Coastal and Vegetation Degradation of the Florida Coast

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Introduction

Coastal regions are some of the most vulnerable on Earth, and Florida's unique peninsular structures means it's characterized by these coastlines. They are facing increasing danger from rapidly rising sea levels, hurricanes, tropical storm activity, and human development. Southern Florida in particular, is highly susceptible to coastal erosion caused by its lower elevation, frequent hurricanes, and extensive development on the coastline. Mangroves and coastal wetlands historically provide natural protection by stabilizing sediments and reducing wave energy. Alongside the land, these ecosystems have also experienced significant degradation over the past decades..

Remote sensing, specifically methods learned in this class, are the most effective way to monitor the long term coastal change across large areas of Florida. Satellite imagery can allow for a much more quantitative analysis of factors like vegetation health, water where water ends, and shoreline shifting over time, all of which are necessary for this examination. I used measurements such as the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI) which are widely used to assess vegetation conditions and mark a boundary between the land and water.

The US Climate Resilience Toolkit has stated, "more than 80,000 acres of coastal wetland has been lost between 1998 and 2009" and with my examination being from 1990 to 2020 I am anticipating it to unfortunately be a significant amount of land lost.

Study Area and Data

Study Area

The study area focuses on the southern portion of Florida, focusing on the Everglades coastline, Florida Bay, portions of the Florida Keys, and the southern Miami-Dade coast. This area was selected because of its ecological importance, extensive mangrove coverage, and exposure to environmental stressors such as hurricanes, sea level rise, and saltwater intrusion.

The code to demarcate this defines an Area of Interest (AOI variable) in Google Earth Engine using four coordinates, with the northwest corner at -82.9, 27.0, southwest at -82.9, 24.5, southeast at -79.8, 24.5, and northeast at -79.8, 27.0. The polygon I formed represents a portion of southern Florida and surrounding waters for spatial analysis in GEE. I manually set the study area within Google Earth Engine by the dimensions of the polygon above, which allowed for a mix of more commercially developed beaches and some very natural, untouched regions in the Southeast region of Florida, like the Everglades.

Data

This analysis used Landsat surface reflectance imagery throughout the decades obtained through Google Earth Engine, some of which have been used before in this class. The datasets include imagery from:

Landsat 5: Thematic Mapper (TM)
Landsat 7: Enhanced Thematic Mapper Plus (ETM+)
Landsat 8: Operational Land Imager (OLI)
Landsat 9: Operational Land Imager-2 (OLI-2)

Methods

All the data processing and analysis were performed using Google Earth Engine (GEE) and JavaScript, as aligned with most of the labs in the class thus far. The coding workflow relied on modular functions to improve clarity, reproducibility, and efficiency, and also helped ensure debugging was effective.

Built-in functions were used throughout the code to handle large image collections more efficiently, including map(), reduceRegion(), and reduceToVectors(). NDVI and NDWI calculations were applied uniformly across these composites, to compare over time. Conditional expressions were used to make some land and water masks, which were then converted into vector polygons for comparison on the shoreline.

To ensure consistency across all of the different Landsat sensors, spectral bands were given more common names (Blue, Green, Red, Near-Infrared (NIR), and Shortwave Infrared (SWIR)). For each year, a median composite image was generated. This was done to reduce noise from clouds, haze, and short-term variability other short term variables that could alter the results.

Using NDVI and NDWI

Vegetation health was assessed using the Normalized Difference Vegetation Index (NDVI), calculated as:

$$NDVI=(NIR-Red)/(NIR+Red)$$

NDVI values range from -1 to 1, with higher values indicating healthier and much more lush vegetation. NDVI was used to identify changes in mangrove and wetland vegetation along the coastline, which the FMNH has said are vulnerable to these natural disturbances, [3] meaning they are some of the most vulnerable to changes, and serve as a good “canary in the coal mine” for large disasters.

Water extent was identified using the Normalized Difference Water Index (NDWI), which is calculated as:

NDWI=(Green-NIR)/(Green+NIR)

NDWI enhances water features by using the strong absorption of near-infrared radiation by water. Pixels with NDWI values greater than zero were classified as water, while values less than or equal to zero were classified as land.

Land Water Masking and Shoreline Extraction

Binary water masks were generated for each year based on NDWI thresholds. These masks visually and quantitatively represent shifts in water boundaries over time. NDWI water masks were then converted into vector polygons using the reduceToVectors function in GEE. These water polygons represent the spatial extent of coastal water and serve as a proxy for shoreline position.

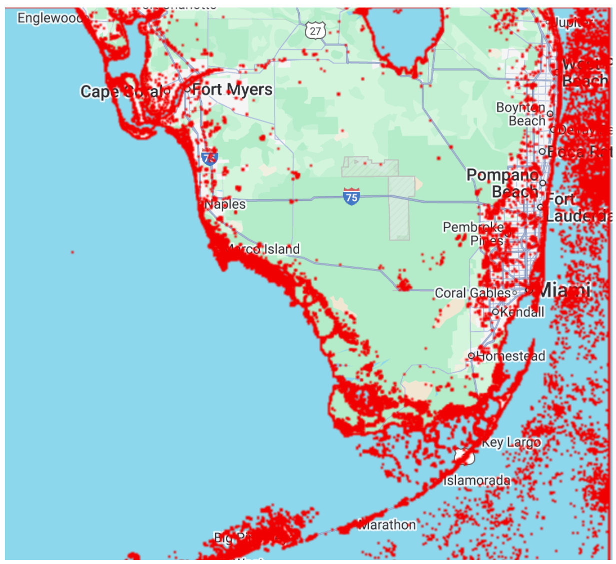

Figure 1 : The resulting water polygons from the reduceToVectors function which display the shoreline position in a clear and easy to identify way when examining using GEE

Results

Vegetation Change (NDVI)

NDVI readouts confirm that there is a significant loss of wetlands and other vegetation, particularly mangrove along the coast. These areas dominated by mangroves along the Everglades coast and Florida Bay showed lower NDVI values in later years, suggesting vegetation stress or loss. Most inland wetland regions maintained relatively stable NDVI values, indicating that vegetation degradation is concentrated near exposed these especially vulnerable coastal zones.

Figure 2: This is the NDVI projection of the southern region of Florida the coastline examination is focused on. Pictured left is 1990 and pictured right is 2020.

Figure 3: Closer view of the southeastern portion of the Everglades where vegetation degradation on the coast is more apparent. Pictured left is 1990 and pictured right is 2020.

While difficult to see on this platform, when examined on GEE we can see a significant difference in vegetation in 2020 versus 1990 especially on the coast. Following the standard pattern of coastal degradation, when mangroves disappear or die, the coast will be more vulnerable to other weather phenomena that can worsen the loss of land. [1]

Water Expansion and Shoreline Change (NDWI)

The NDWI examination shows the intrusion of water into the shoreline, as it slowly works at the coastal features and removes sediment with greater ease. The comparison of water polygons from this same time highlights consistent landward movement of the shoreline, especially along the western Everglades coast and Florida Bay margins.

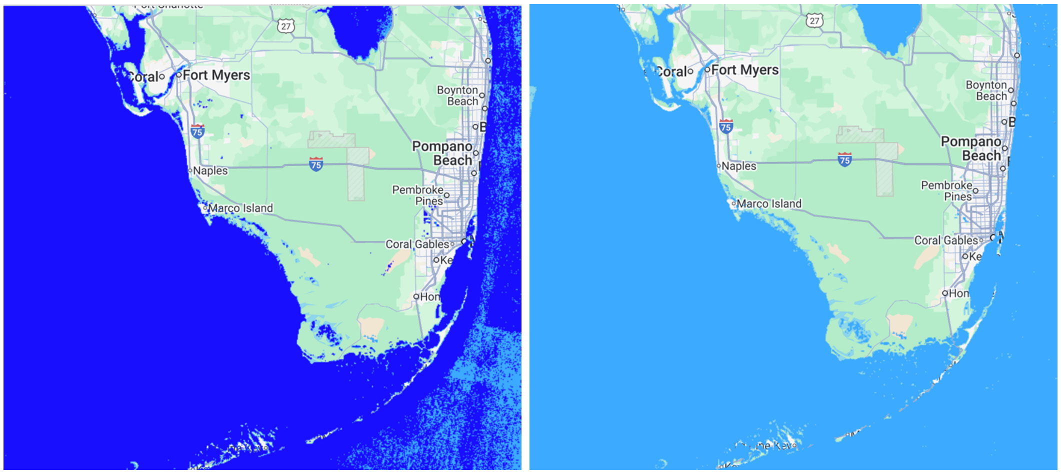

Figure 4: The NDWI projection of southern Florida. Pictured left is 1990 and pictured right is 2020.

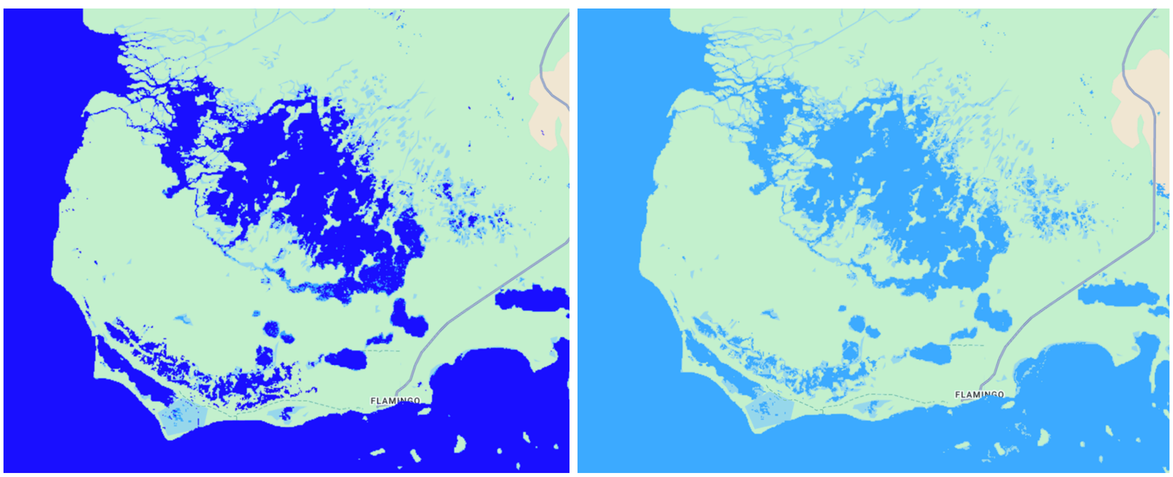

Figure 5: Closer view of the southeastern portion of the Everglades. Pictured left is 1990 and pictured right is 2020.

Similar to the NDVI analysis above it is hard to see on this platform, but we see this expansion of water in greater detail when enhancing on GEE. Even in the 1990 above, when overlaid we can see the lighter shade of blue peeking out when they are overlaid on top of each other.

Land Area Change

Quantitative analysis shows a significant land loss in the 30 decade period. The calculated land loss is approximately ~287,000,000 square meters, or 2,877 square kilometers. But it is important to note that the land loss is not totally uniform. Erosion hotspots correspond closely with areas of mangrove degradation and water expansion.

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Land LOST between 1990 and 2020 (m²):
-2877098660.1178207
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Land LOST between 1990 and 2020 (km²):
-2877.098660117817
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Figure 6: Console outputs when land loss is calculated in square meters and square kilometers

There is absolutely some room for error here, some of these calculations are prone to noise from the masks that may have mistakenly categorized some land types, but even with a margin of error allotted the number is significant enough to note.

Conclusion and Discussion

This study demonstrates that southern Florida has experienced undeniable coastal and vegetation change over the past 30 years.The remote sensing methods employees, NDWI and NDVI show both water encroaching on land as well as vegetation disappearing over the years. I believe mangroves are a fairly significant portion of this, with their loss as shown in the NDVI, creating a chain reaction which allows for the water to continue expanding. Mangroves are key anchors to the ecosystem, reducing the impact to the waves and shifts on the land, and ensuring that sediment is not eroded quickly. These findings align with known impacts of sea-level rise, storm surge, and saltwater intrusion in the region.

Overall, the effectiveness of remote sensing and Google Earth Engine for monitoring long-term coastal change are proved through what they have accomplished in clearly demonstrating how they can visualize something as significant as the loss of land. The results underscore the increasing vulnerability of southern Florida's coasts and emphasize the importance of continuing to monitor and mitigate future impacts.

References

[1] Evans, Jessica. "NASA Study Maps the Roots of Global Mangrove Loss - NASA." *NASA*, 18 Aug. 2020,
www.nasa.gov/centers-and-facilities/goddard/nasa-study-maps-the-roots-of-global-mangrove-loss/

[2] "Coastal Erosion | U.S. Climate Resilience Toolkit." *Climate.gov*, 2017,
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[3] Florida Museum. "Impacts on Mangroves." *Florida Museum*, 3 Oct. 2018,
www.floridamuseum.ufl.edu/southflorida/habitats/mangroves/impacts/.