**Great Lakes Water Resources II**

*A Google Earth Engine Tool to Automate Wetland Extent Mapping Using Optical and Radar Satellite Sensors in the Great Lakes Basin for Wetland Management and Monitoring*

**VPS Title:** Watching the Wetlands: Using Google Earth Engine to Automate Mapping and Monitoring of Wetlands in the Great Lakes

**Project Team**

***Project Team:***

Vanessa Valenti (Project Lead)

Erica Carcelen

Katie Lange

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***Advisors & Mentors:***

Bruce Chapman (NASA Jet Propulsion Laboratory, California Institute of Technology)

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***Past or Other Contributors:***

Erica O’Connor

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**Project Overview**

***Project Synopsis:*** The NASA DEVELOP Great Lakes Water Resources II team partnered with public and private organizations in the Great Lakes Region to create a Google Earth Engine tool that automates mapping of wetland extent in the Great Lakes Basin. The tool utilizes optical and radar satellite data to conduct classifications of user-selected areas in the basin and outputs wetland classification map layers, allowing end-users and natural resource managers to conduct spatiotemporal analysis and improve monitoring capabilities of one of North America’s most vulnerable regions.

***Abstract:***

The Great Lakes Basin is one of the world’s largest freshwater ecosystems. The Basin harbors over 200,000 acres of wetlands that provide a variety of environmental, ecological, and recreational functions to over 30 million people in the region. Some of these functions include improving water quality, mitigating flood impacts, providing wildlife habitat, and housing recreational activities. However, due to anthropogenic activities, habitat conversion and degradation threaten to disrupt or destroy remaining wetland ecosystems. Maps of wetland distribution based on ground surveys are costly and labor-intensive, prohibiting timely evaluations of wetland loss and gain. The Great Lakes Water Resources II team at the NASA Jet Propulsion Laboratory developed the Wetlands Extent Tool 2.0 (WET 2.0) in Google Earth Engine to automate mapping of wetland distribution in the Great Lakes Basin. The team partnered with the US Fish and Wildlife Service, Environmental Protection Agency, Minnesota Department of Natural Resources, the National Oceanic and Atmospheric Administration, and Ducks Unlimited. WET 2.0 incorporates Landsat 8 Operational Land Imager (OLI), Sentinel-1 C-band Synthetic Aperture Radar (C-SAR), and Sentinel-2 Multispectral Instrument (MSI) data. Utilizing a Random Forest classifier, WET 2.0 is capable of automatically mapping wetland extent in the entire Great Lakes Basin, achieving a mean overall accuracy of 80.12% when tested in Michigan. Findings and maps produced by WET 2.0 will enable our partners to identify areas of ecosystem degradation and wetland destruction in order to enact environmental practices and policy initiatives to maintain environmental and economic health in the area.

***Keywords:***

Google Earth Engine, wetland, land-type classification, random forest, Synthetic Aperture Radar

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

***Study Location:*** Great Lakes Basin: MN, WI, OH, MI, OH, NY, IN, IL, PA, Ontario

***Study Period:*** 2017 to 2019 (May to September)

***Community Concerns:***

* Wetlands provide critical ecosystem services to both humans and wildlife. In the Great Lakes Basin, habitat conversion, such as agriculture, infrastructure, and urban development, threatens the health of wetland ecosystems.
* More than 30 million people, 10% of the US population, and more than 30% of the Canadian population, live in and rely on the Great Lakes Basin, which contains 84% of North American surface freshwater and 21% of the entire world’s surface freshwater supply.
* Mapping wetlands using ground-based survey methods or manual identification with aerial imagery is costly and labor intensive, limiting the ability of decision-makers in the Great Lakes Basin to use reliable data for wetland and water resource management.

***Project Objectives:***

* Increase the accuracy of wetland classification produced by WET 2.0 in Google Earth Engine
* Develop a user interface for WET 2.0 that allows for user-specified spatiotemporal analysis
* Extend wetland-mapping coverage of WET 2.0 from only Minnesota to the entire Great Lakes Basin

***Previous Term:*** 2019 Spring (JPL) – Great Lakes Water Resources I

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| Organization | POC (Name, Position/Title) | Partner Type | Boundary Org? |
| **US Fish and Wildlife Service, National Wetlands Inventory** | Megan Lang, Chief Scientist | End User | Yes |
| **Minnesota Department of Natural Resources** | Jennifer Corcoran, Remote Sensing Program Consultant | End User | Yes |
| **US Environmental Protection Agency, Office of Research and Development** | Tom Hollenhorst, Ecologist | End User | No |
| **Ducks Unlimited** | Robb Macleod, National GIS Coordinator | End User | Yes |
| **University of Minnesota** | Joe Knight, Associate Professor | Collaborator | Yes |
| **NOAA, Office for Coastal Management** | Brandon Krumwiede, Remote Sensing Specialist and Great Lakes Geospatial Coordinator | Collaborator | Yes |
| **Michigan Technological University** | Laura Borgeau-Chavez, Research Scientist/Adjunct Associate Professor | Collaborator | Yes |
| **Natural Resources Canada, Canada Centre for Mapping and Earth Observation, Canada Centre for Remote Sensing** | Brian Brisco, Senior Research Scientist | Collaborator | No |

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

Organizations like USFWS, MNDNR, US EPA, and DU use wetland maps to inform decisions concerning wetland conservation and restoration. In 1986, the Emergency Wetlands Resources Act mandated that United States wetlands be monitored, which the USFWS achieves through the NWI. The NWI is a trusted and frequently utilized resource with over 270,000 unique users annually that maps wetland extent, status, and trends in the United States. However, this dataset was created in the 1970s and has not received frequent, comprehensive updates. Currently, organizations like MNDNR can only track areas of wetland change with the NWI through a user-reporting application to request an update to the map product. This poses a problem for frequent monitoring needed to inform daily policy and management decisions. Private organizations like DU are involved in waterfowl habitat conservation and utilize manual wetland maps to identify ideal locations for restoration and monitoring. Each of our end users rely on reliable, updated wetland maps to inform projects including wetland restoration, waterfowl surveys, invasive species control, and general wetland resource management.

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

The main objective of this study is to automate wetland mapping with a tool in Google Earth Engine (GEE) that is accessible for our partners, regardless of GEE experience. This tool will allow our partners to obtain frequently updated and accurate maps that capture the dynamic nature of wetlands to better inform their decisions for the protection and management of wetland resources. Our tool will also build our partners’ capacity to use the GEE platform, NASA Earth observations, and remote sensing techniques for wetland monitoring. Traditional surveying techniques necessary to monitor wetlands in the Great Lakes region throughout the year require a huge investment of time and money. This tool will ultimately allow partners to monitor wetlands in a more efficient manner.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| Platform & Sensor | Parameters | Use |
| **Landsat 8 OLI** | Surface reflectance, Dynamic Surface Water Extent (DSWE) | Spectral signatures and indices were used to classify wetland inundation extent at a 30 m resolution. Variation in spectral signatures will indicate significant change in wetland cover types. |
| **Sentinel-1 C-SAR** | Backscatter, vertical polarization (VV), horizontal polarization (VH), VV/VH polarization ratio | Radar data were used to identify inundated areas and classify wetland extent at 20 m resolution. |
| **Sentinel-2 MSI** | Surface reflectance, Modified Normalized Difference Water Index (MNDWI), Tasseled Cap Greenness Wetness Index (TCGWI), Normalized Difference Vegetation Index (NDVI) | Spectral signatures and indices were used to classify wetland areas at a 10 m resolution. Variation in spectral signatures will indicate significant change in wetland cover types. |
| **SRTM** | Elevation, hillshade | Elevation data was incorporated in indices to identify wetland areas at 30m resolution. Variation in elevation data will indicate likelihood of wetland presence. |

***Ancillary Datasets:***

* United States Department of Agriculture, National Agricultural Statistics Service (NASS) Cropland Data Layer – Created agricultural masks to improve wetland identification accuracy
* Agriculture and Agri-Food Canada (AAFC) – Created agricultural mask to improve wetland identification accuracy
* United States Geological Survey (USGS), Great Lakes Restoration Initiative Great Lakes Sub Basins Shapefile, HUC 08 – Divided Great Lakes Basin into sub-basins for efficient tool processing
* Natural Resources Canada, Canada Centre for Remote Sensing, USGS North America Land Change Monitoring System (NALCMS) – Created urban and agriculture mask to improve wetland identification accuracy
* Minnesota Department of Natural Resources Wetland Monitoring Sample Plots and Validation Points – Tested the accuracy of wetland extent and classification generated by the tool
* Michigan Tech Research Institute; Canada Natural Resources Wetland Identification Field Points – Informed training of the tool and used to complete accuracy assessment tests

***Software & Scripting:***

* Google Earth Engine API – Created a user-friendly tool for remote sensing data collection, preprocessing, and delineation of wetlands using satellite imagery
* Esri ArcMap 10.6 – Created visuals of tool products
* R 3.6.1 – Performed statistical computation, chart and graph generation of results

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| End Products | Earth Observations Used | Partner Benefit & Use | Software Release Category |
| **Wetland Classification Maps** | Landsat 8 OLI  Sentinel-1 C-SAR  Sentinel-2 MSI  SRTM Digital Elevation Data | These maps will be used to identify wetland areas. Partners will be able to update map inventories such as the NWI and use accurate wetland maps in their decision-making processes. | I |
| **Wetland Extent Tool (WET) 2.0** | Landsat 8 OLI  Sentinel-1 C-SAR  Sentinel-2 MSI  SRTM Digital Elevation Data | This tool will automate and streamline wetland delineation for end users and on-the ground conservation. Partners can select areas of interest to monitor wetland change and inform wetland management efforts. | V |
| **WET 2.0 Video Tutorial and Written Manual** | N/A | To ensure reproducibility and understanding, the team will create a video tutorial demonstrating the tool in detail. The partners will be able to share this tutorial with anyone interested in the tool, even if their technical knowledge is limited. | I |

**Project Handoff Package**

***Transition Plan:*** The team delivered the handoff package, detailed below, to partners (excluding WET 2.0, video tutorial, and written manual) using Google Drive at the end of the term. The WET 2.0 tool was demonstrated to partners via video conference where the team explained methodology, maps, analysis, and applications of WET 2.0.  In addition, the team created both a video tutorial and written manual for partners’ reference when using the tool. WET 2.0, the video tutorial, and the written manual will be delivered to partners after the code has undergone NASA’s software release process for partners’ future use.

***Software Release Plan:*** From the start of the project, partners were informed that due to NASA software release policy, the tool would not be available for use until Software Release is complete. Partners were given an overview of the Wetland Extent Tool 2.0 via video conference at the end of the term. Since the tool was not available for immediate use by partners, the team created a video tutorial and written manual for partners’ future reference. In addition, the team included a README document in the release package that details instructions and applications for its use.

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***Handoff Package:***

* WET 2.0
* Wetland Classification Maps
* WET 2.0 Video Tutorial
* WET 2.0 Written Manual
* Project Summary
* Technical Paper
* Poster
* Presentation
* Project Video

**References**

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