**Great Lakes Water Resources**

*Improving Wetland Change Mapping using Optical and Radar Satellite Sensors to Assess Wetland Gain and Loss Metrics in Minnesota*

**VPS Title:** The Land of Ten Thousand Lakes: Automated Wetland Mapping in Minnesota

**Project Team**

***Project Team:***

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***Advisors & Mentors:***

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**Project Overview**

***Project Synopsis:*** Current and accurate wetland maps in the Midwestern United States are needed by stakeholders for various efforts, including conservation and infrastructure development. However, it is time and resource intensive to map these features using conventional methods involving aerial orthophotography in conjunction with *in situ* data. To address this, the 2019 Spring NASA DEVELOP Great Lakes Water Resources team worked with partners in Minnesota to create an automatic wetland delineation tool hosted on Google Earth Engine (GEE). This will help increase the efficiency of wetland mapping, allowing for more frequent wetland inventory updates.

***Abstract:***

Wetlands are a critical feature of our landscape for the ecological services they provide, including protecting water quality, providing habitat to rare species, mitigating erosion, and providing opportunities for recreation. Despite this, wetlands are facing increasing threats from a variety of anthropogenic sources, including pollution, change in climate, and commercial development. Although an accurate baseline inventory of wetland extent is essential for addressing these threats and quantifying future wetland change, traditional wetland mapping methods are time intensive, costly, and difficult to implement on a large scale. Here we show that statewide, fully-automated wetland mapping is possible to a high degree of accuracy by combining recent advances in remote sensing and cloud computing. Using a multi-source, multi-temporal, object-based random forest classification approach in Google Earth Engine, we generated 30 m resolution maps of wetland extent and change for the growing seasons (May through September) of 2017 and 2018 in Minnesota. In particular, inclusion of Sentinel-1 C-Band Synthetic Aperture Radar (C-SAR) composites, Landsat 8 Operational Land Imager (OLI) composites, and a topographically derived wetness index allowed us to achieve and overall accuracy of 87%when compared to the National Wetland Inventory. Our partners included US Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI), Minnesota Department of Natural Resources (MN DNR), Environmental Protection Agency (EPA), Ducks Unlimited (DU), National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management, and the University of Minnesota (UMN). We anticipate that our tool can be of immediate use to these end users in Minnesota who rely on accurate wetland data to inform their research, policy, and development decisions. Furthermore, these methods can quickly be applied to any region of the United States for which adequate training data exists.

**Keywords:**

remote sensing, GIS, Google Earth Engine (GEE), Landsat 8 Operational Land Imager (OLI), Sentinel-1 C-Band Synthetic Aperture Radar (C-SAR), automation

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

***Study Location:*** MN

***Study Period:*** 2017 to 2018 (May to September)

***Community Concerns:***

* The Intergovernmental Panel on Climate Change (IPCC) declared wetlands the most vulnerable landscape feature on the planet.
* Wetland managers, homeowners, highway engineers, and farmers all need current and accurate wetland maps to plan for conservation, home development, transportation infrastructure, and agricultural management.
* Currently, mapping wetland extent is a time consuming and labor-intensive process that requires the participation of multiple agencies in order to be implemented.

***Project Objectives:***

* Improve wetland change mapping using radar and optical datasets, including NASA Earth observations, to aid end users in assessing wetland gain and loss in Minnesota
* Create an automated, multi-satellite, and seasonal approach for wetland mapping that can efficiently account for changes in wetland extent
* Build our end users’ capacities to utilize radar data and the cloud computing abilities of GEE for wetland mapping

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **US Fish and Wildlife Service, National Wetlands Inventory** | Brian Huberty, Regional NWI and USFWS Remote Sensing Coordinator | End User | Yes |
| **Minnesota Department of Natural Resources** | Steve Kloiber, Wetland Monitoring Coordinator | End User | Yes |
| **US Environmental Protection Agency, Office of Research and Development** | Tom Hollenhorst, Ecologist | End User | Yes |
| **Ducks Unlimited** | Robb Macleod, National GIS Coordinator | End User | Yes |
| **University of Minnesota** | Joe Knight, Associate Professor | End User | Yes |
| **NOAA Office for Coastal Management** | Brandon Krumwiede, Remote Sensing Specialist and Great Lakes Geospatial Coordinator | Collaborator | Yes |

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

Wetland map products are consistently in demand from agencies in the state of Minnesota, including the

USFWS, MN DNR, EPA, UMN, and DU, in order to make educated and informed decisions on the conservation of natural wetland habitat and resources. This may include wetland type classification, wetland restoration, and the eradication of invasive species of flora and fauna. Some portions of the currently available NWI map for Minnesota only have data from the 1970s. This is problematic because the UMN has used the NWI map to help create state land cover maps. The lack of reliable inventory information also hinders the decision making by field managers working with our partners at the USFWS and UMN. They are involved in projects including wetland restoration, invasive species control, and waterfowl counts that require up-to-date wetland maps.

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

The major end product of this project is a tool derived from GEE that automates the creation of wetland change maps. This tool will benefit our various partners by giving them accurate and current wetland maps that can inform their daily decisions regarding conservation and restoration work. It also builds their capacities to use the GEE platform, radar imagery, and NASA Earth observation data. Ultimately, this automated tool will save time and resources that would otherwise be spent on field surveying and traditional remote sensing approaches.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface reflectance, Modified Normalized Difference Water Index, Tasseled Cap Greenness Wetness | Optical and infrared bands in addition to spectral indices were used to classify wetland areas at a resolution of 30 m. |
| **Sentinel-1 C-SAR** | Backscatter, vertical polarization (VV), horizontal polarization (VH) | Radar data were used to identify inundated areas to help classify wetland extent. |

***Ancillary Datasets:***

* Minnesota Department of Natural Resources National Wetland Inventory Update for Minnesota – Train and validate our tool
* Minnesota Department of Natural Resources Wetland Monitoring Sample Plots and Validation Points – Test the accuracy of wetland extent generated by our tool
* Minnesota Department of Natural Resources 3-meter Digital Elevation Data – Identify hydrological features where wetlands may be located

***Software & Scripting:***

* Google Earth Engine API – Create a tool for remote sensing data collection, preprocessing, and delineation of wetlands
* Harris Corporation ENVI – Perform accuracy assessment of products from the tool
* Esri ArcMap – Create visuals of products from the tool

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Wetland Change Maps** | Landsat 8 OLI  Sentinel-1 C-SAR | These maps are essential to identify wetland areas and quantify changes in wetland extent. They can also be used by partners to update map inventories such as the NWI. | I |
| **Wetland Extent Tool (WET)** | Landsat 8 OLI  Sentinel-1 C-SAR | By leveraging cloud computing, the tool automates and streamlines wetland delineation for end users. This customizable tool will allow for efficient wetland change detection to inform partners’ conservation efforts. | IV |

**Project Handoff Package**

*Transition Plan:* A handoff package in the form of a Google Drive folder was prepared for handoff at our last partner meeting during week 10. Items included in this package are detailed below. For our last partner meeting, we scheduled a video conference with all end users to discuss the progress of the GEE tool as well as provide an evaluation of the accuracy of the wetland maps it produces. We presented an overview of the tool and its series of preprocessing and classification steps. Visuals of preliminary maps in comparison to validation products were shown.

*Software Release Plan:* The partner has been notified that the code for the Wetland Extent Tool (WET) will not be available for them until it has successfully completed the NASA Software Release process. We provided a README file outlining instruction for the use and customization of the tool. After the completion of the Software Release process and notification by the POC listed below, the partners will review and test the code to generate suggestions for improvement and regional expansion by future DEVELOP participants.

*Project Continuation Plan:* This term produced code for a tool that has been validated for Minnesota. In order for expansion by future terms, the code contains comments explicitly describing the function of different sections of the script. Comments and suggestions from this term’s partner handoff meeting were recorded and archived to give future participants guidance. The tool’s script will be further validated and calibrated for the rest of the states surrounding the Great Lakes in the second term.

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**Handoff Package:**

* Presentation
* Poster
* Project Summary
* Technical Paper
* Project Video
* Wetland Change Maps
* Wetland Extent Tool (WET) Tutorial
* Shapefiles

**References:**

Kloiber, S. M., Macleod, R. D., Smith, A. J., & Huberty, B. J. (2015). A semi-automated, multi-source data fusion update of a wetland inventory for East-Central Minnesota, USA. *Wetlands*, *35*(2), 335-348. https://doi.org/10.1007/s13157-014-0621-3