Tracking Spatio-Temporal Changes in Coastal Wetlands of Lake Superior Using High-Resolution Remote Sensing and Machine Learning

MOTIVATION

Wetlands play a vital role in providing habitats for numerous aquatic species, and terrestrial plants and animals (USGS). Wetlands reduce flood risks, improve water quality, preserve shorelines, and provide recreational areas (USGS). The United States Environmental Protection Agency emphasizes wetlands' significance, stating, “Wetlands are among the most productive ecosystems in the world comparable to rain forests and coral reefs.” (EPA, 2023). They go one step further by explaining that preserving and protecting wetlands can protect our safety and welfare (EPA, 2023).

However, wetlands are continuously threatened by agriculture and urban development, extreme management, water pollution, mining, recreational use, and climate change (Mitsch and Hernandez, 2013). The dynamics of wetlands are directly reflected in the boundary changes which have different temporal scales and variabilities. Wetland delineation is the identification and determination of wetland boundaries. To understand the effects of human activities and climate change on wetlands, we must better delineate wetlands and track the boundary changes. If we can determine the changes in wetland boundaries, we can take action to better preserve and manage land use (Fortin et al., 2000).

Conventionally, field observations are used to delineate wetlands. The U.S. Army Corps of Engineers uses field observations of hydrology, soils, and vegetation to track boundary changes in wetlands (Wu et al., 2014). The disadvantage of field observations is that they are labor-intensive with limited spatial details and sampling points. More advanced, the U.S. Fish and Wildlife Service’s National Wetland Inventory Program uses photo interpretation as their

way to delineate wetlands (Wu et al., 2014). The limitation of photo interpretation is the low resolution of the image, making it challenging to capture subtle movements along the boundary. Additionally, simple algorithms such as linear regression, used to analyze the boundary changes, may not capture the non-linear movements. Therefore, the solution lies in high-resolution images and machine learning. This project aims to bridge the knowledge gap by measuring spatially resolved wetland changes over a large period and tracking their changes with the use of high-resolution satellite imagery and machine learning.

We will use Lake Superior as our study site. Lake Superior is the largest of the Great Lakes and the world's largest fresh body of water (Wiener, 2018). It supports commerce, impacts the weather, provides tourism, and is also a crucial aspect of the world's freshwater resource (Wiener, 2018). The water in Lake Superior is fed by approximately 200 rivers, some of the largest Nipigon and the St. Louis rivers (Britannica, 2024). Even though Lake Superior is an important part of the flora and fauna, there has been a decline in water quality due to pollution, deforestation, and industrial discharge which could have lasting effects for over 200 years (Lakehead region).

METHOD

We propose to use satellite imagery and machine learning to develop a long-term, spatially inclusive wetland delineation algorithm to better determine the spatial and temporal changes in wetland boundaries. Using Landsat surface reflectance and land cover maps as our satellite imagery, we will set the land cover maps as ground truth to train the machine learning algorithm with the Landsat images and quantitatively depict wetland boundaries. We will further the development of the algorithm by populating it to a longer time series as well as state-wide wetland areas to evaluate any uncertainties. Through our machine learning algorithm, we will

accomplish the measurement of changes that occur over time in the boundaries of wetlands near Lake Superior over decades, therefore contributing to answering the question of what environmental factors contribute to changes in the wetlands near Lake Superior.

SUMMARY AND BROAD IMPACT

This project will deliver a machine-learning model to delineate wetlands and track the temporal changes. It will help improve the management plans for wetland restoration and conservation in Lake Superior and state-wide wetlands. The knowledge will be showcased through a presentation highlighting the model created and the data analyzed. The public policy implications of understanding wetland delineation include land use changes, land clearance, and wetland restoration, all of which are valuable for the future and further preservation of wetlands.

REFERENCES

Britannica, The Editors of Encyclopaedia. "Lake Superior". Encyclopedia Britannica, 15 Jan. 2024, https://www.britannica.com/place/Lake-Superior-lake-North-America.

Fortin, MJ., Olson, R., Ferson, S. et al. Issues related to the detection of boundaries. Landscape Ecology 15, 453–466 (2000). https://doi.org/10.1023/A:1008194205292

Mitsch, W.J., Hernandez, M.E. Landscape and climate change threats to wetlands of North and Central America. Aquat Sci 75, 133–149 (2013). https://doi.org/10.1007/s00027-012-0262-7

“Lake Superior Watershed.” Lakehead Region Conservation Authority, https://lakeheadca.com/great-lakes/lake-superior-watershed.

“Why are wetlands important? | U.S. Geological Survey.” USGS.gov, https://www.usgs.gov/faqs/why-are-wetlands-important.

“Why are Wetlands Important? | US EPA.” Environmental Protection Agency (EPA), 22 March 2023, https://www.epa.gov/wetlands/why-are-wetlands-important.

Wiener, Rob. “Lake Superior is much more than simply a big body of water, it is an ecological engine.” MSU College of Agriculture and Natural Resources, 4 June 2018, https://www.canr.msu.edu/news/lake_superior_is_much_more_than_simply_a_big_body_of_water_it_is_an_ecologi.

Wu, M., Kalma, D. & Treadwell-Steitz, C. Differential Assessment of Designations of Wetland Status Using Two Delineation Methods. Environmental Management 54, 23–29 (2014). https://doi.org/10.1007/s00267-014-0273-3