**Southeast Coast Ecological Conservation**

*Investigating the Development of Ghost Forests Due to Saltwater Intrusion along the Savannah River, Georgia Coastline of the United States*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

In an exciting partnership with the USGS, USDA, and Georgia Southern University, this project used remote sensing and in-situ data to map the increasing expanse of dying vegetation (ghost forests) and investigate the distressing effects of saltwater intrusion along the Savannah River’s coastal ecosystem.

***Abstract:***

Shallow aquifers along the southeastern US are experiencing saltwater intrusion from rising sea levels, changes in tidal cycles, and groundwater pumping, which are leading to higher soil salinity. Ghost forests, or areas where coastal forests have deteriorated due to salt water, are expanding in the Southeast US. We partnered with the USGS, USDA, and Georgia Southern University to investigate saltwater intrusion effects on coastal forests in the lower Savannah River using NASA Earth observation data spanning 2013 to 2023. The multi-sensor approach used Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), and Planet Labs’ Dove PlanetScope & RapidEye RapidEye Earth Imaging Sensor (REIS). Our project aimed to determine the feasibility of detecting coastal forest health decline by creating a supervised land cover classification and analyzing the normalized difference vegetation index (NDVI). We directly linked a remote-sensing based time-series to *in-situ* porewater salinity trends throughout the extent of the Savannah River. Our project ran at both a regional and site-level scale (4 USGS-monitored sites). We found differences in site-level NDVI values over 2013-2023 from both Landsat and Planet sensors. At the three sites nearest to the coast, we observed a muted seasonal variation that exhibited an inverse relationship with the increasing levels of river and porewater salinity found in those locations. The results provided here add to the growing body of research seeking to understand saltwater effects on coastal forests using spaceborne remote sensing and emphasize the need for proactive measures to mitigate saltwater intrusion's effects on coastal ecosystems.

***Key Terms:***

Savannah River, Ghost Forests, Saltwater Intrusion, Coastal Ecosystems, NDVI, Land Cover Classification, Landsat 8, Planet

***National Application Area Addressed:*** Ecological Conservation

***Study Location:*** Savannah River, GA

***Study Period:*** March 2013 to March 2023

***Community Concerns:***

* As sea level rises and SWI continues to threaten the health of coastal ecosystems, the communities that live in these areas are experiencing chronic changes to their environment and impacts on the ecosystem services that coastal forests provide.
* These changes include loss of biodiversity and habitats for native plants and animals, inhibited carbon sequestration and protection from storm surges, and saline contamination of shallow freshwater aquifers which provide drinking water and are important sources for agricultural production.
* Due to these impacts, communities must create climate adaptation strategies to adapt to these changing environments.

***Project Objectives:***

* **Investigate** changes in sea level rise and vegetative health
* **Synthesize & Analyz**e trends in saltwater intrusion
* **Validate & Correlate** NASA Earth Observations with in-situ (field-derived) data

**Partner Overview**

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| --- | --- | --- | --- |
| **Organization** | **POC** | **Partner Type** | **Sector** |
| **USGS, Wetland and Aquatic Research Center** | Dr. Ken Krauss, Research Ecologist; Dr. Beth Middleton, Research Ecologist | End User | Federal Government |
| **USGS, Florence Bascom Geoscience Center** | Dr. Gregory Noe, Research Ecologist | Collaborator | Federal Government |
| **USDA, Southeast Regional Climate Hub** | Dr. Steve McNulty, Director; Michael Gavazzi, Coordinator | Collaborator | Federal Government |
| **Georgia Southern University** | Dr. Georgianne Moore, Biology Chair  Dr. CJ Pell, Postdoc | Collaborator | Academia |

***Decision-Making Practices & Policies:***

The USGS Wetland and Aquatic Research Center (WARC) leads in the efforts to understand, manage, conserve, and restore aquatic and coastal ecosystems and their related fauna and flora throughout the United States and the world. In 2021, the USDA released its Action Plan for Climate Adaptation and Resilience, a guide to preparing American agriculturalists and land managers for the current and future impacts of climate change. The Climate Hubs and their partners build locally specific tools to help increase climate change adaptation capacity nationwide. The USDA and USGS have extensive knowledge utilizing NASA Earth observations and have applied NASA EO on several projects, including but not limited to land management, agriculture, ecological forecasting, disaster prevention and response, and carbon assessment.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 7 ETM+** | Normalized Difference Vegetation Index (NDVI) | Spectral signatures and indices helped identify the extent of land cover and vegetative health at a 30-meter resolution. Variations in spectral signatures helped indicate a change in land cover and vegetative change over time. This sensor was used to normalize the data where outliers occurred due to cloud cover obstruction. |
| **Landsat 8 OLI** | Normalized Difference Vegetation Index (NDVI), Salinity Mapping, Landcover Classification | Spectral signatures and indices helped identify the extent of land cover and vegetative health at a 30-meter resolution. Variations in spectral signatures helped indicate a change in land cover and vegetative change over time. This sensor was the primary source for Landsat-derived NDVI calculations. |
| **Dove PlanetScope** | Normalized Difference Vegetation Index (NDVI) | This sensor was used to calculate vegetative health indices to compare with Landsat 8 OLI, to investigate possible differences in result due to a fine spatial resolution. |
| **RapidEye Earth Imaging System** | Normalized Difference Vegetation Index (NDVI) | This sensor was used to calculate vegetative health indices to compare with Landsat 8 OLI, to investigate possible differences in result due to a finer spatial resolution (5 meter). |

***Ancillary Datasets:***

* NOAA's Center for Operational Oceanographic Products and Services – tide gauge data to display sea level rise over time
* USGS’s Wetland and Aquatic Research Center – *in-situ* porewater salinity data for salinity time series analysis
* USGS’s National Land Cover Database – urban and water area mask for land cover analysis

***Software & Scripting:***

* Google Earth Engine (GEE) API – Landsat and Planet-derived NDVI and land cover classification time series
* Esri ArcGIS Pro 3.1.0 – Landsat and Planet-derived NDVI and land cover classification time series
* R 4.2.3 – Salinity and Landsat-derived NDVI time series
* Microsoft Excel Version 2305 – Tabular data storage

***End Product(s):***

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| --- | --- | --- |
| **End Product(s)** | **Earth Observations Used** | **Partner Benefit & Use** |
| **NDVI Change Detection** | Landsat-7 ETM+, Landsat 8 OLI, PlanetScope & Dove | This product will help inform our end users of the spatiotemporal variations of vegetative health across the regions of interest (ROI). Visualizations of vegetative health will help inform partner’s future adaptation management strategies. |
| **Sea Level Rise Time Series, USGS Porewater Salinity Time Series, and Landsat-Derived NDVI Time Series** | Landsat-8 OLI | The time series created with these NOAA tide gauge data (sea level rise) partner-provided in-situ data (salinity), and NDVI values calculated from Landsat imagery will help visualize and understand sea level rise and porewater salinity trends in relation to vegetation health across the ROI throughout our time period. |
| **Land Cover Classification** | Landsat-8 OLI | This land cover classification time series will help the end users identify areas of land cover change to influence future ecological adaptation strategies in the face of saltwater intrusion. |

***Product Benefit to End User:***   
This project is designed to offer targeted assistance to our partners by providing them with valuable tools and insights for the management of the coastal ecosystem along the Savannah River in Georgia. These partners will be equipped with actionable information derived from a comprehensive methodology that encompasses NDVI comparisons, land cover time series analysis, and porewater salinity analysis.

The project's outcomes will enable our partners to make informed decisions regarding land management and climate change adaptation strategies within the coastal zone. By analyzing our NDVI data outputs, they can assess the health of vegetation in these areas and tailor their strategies for sustainable land management. The land cover time series analysis will allow them to identify shifts in tidal and freshwater zones as well as potential ecological disruptions. This information can inform their efforts to safeguard critical ecosystems and maintain a balance between development and environmental preservation. The porewater salinity analysis can provide them with a deeper understanding of the relationships between salinity fluctuations and land cover or vegetative health change.

**References**

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