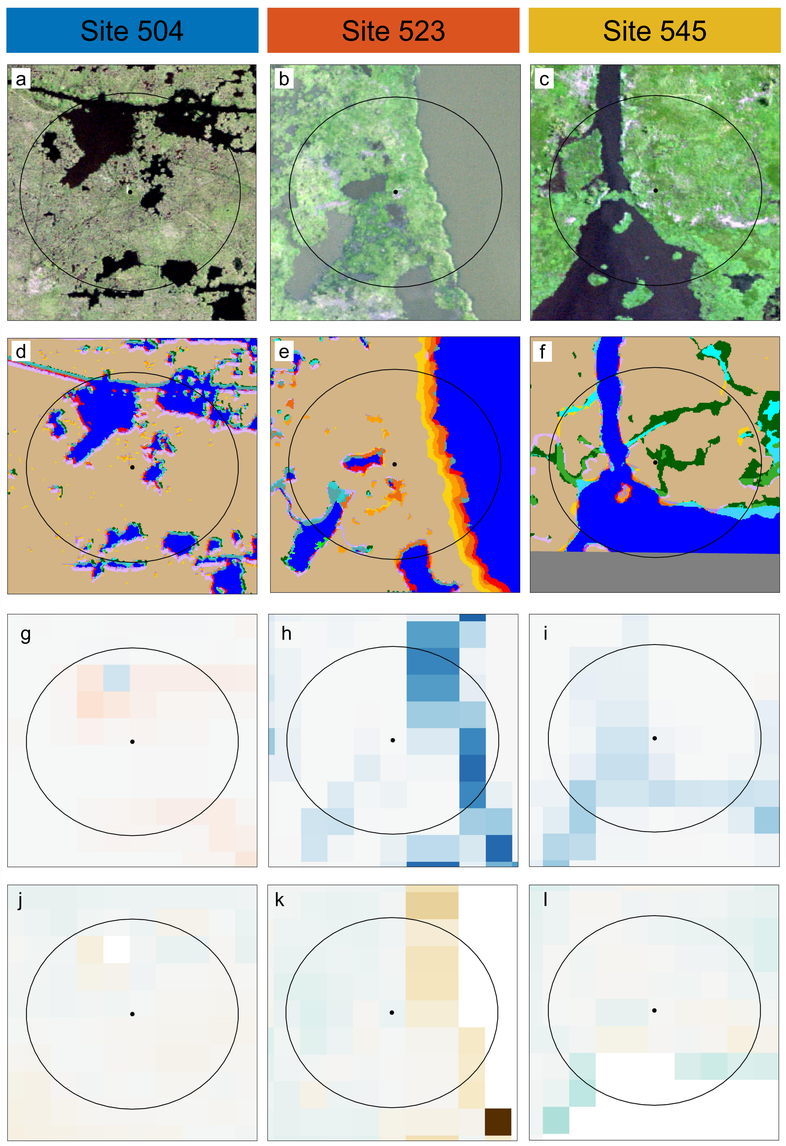

Fig. 2a-c: *NAIP 1-meter resolution aerial imagery of CRMS sites 504, 523, and 545 locations in 2019.*

Fig. 2d-f: *Land change analyses of the 3 sites by USGS as derived from NAIP aerial imagery. Legend describes land change pattern and the respective year it is observed.*

Color	Description
	Persistent land
	New Water - 2018
	Oscillating - Ephemeral water - 2016
	Persistent loss - 2016
	Oscillating - Ephemeral water - 2012
	Oscillating - Ephemeral water - 2012, 2018
	Oscillating - Water - 2012, 2016
	Persistent loss - 2012
	Oscillating - Ephemeral water - 2008
	Oscillating - Ephemeral water - 2008, 2018
	Oscillating - Ephemeral water - 2008, 2016
	Oscillating - Water - 2008, 2016, 2018
	Oscillating - Ephemeral water - 2008, 2012
	Oscillating - Water - 2008, 2012, 2018
	Oscillating - Water - 2008, 2012, 2016
	Persistent loss - 2008

Color	Description
	Persistent gain - 2008
	Oscillating - Land - 2008, 2012, 2016
	Oscillating - Land - 2008, 2012, 2018
	Oscillating - Ephemeral land - 2008, 2012
	Oscillating - Land - 2008, 2016, 2018
	Oscillating - Ephemeral Land - 2008, 2016
	Oscillating - Ephemeral Land - 2008, 2018
	Oscillating - Ephemeral land - 2008
	Persistent gain - 2012
	Oscillating - Land - 2012, 2016
	Oscillating - Ephemeral land - 2012, 2018
	Oscillating - Ephemeral land - 2012
	Persistent gain - 2016
	Oscillating - Ephemeral land - 2016
	New land - 2018
	Persistent water

Under a 30-m Landsat resolution, Site 523 reflects the 1-m land changes the best. This is observed by the intruding water in Fig. 2e and h.

Fig. 2g-i: *The trend of each Landsat pixel's land fraction described by the linear regression slope calculated from 2000 - 2020. Red/Positive = increasing land fraction. Blue/Negative = decreasing land fraction (increasing water fraction).*

Fig. 2j-l: *The trend of each Landsat pixel's NDVI described by the linear regression slope calculated from 2000 - 2020. Green/Positive = increasing NDVI. Brown/Negative = decreasing NDVI.*

Corresponding to the pixels reflecting increasing water fractions (Fig. 2h) are decreasing NDVI trends (Fig. 2k).

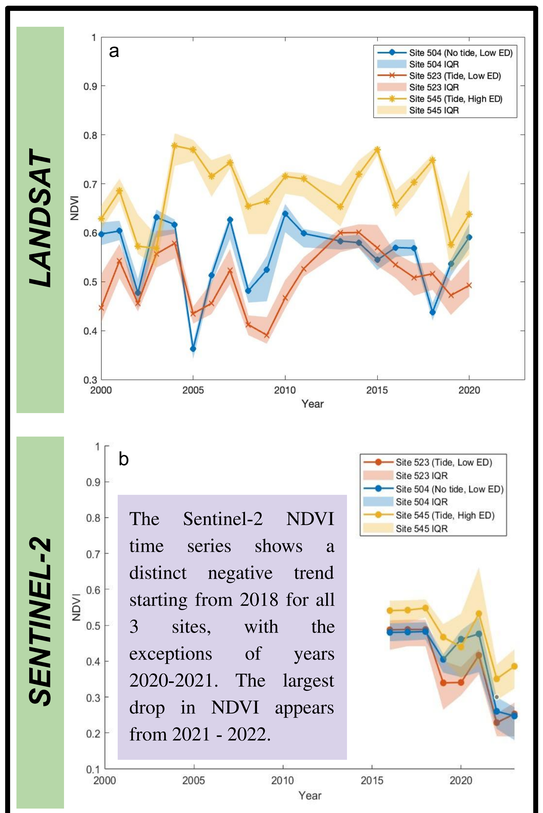

Fig. 5: ***(a)*** *NDVI time series of Landsat imagery from 2000 - 2020 for the 3 sites. NDVI values represent the median NDVI of pixels within a buffer radius of 105 m.* ***(b)*** *NDVI time series of Sentinel-2 imagery from 2016 - 2023 for the 3 sites. NDVI values represent the median NDVI of pixels within a buffer radius of 100 m. IQR = interquartile range of that radius.*

Although Site 545 is classified as 'drowning complete' (Fig. 3c), the vegetation is healthier (overall higher NDVI) than Sites 504 and 523 (Fig. 5a & b). Additionally, Site 545 has greater diversity in vegetation species than the other 2 sites (Fig. 4a-c). However, vegetation species have started to disappear, which may signify a start of wetland collapse.

Table 2: *Descriptive comparisons of the 3 sites split into 4 categories: (1) Landsat NDVI trend before 2010, (2) Landsat NDVI trend after 2010, (3) Overall NDVI values for that site, and (4) Changes in vegetation species percent coverage.*

Site Comparisons	Site 504	Site 523	Site 545
Landsat NDVI trend before 2010	Mainly oscillating	Slight negative trend	Negative trend 2004 - 2010
Landsat NDVI trend after 2010	Negative trend 2010 - 2018; Positive trend 2018-2020	Positive trend 2010 - 2013; Negative trend 2013 - 2020	Slight negative trend
Overall NDVI	About the same NDVI values as Site 523	About the same NDVI values as Site 504	Overall higher NDVI values than Sites 504 and 523
Vegetation species percent coverage	1 species increase; 1 species decrease	1 species decrease	3 species disappear

CONCLUSIONS

- NDVI trends can vary with land fraction trends. NDVI can decrease with decreasing land fraction or it can increase with increasing land fraction.
- The NDVI time series reveals potential negative NDVI trends, although not at the same time for all 3 sites.
- Percent coverage of vegetation species can be used to give additional insight into vegetation dynamics such as the decline or disappearance of a species.

FUTURE WORK

- Examine if there are any patterns related to hydrologic basins.
- Explore reasons related to environmental settings that explain the time series trends (e.g., vegetation species, hurricane paths, etc.)
- Explore patterns in vegetation health in response to different magnitudes of elevation deficit and tidal range.

References:
Coastwide Reference Monitoring System-Wetlands Monitoring Data (2023). http://cims.coastal.louisiana.gov.
Couvillion, B. (2021). Coastal wetland area change in the Gulf of Mexico, 1985-2020: U.S. Geological Survey data release.
Li, G. et al. (2024). *Nature Communications, 15*(1), 1226.
Gorelick N., et al. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone.
Dangendorf, S., et al. (2023). *Nature Communications, 14*(1), 1935.