**Delaware Urban Development**

*Utilizing NASA Earth Observations to Assess Coastline Replenishment Initiatives and Shoreline Risk Along Delaware's Coasts*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:*** Delaware’s economically and ecologically valuable coastline is currently threatened by numerous climatic and geological forces. With the lowest mean elevation of any state, Delaware is in a uniquely vulnerable position. In partnership with Delaware’s Department of Natural Resources and Environmental Control (DNREC), this project utilized NASA Earth observations (EO) to assess the performance of the state’s land loss management projects. The project also identified at-risk areas to strengthen future replenishment strategies and better protect coastal properties and ecosystems.

***Abstract:***

Delaware’s coastline is a vibrant tourist destination and rich, unique habitat for many vulnerable species. Yet, with the lowest mean elevation of any state, this indispensable stretch of land is threatened by numerous geological and climatic forces, including coastal erosion, sea level rise, storm surge, and subsidence. The state’s Department of Natural Resources and Environmental Control (DNREC) has, therefore, served as a diligent combatant of coastal land loss since the 1950s. In partnership with the DNREC, this team utilized Landsat 8 Operational Land Imager (OLI), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 5 Thematic Mapper (TM), and the Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) in combination with ancillary datasets to create a suite of time-series maps that identified shoreline extent changes in response to management projects and to generate a coastal land loss susceptibility map. A statistical analysis incorporated these maps with project-specific information and socioeconomic data using geographically weighted regressions to evaluate the performance of management strategies and identify socioeconomic-related concerns. These maps can be used by the DNREC to support the development of future coastal protection and replenishment strategies through the evaluation of technique effectiveness and identification of at-risk areas. Finally, these products were implemented into a story map that demonstrated the unique geological circumstances that put Delaware at risk and showcased the impacts of the state’s efforts to protect it. The team found that there was a statistically significant shift of land to water between 1988 and 2018. The Prime and Bombay Hook National Wildlife Refuges were designated as the most susceptible areas to land loss. The team also identified a correlation between the number and timing of beach nourishment projects and decrease of land loss.

***Keywords:***

Delaware, coastline management, erosion, sea level rise, storm surge, Terra MODIS, Landsat, subsidence

***National Application Areas Addressed:*** Urban Development, Disasters, Water Resources

***Study Location:*** DE

***Study Period:*** January 1988 to December 2018

***Community Concerns:***

* Delaware’s coastline is not only an economically valuable area, but it is also a crucial habitat for many threatened species. It is an ecological transition zone and a globally important migration area with significant ecological value.
* Delaware’s coastline is threatened by many geological and climatic forces, including coastal erosion, sea level rise, subsidence, and storm surge.
* The coastline of the Delaware Bay is largely understudied in comparison to the Atlantic coastline, and there may be socioeconomic concerns compounded by land loss vulnerability of the bay area.

***Project Objectives:***

* Illustrate coastline changes in response to the state’s management projects over the past thirty-one years with a time-series map
* Generate a susceptibility map to identify areas that are vulnerable to land loss that incorporates soil hydrology, land cover, slope, elevation, wind, wave, sea level rise, and subsidence
* Evaluate the performance of Delaware’s management strategies by testing for statistical correlation between management projects, land loss susceptibility, socioeconomic circumstances, and changes in coastline
* Demonstrate the environmental issues that put Delaware’s unique geographical area at risk and display the impacts of measures taken to protect the coastline through an ArcGIS Story Map

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC**  | **Partner Type** | **Boundary Org?** |
| **Delaware Department of Natural Resources and Environmental Control, Division of Watershed Stewardship** | Jesse Hayden, Environmental Scientist  | End User | Yes |

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

The DNREC Shoreline and Waterway Management Program (SWMP) regulates coastline protection and restoration by enforcing the *Beach Preservation Act of 1972* and the *Management Plan for the Delaware Beaches*. With limited resources, the DNREC must carefully design long-term projects in partnership with the US Army Corps of Engineers (USACE), designating an allowance for unforeseen short-term projects. While Delaware has collected substantial amounts of observational coastal data, this information is largely unanalyzed. The DNREC SWMP currently does not use any NASA EOs.

***Project Benefit to End User:***

This project will provide coastal engineers and scientists of Delaware’s DNREC with a time-series map to illustrate and evaluate the performance of the state’s land loss management projects and a susceptibility map to identify areas at-risk of land loss. A variety of statistical analyses, namely geographically weighted regressions, will evaluate if the coastline changes correlate with management projects, susceptible areas, or socioeconomic factors. Finally, an ArcGIS Story Map will be designed to increase public awareness of the unique geological circumstances that put the state at risk and illustrate the impacts of steps that DNREC has taken to protect the coast, as observed from project end products.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface reflectance, Normalized Difference Water Index (NDWI), Modified NDWI (MNDWI) | Landsat 8 OLI surface reflectance imagery from 1988-2018 were processed and used to extract water indices by applying DEVELOP’s Coastal Annual Land Cover Change (CALCC) algorithm in Google Earth Engine. This produced rasters that were used for the visualization of annual coastline change in the time-series map. |
| **Landsat 7 ETM+** | Surface reflectance, NDWI, MNDWI | Landsat 7 ETM+ surface reflectance imagery from 1988-2018 were processed and used to extract water indices by applying DEVELOP’s CALCC algorithm in Google Earth Engine. This produced rasters that were used for the visualization of annual coastline change in the time-series map. |
| **Landsat 5 TM** | Surface reflectance, NDWI, MNDWI | Landsat 5 TM surface reflectance imagery from 1988-2018 were processed and used to extract water indices by applying DEVELOP’s CALCC algorithm in Google Earth Engine. This produced rasters that were used for the visualization of annual coastline change in the time-series map. Landsat 5 TM data was also used in land cover classification through NOAA’s Coastal Change Analysis Program. |
| **Terra ASTER** | Global Digital Elevation Model, slope | Digital elevation data were used to analyze topography and to derive slope to produce the land loss susceptibility map. |

***Ancillary Datasets:***

* Delaware Environmental Observing System (DEOS) Wind Data – This dataset enabled the creation of the susceptibility map locating areas most vulnerable to coastline erosion by wind.
* National Oceanic and Atmospheric Administration (NOAA) Marine Environmental Buoy Database – This dataset holds wind and wave data collected by NOAA’s Data Buoy Center (NDBC). These datasets, along with data provided by DNREC, supported the identification of at-risk areas on the susceptibility map.
* NOAA Coastal Change Analysis Program (C-CAP) – Land cover data helped identify and classify land type most susceptible to erosion for the susceptibility map.
* US Census Bureau Population & Demographic Data – Population and demographic data, compounded with the susceptibility map, allowed for identification of populations that may be affected by coastal erosion.
* USDA Soil Survey Geographic Database (SSURGO) – Soil data was crucial in the classification of areas most susceptible to erosion along the Delaware bay and Atlantic shorelines.
* DNREC *In Situ* Measurements of Delaware’s Coastline – Data including elevation and beach profiles from field surveys helped validate the data and mapping derived from EOs.

***Software & Scripting:***

* Google Earth Engine Application (GEE) Programming Interface (API) – GEE API enabled the acquisition and processing of EO data (Landsat 5, 7, and 8 imagery).
* ArcGIS Pro 2.4 – This software was used to manipulate and analyze EO and ancillary data for the time-series and susceptibility maps.
* ArcMap 10.5 – This software was used to manipulate and analyze EO and ancillary data for the time-series and susceptibility maps.
* R – R coding served as an additional statistical analysis tool.

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Coastal Land Loss Time-Series Map** | Landsat 8 OLILandsat 7 ETM+Landsat 5 TM | This product allowed partners to visualize coastal land loss over time. The addition of historical management project information, such as timing, technique, and location of restoration efforts, enabled an analysis of management impacts on coastline change.  | N/A |
| **Coastal Land Loss Susceptibility Map** | Landsat 5 TMTerra ASTER | This product highlighted areas at risk to improve future land-use planning and support the decision-making process of future management projects. | N/A |
| **Coastal Land Loss and Management Strategy Statistical Analysis** | Landsat 8 OLI Landsat 7 ETM+Landsat 5 TMTerra ASTER  | This product provided a statistical analysis on the correlation between management projects, land loss susceptibility, socioeconomic circumstances, and coastline change. | Class E software |
| **Delaware’s Coastal Land Loss and Management Strategy Story Map** | N/A | This product featured the geographic circumstances that influence Delaware’s coast along with historical management efforts and their impact. | N/A |

**Project Handoff Package**

***Transition Plan:*** At the end of the term, our team participated in a presentation and handoff of project end products to our partner via video conference and Dropbox.

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***Handoff Package:***

* Map Package:
	+ Coastal Land Loss Time-Series Map
	+ Coastal Land Loss Susceptibility Map
	+ Coastal Land Loss and Management Strategy Statistical Analysis
	+ Delaware’s Coastal Land Loss and Management Strategy Story Map
* Project Summary
* Technical Paper
* Poster
* Presentation

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