**South Carolina Water Resources**

*Implementing the Unvegetated-Vegetated Ratio to Assess Salt Marsh Vulnerability in South Carolina Using Airborne and Space-Based Remote Sensing Imagery*

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**Project Overview**

***Project Synopsis:***

In partnership with the South Carolina Department of Health and Environmental Control (DHEC), the South Carolina Department of Natural Resources (DNR), and the US Geological Survey (USGS) Woods Hole Coastal and Marine Science Center, this project analyzed salt marsh vulnerability using the unvegetated-vegetated ratio (UVVR). UVVR, used as a proxy for a sediment budget, was derived from Landsat 8 OLI, Landsat 7 ETM+, and high-resolution aerial imagery provided by the DNR. These maps will allow the South Carolina DNR to support policymakers at the DHEC in prioritizing resources for salt marsh conservation and restoration efforts. Maps of UVVR provided current marsh vulnerability while change maps provided a deeper understanding of the changes in sediment dynamics over the past two decades.

***Abstract:***

Among the most productive ecosystems on earth, salt marshes provide crucial ecosystem services including water filtration, shoreline protection, storm surge buffering, and flood mitigation. Marshes are largely dependent on their sediment budget which can significantly vary across a region. Upstream land use change near Charleston, South Carolina, along with rising sea levels, are expected to alter sediment budgets and threaten marsh stability and long-term health. The unvegetated-vegetated ratio (UVVR) is a scalable and efficient method to assess vulnerability. This NASA DEVELOP project collaborated with the South Carolina Department of Natural Resources, the South Carolina Department of Health and Environmental Control, and the United States Geological Survey Woods Hole Coastal and Marine Science Center. Marsh vulnerability was analyzed using UVVR derived from Landsat 8 Operational Land Imager (OLI) and Landsat 7 Enhanced Thematic Mapper (ETM+) in conjunction with National Agriculture Imagery Program (NAIP) high-resolution aerial imagery. A Landsat random forest regression showed a low correlation (r2 = 0.247) between Landsat 7 ETM+ bands and NAIP aggregated UVVR suggesting the need for a more complex model and higher resolution sensors. Google Earth Engine scripting provided a novel approach to UVVR methodology that will allow decision makers to input new marsh areas and easily calculate UVVR without external data downloading.

***Key Terms:***

 NAIP, Landsat, UVVR, Google Earth Engine, classification, vulnerability assessment, salt marsh

***National Application Area Addressed:*** Water Resources

***Study Location:*** Charleston and Berkeley Counties, SC

***Study Period:*** June 2009 to September 2019

***Community Concerns:***

* Salt marshes serve as a habitat for diverse species, support recreational and commercial fisheries, and provide numerous ecosystem services but rising sea level could significantly alter their sediment budgets.
* The US Army Corps of Engineers and the National Oceanic and Atmospheric Administration estimate that South Carolina may experience between 7 and 21 inches of sea level rise in the next decade, which could result in increased erosion in these estuaries.
* Charleston and Berkeley counties are expected to see an increase in population density, saltwater flooding, and dredging which could threaten salt marsh stability and long-term health.

***Project Objectives:***

* Reproduce USGS's UVVR methodology in Google Earth Engine to enhance project reproducibility, applicability to diverse study sites, and accessibility to partner organizations
* Design vulnerability maps for the South Carolina DNR to enhance its decision making
* Write an accessible tutorial describing the methodology to enable users to apply it to other areas throughout the region and successfully reproduce results

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **South Carolina Department of Natural Resources**  | Tanner Arrington, GIS Specialist; Katie Luciano, Coastal Geologist; Evan Cook, Marine Resources GIS Manager | End User | Yes |
| **South Carolina Department of Health and Environmental Control** | Adam Bode, Coastal Services Project Manager, Planning; Jessica Boynton, Coastal Services Project Manager, Shoreline Management | Collaborator | Yes |
| **USGS, Woods Hole Coastal and Marine Science Center** | Dr. Neil Ganju, Research Oceanographer; Zafer Defne, Oceanographer | Collaborator | No |

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

The DHEC is responsible for managing development, alterations, and shoreline stabilization activities in coastal and estuarine tidelands. DHEC carries out these responsibilities through various research and policy development initiatives, regulation and enforcement, restoration, extension, and education activities. GIS experts and coastal services managers at the South Carolina DNR work directly with the DHEC and other local decision-makers to implement scientifically informed policies.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | Surface reflectance | Surface reflectance from Landsat 8 OLI was used to calculate UVVR from 2013 – 2020 to assess salt marsh vulnerability. |
| **Landsat 7 ETM+** | Surface reflectance | Surface reflectance from Landsat 7 ETM+ was used to calculate UVVR from 2009 - 2013 to assess salt marsh vulnerability. |

***Ancillary Datasets:***

* US Department of Agriculture Farm Service Agency National Agriculture Imagery Program (NAIP) aerial imagery (2009, 2015, 2017, and 2019) – high-resolution surface reflectance from NAIP were used to evaluate UVVR in conjunction with Landsat imagery
* US Fish and Wildlife Service National Wetlands Inventory wetland classification maps – maps from the 1970s to present were used to clip tidal marsh boundaries
* South Carolina Department of Natural Resources LiDAR maps – were used for marsh unit delineation and as an input band in the classification

***Software & Scripting:***

* Google Earth Engine API (JavaScript) – processing of Landsat data using preexisting scripts as well as original scripting
* R 3.6.1 – statistical analysis of reflectance raster files
* Esri ArcGIS Pro 2.4.1 – shapefile creation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **UVVR Maps****2009 - 2019** | Landsat 8 OLI, Landsat 7 ETM+ | End users will use these biannual UVVR maps to assess the vulnerability of salt marsh ecosystems and prioritize areas for future restoration efforts or develop policy regarding future development near the estuary.  | N/A |
| **UVVR Time Rate-of-Change Maps****2009-2019** | Landsat 8 OLI, Landsat 7 ETM+ | Maps of UVVR time rate-of-change will allow partners to understand how quickly the estuary’s vulnerability is changing throughout the 10-year study period to anticipate future changes in vulnerability and recognize factors influencing the observed change in vulnerability.  | N/A |
| **Tutorial of Methods** | Landsat 8 OLI, Landsat 7 ETM+ | End users and collaborators will be able to use this thorough tutorial of the methodologies conducted in this project to replicate the work for future marsh vulnerability assessments and to implement this work in other study areas throughout the region. | N/A |
| **Salt Marsh Assessment of Vulnerability (SMAV) Tool**  | Landsat 8 OLI, Landsat 7 ETM+ | End users and collaborators will be given access to scripts developed through this project to implement within new areas of study. | III |

***Product Benefit to End User:***

These assessments of marsh vulnerability and marsh vulnerability change over time will provide local and state managers with tools to estimate the vulnerability of estuarine ecosystems throughout the state and evaluate the associated ecosystem service potential. Understanding the response and resilience of coastal wetlands to physical factors such as changing sediment loads and shifting shorelines can help managers assess ensuing changes in vulnerability and prioritize areas for conservation or restoration. This metric will provide a meaningful measure of vulnerability that is less costly and less labor-intensive than a complete sediment budget evaluation, which will help our partners complete more comprehensive and frequent estuary evaluations.

**References**

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