Quantifying Winter Storm Impacts on Wetlands in Coastal Cumberland County
Louisa Linkas, 2026

Purpose: The goal of this research is to utilize publicly available satellite imagery and remote sensing data to investigate the impact of winter storms on wetlands in Coastal Cumberland County. This data was integrated with Google Earth Engine (GEE) software to map the episodic pre- and post-winter damage on our coastline. My main goal was to identify the most effective focus for my time and resources in addressing coastal damage so that it would be beneficial to local scientists and politicians as well as aid me in my learning and skill set.

Process: After connecting with the Maine Fishermen's Association and scientists such as Tora Johnson from the University of Maine and Jeremy Gabrielson from the Maine Coast Heritage Trust, it became clear that quantitative analysis was needed to measure the impact of sea level rise, often experienced through storm surges, on the wetlands along the coast of Maine: Maquoit Bay and Cousins River Marsh areas. (Fig. 1) This project focused on the same wetlands in Brunswick investigated by the Living Shorelines in Maine project, using satellite imagery and change detection methods. [10] I plan to share my findings with those involved in wetland research and climate change local to the Coastal Cumberland county area.

Background: I began by parsing through tutorials on the Google Colab software, geemap, that provides access to remote sensing data via python and reading scientific articles. [5, 14] I retrieved the data and analyzed vegetation damage via two indices and two satellite sources. [4] The Normalized Difference Vegetation Index (NDVI) is an index which uses the NIR and red bands from Landsat 8 images to measure water content in vegetation and soil. [1] This index estimates plant health remotely by calculating the NDVI of a crop or plant over time. Synthetic Apature Radar (SAR) data operates in the electromagnetic spectrum, making it available irregardless of cloud, rain and fog, it also has a more frequent revisit time. [2] The Radar Vegetation Index (RVI) effectively measures the amount of vegetation on a scale of 0 (barren) to 1(forested). [9] It is sensitive to vegetation structure and density, making it a suitable index for assessing changes in vegetation over time. [7] Then the difference of each pixel from the pre-winter and post-winter images was calculated. [6]

Methods: To analyze NDVI and RVI changes from 2015 to 2024, I used GEE and geemap in Python. First, I initialized the GEE API and defined a study area with a 10 km buffer around Maquoit Bay Marsh. Then, using Landsat 8, I filtered for cloud coverage below 10%, selecting the NIR and Red bands. [3] For SAR data collection, Sentinel-1 images were used, filtering for the relevant backscatter coefficients. [6] I classified vegetation changes, by pixel, into six categories, images were produced for each year analyzed and visualised using a line plot with markers. [4, 15] The values plotted represent the change in RVI and NDVI from before to after the winter season for each year. (Fig. 2) This information can be compared to the severe weather dataset produced by NOAA's Storm Events Database, visualised on the corresponding line plot. [8] (Fig. 3)

Results: Particular years of interest include 2015, 2019 and 2021: SAR from 2015 reflects net vegetation loss whereas NDVI shows vegetation gain, 2019 appears to have coastal vegetation loss, and 2021 has the most dramatic vegetation loss. (Fig. 4) The 2015 period experienced three coastal flood events pre-winter, and during/after winter, two events of heavy snow and two events of coastal flooding. (Fig. 3) The landsat post-image count was heavily restricted by cloud coverage, both generating less than half of the images of all other years analyzed. Post-winter, 2019 experienced a coastal flood, 2 heavy snow events, 2 winter storm events, and one tropical storm. (Fig. 3) There is no significant weather in the Fall of 2021, post-Fall, there were two winter storms and two coastal floods. Drought conditions in the summer following these winter storms likely contributed to the overwhelmingly positive NDVI and RVI for the following year (2022).

Analysis: Between 2015 and 2023 severe weather events, especially coastal flooding and winter storms, appeared to significantly impact the health and coverage of wetland vegetation in Brunswick. The data indicates a correlation between an increase in such events and a decrease in vegetation health and density, as measured by NDVI and RVI values.

Limitations: This study has several limitations that should be acknowledged. The analysis was conducted over a limited timeframe, which may not capture long-term trends or the full variability of coastal weather events and their impacts. The quality and quantity of Landsat imagery were limited by cloud cover, which could have influenced the accuracy of the vegetation change detection. The methods used for change detection and analysis were relatively simplistic, relying on basic pixel calculations and categorization, which may not capture more nuanced changes in vegetation health.

Faculty Mentor: Jeova Farias
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Fig. 1: The site locations chosen: Cousins River Marsh, Maquoit Bay and Gamble Marsh Estuary.

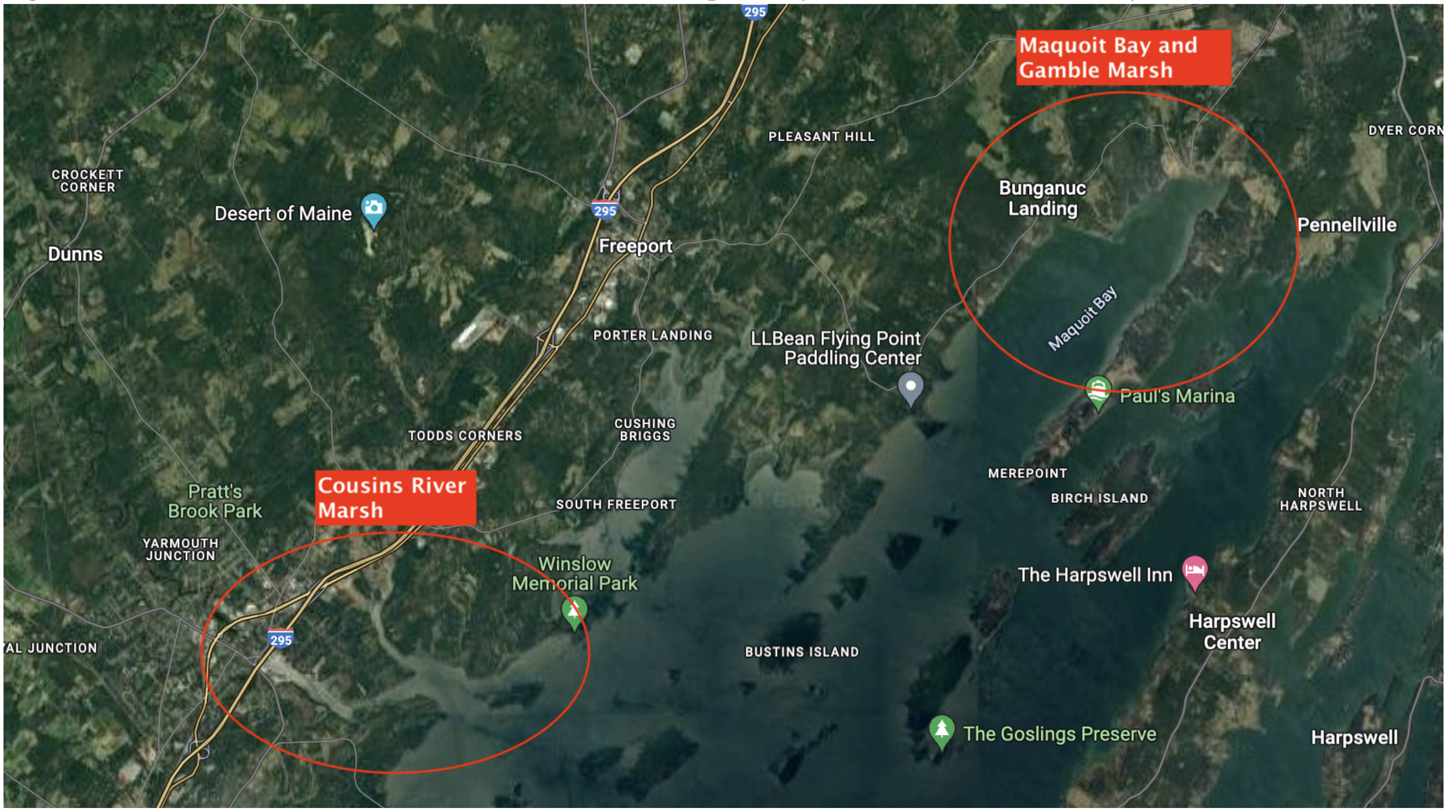


Fig. 2: The index of change from before to after the winter season from 2015 to 2023 at Maquoit Bay and Cousins River Marshes. Positive NDVI values indicate a gain in vegetation health, while negative values indicate a loss. Positive RVI values indicate a gain in vegetation cover, while negative values indicate a loss. The assigned year of each marker indicates the start year for the pre-image dates of image analysis, where pre_start = f'{year}-08-01', pre_end = f'{year}-12-01', post_start = f'{year+1}-04-01', and post_end = f'{year+1}-08-01'.

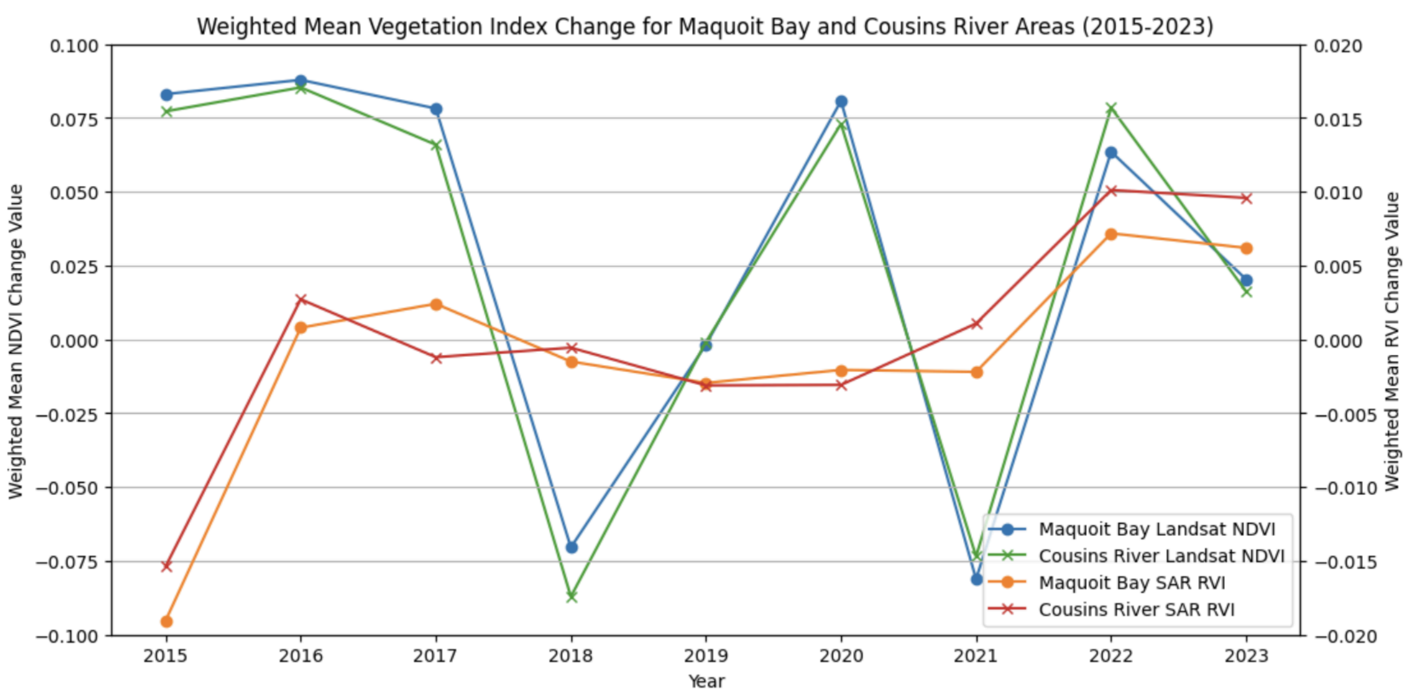


Fig 3: Timeline of severe weather events for Coastal Cumberland County from 2015 to 2023. Each dot represents one instance of the respective event type.

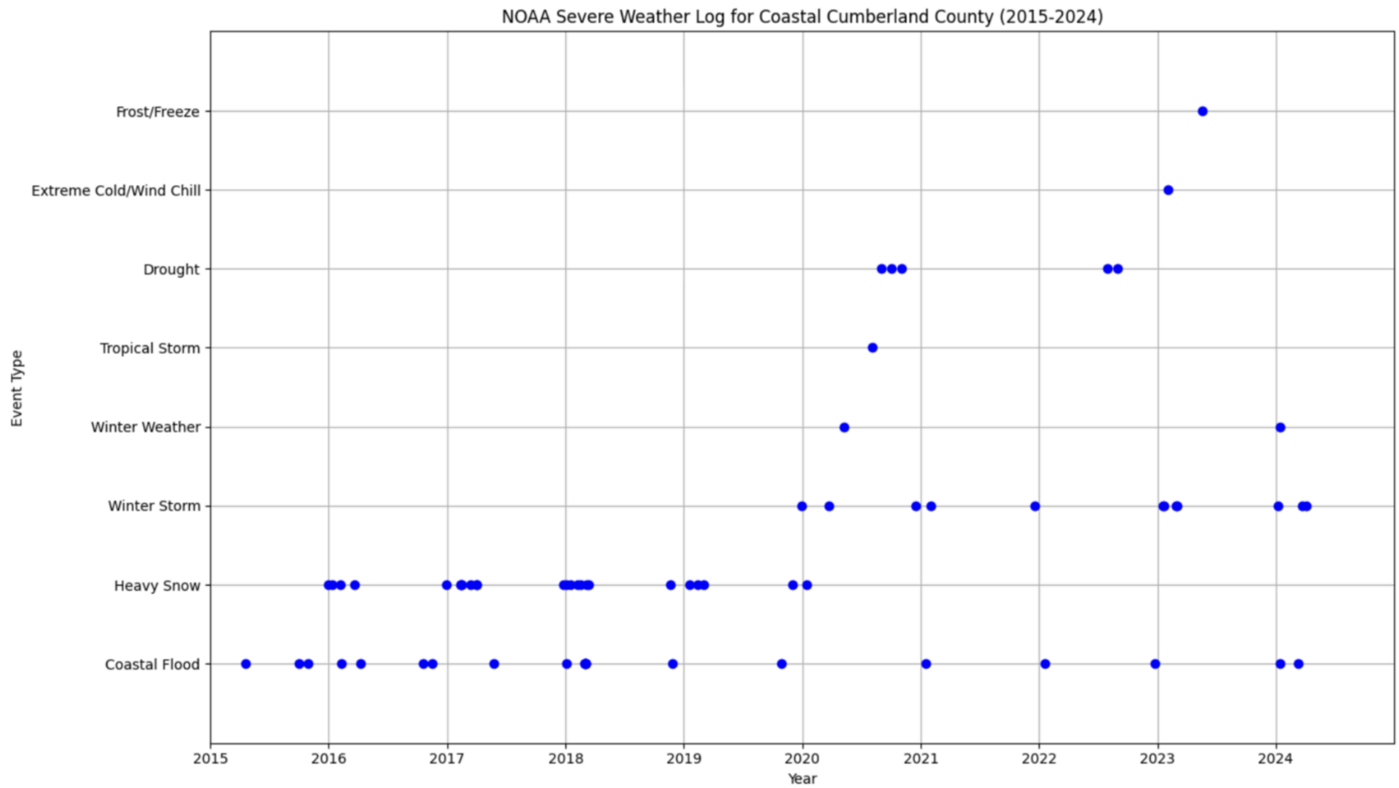
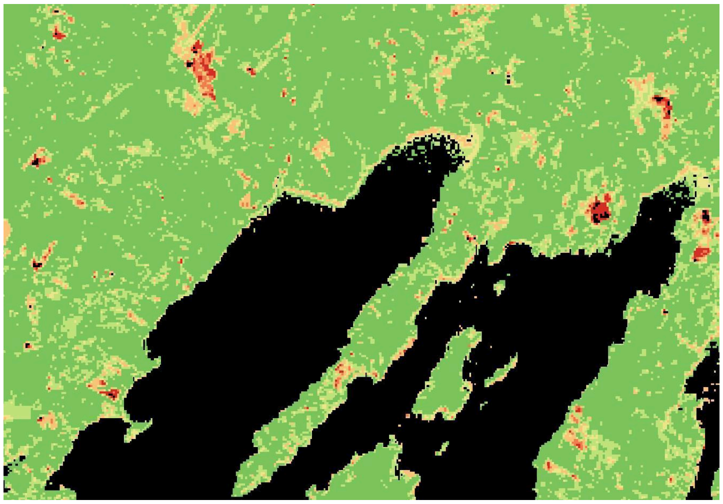


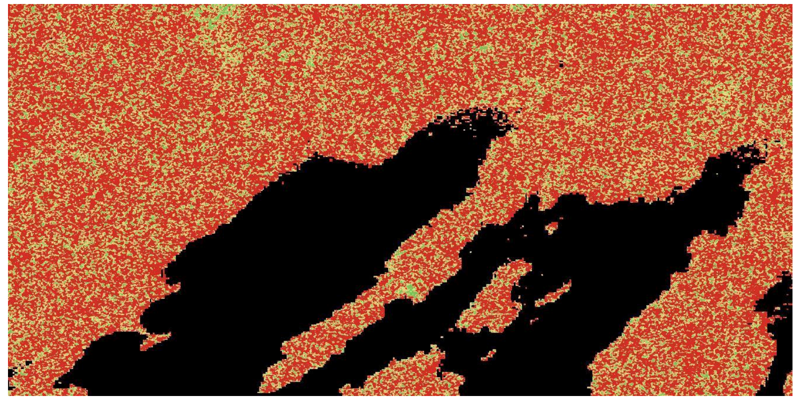
__Fig. 4:__ Maquoit Bay Landsat NDVI (left) vs RVI (right) Classified Change Images (2015-2023) *(next page)*

Key:

Significant vegetation gain	+ 0.1	
Moderate vegetation gain	+ 0.05	
Slight vegetation gain	+ 0.025	
Slight vegetation loss	- 0.025	
Moderate vegetation loss	- 0.05	
Significant vegetation loss	- 0.1	

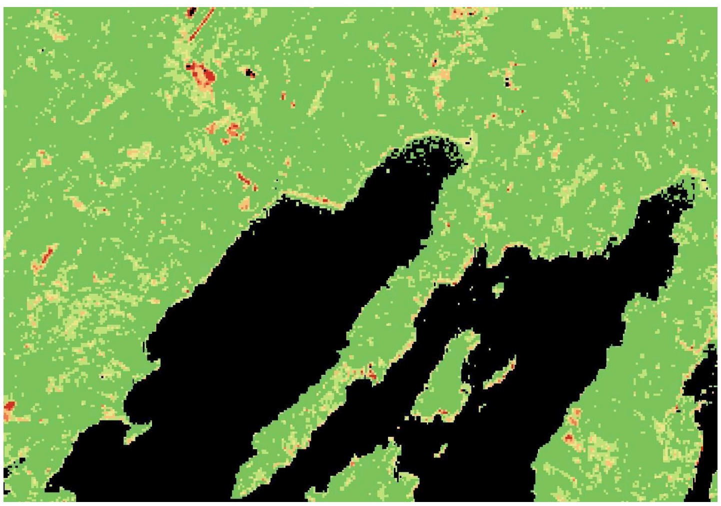
2015

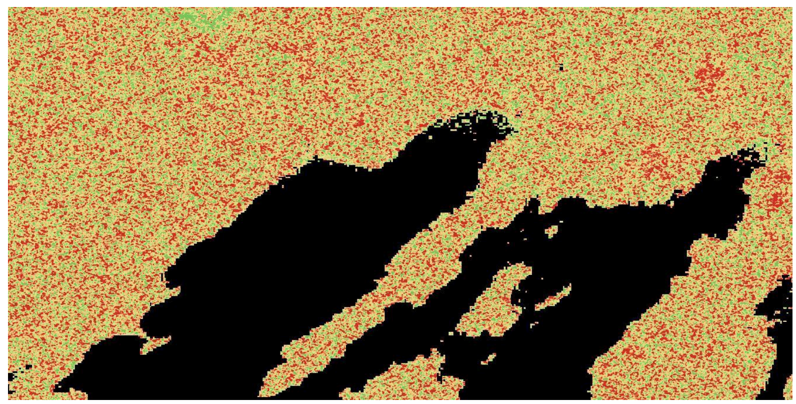




2015 shows a significant increase in vegetation health (left) and a significant decline in vegetation density (right). Fig. 3 details four coastal floods and 4 heavy snow events in this time frame.

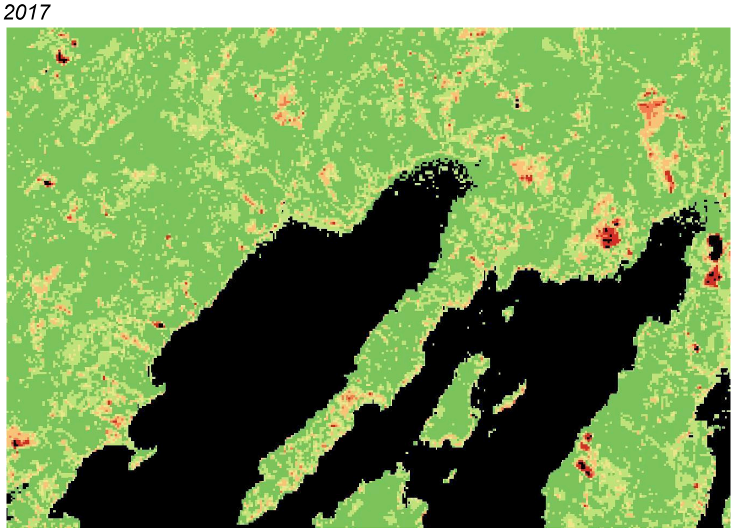
2016/2017

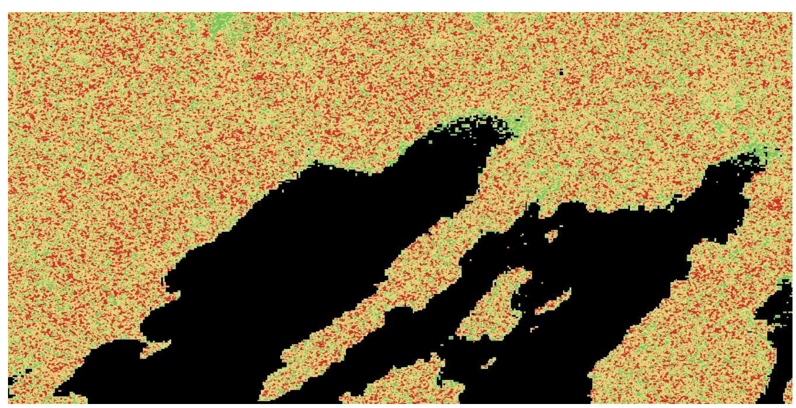




2016 shows significant increase in vegetation health (left) and neutral vegetation density change (right). Fig. 3 details three flood events and seven cases of heavy snow in this time frame.

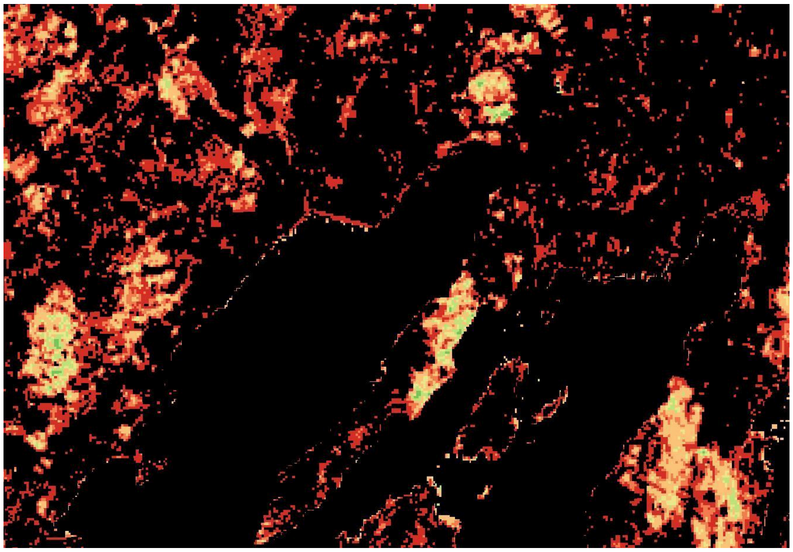
2017

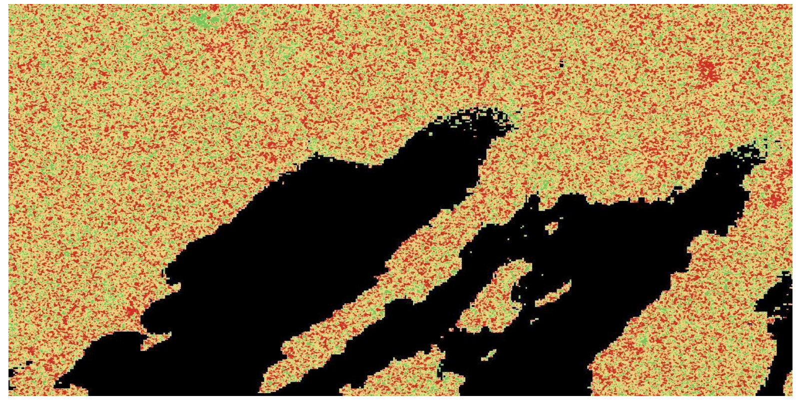




2017 shows significant increase in vegetation health (left) and neutral vegetation density change (right). Fig. 3 details six coastal flood events and six events of heavy snow in this time frame.

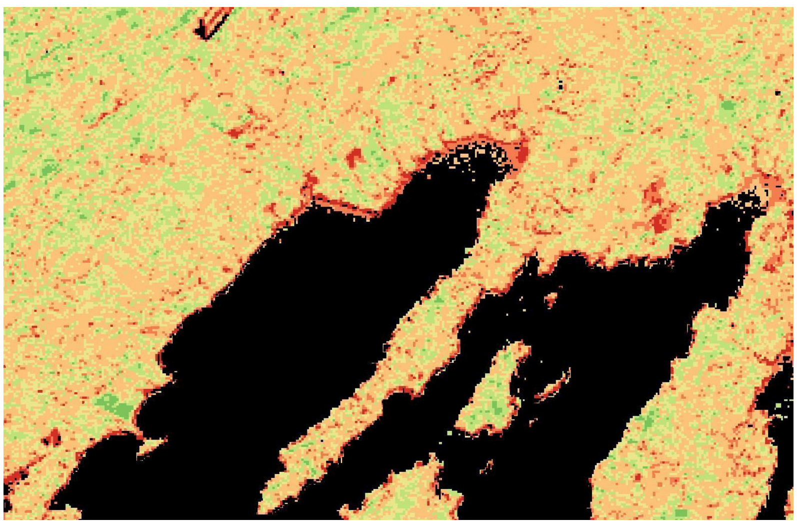
2018

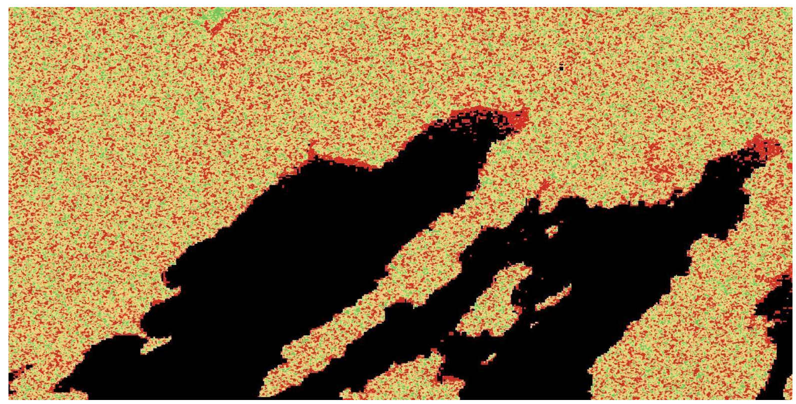




Black indicates vegetation health decline beyond the indicated threshold (>0.1). 2018 shows significant decrease in vegetation health (left) and slight vegtation density loss (right). Fig. 3 details 4 heavy snow events and one coastal flood in this time frame.

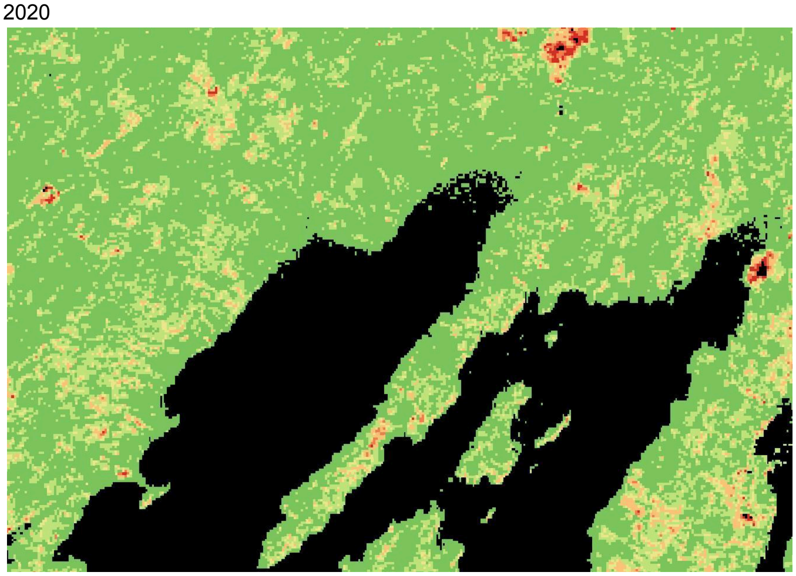
2019

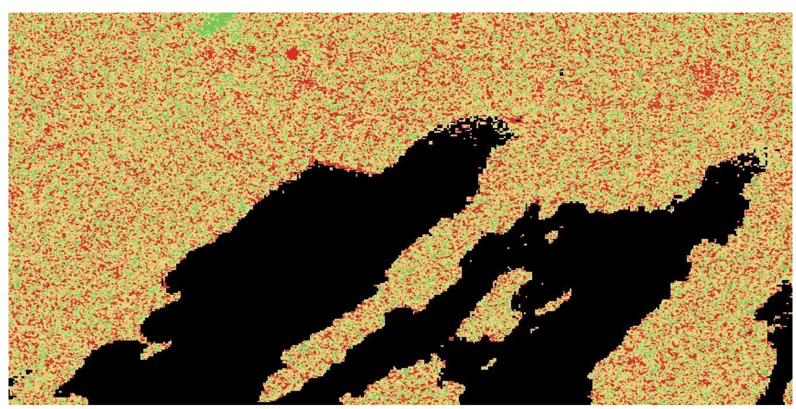




2019 shows neutral vegetation health (left) and neutral vegetation density change (right). Decline in health and density is concentrated on the shorelines. Fig. 3 details one coastal flood, two winter storms, two heavy snows and one event of winter weather in this time frame.

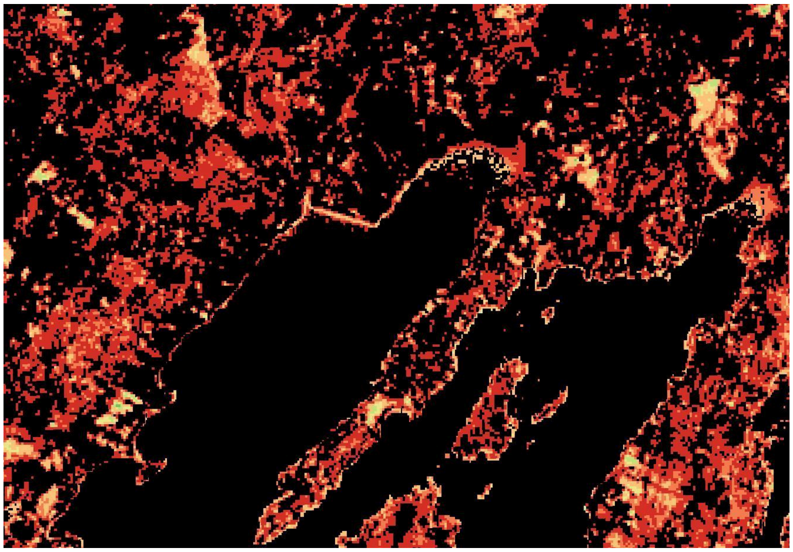
2020

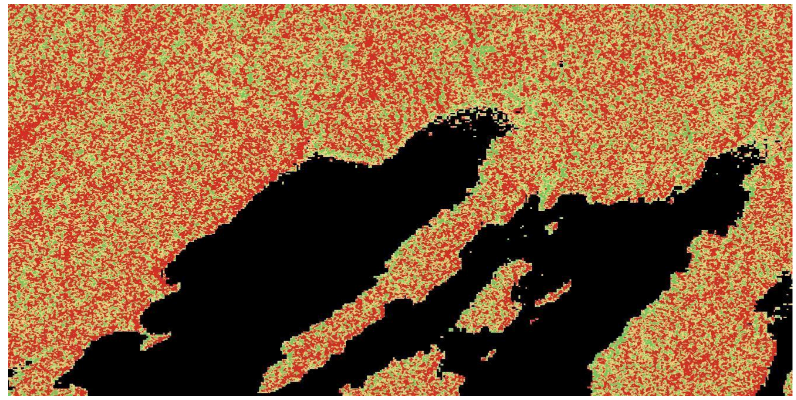




2020 shows significant increase in vegetation health and slight-moderate decline in vegetation density. Fig. 3 details one tropical storm, one coastal flood, three instances of drought, and two winter storms in this time frame.

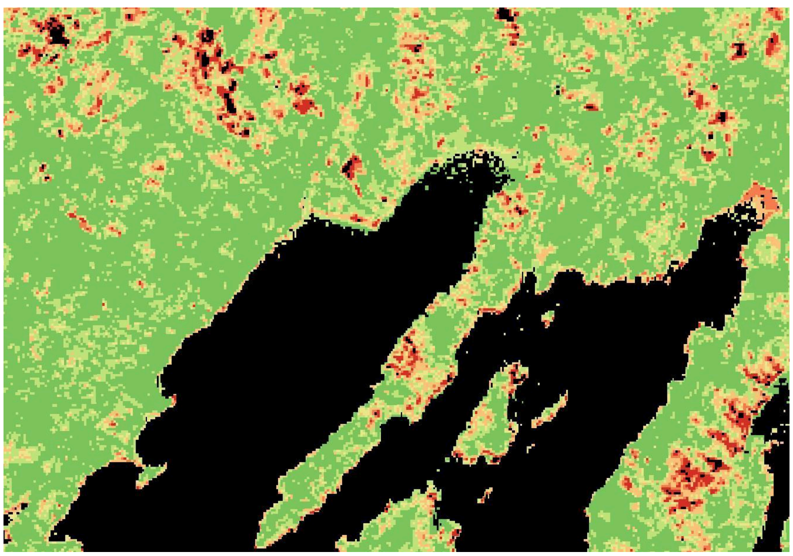
2021

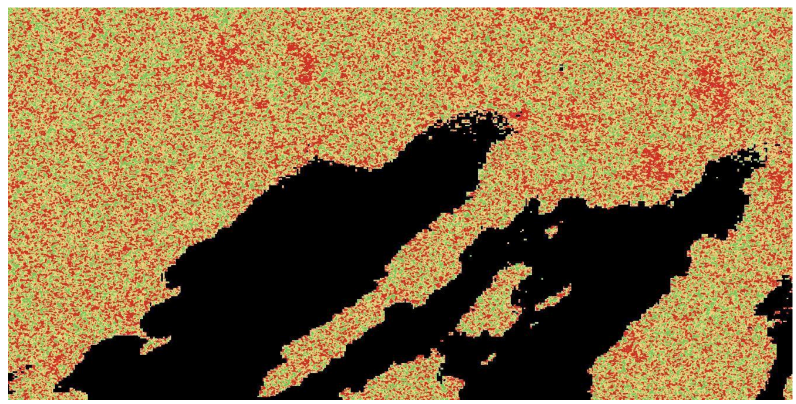




2021 shows significant decrease in vegetation health (left) and moderate-severe vegetation density loss (right). Fig. 3 details one winter storm and one coastal flood in this time frame.

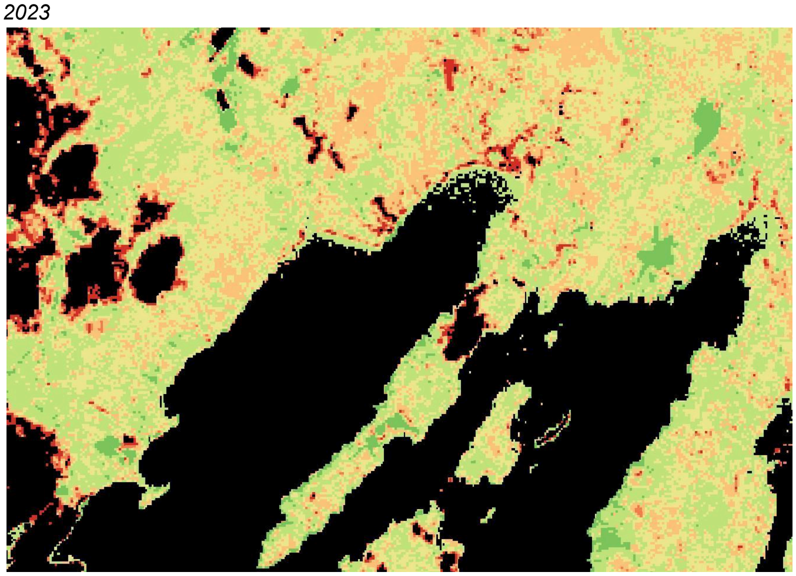
2022

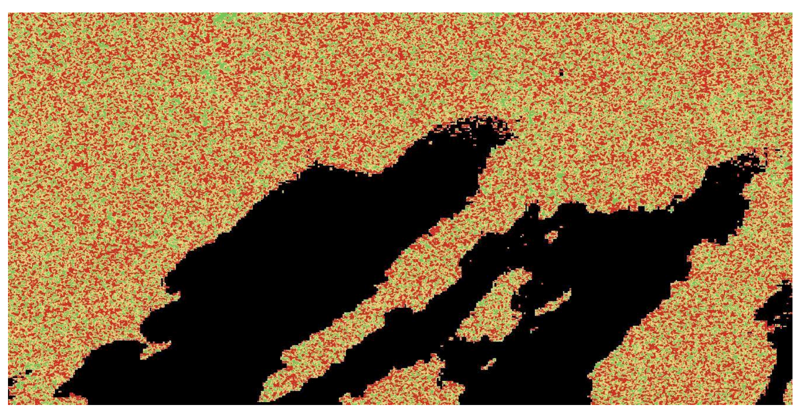




2022 shows significant increase in vegetation health (left) and moderate-severe vegetation density loss (right). Fig. 3 details one coastal flood, two instances of drought, one instance of extreme cold, one springtime frost/freeze and four winter storms in this time frame.

2023





2023 shows scattered decline in vegetation health (left) and moderate-severe vegetation density loss (right). Fig. 3 details three winter storms, two coastal floods, and one instance of winter weather in this time frame.

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