**Massachusetts Water Resources**

*Assessing Flood Events Resulting from North American Beaver Reintroduction with NASA Earth Observations to Inform Biodiversity and Infrastructure Management*

**VPS Title:** Something to Chew on: Detecting Beaver-Induced Flooding in Massachusetts

**Project Team**

***Project Team:***

Ahmed Baqai (Project Lead)

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***Advisors & Mentors:***

Dr. Cedric Fichot (Boston University)

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**Project Overview**

***Project Synopsis:*** Massachusetts communities are increasingly impacted by growing beaver populations, with beaver-induced flooding drastically changing the landscape and affecting human infrastructure. Given the biological, environmental, and infrastructural impacts resulting from beavers and their dams, there is high interest in understanding the spatial and temporal patterns in the distribution of beaver activity from both a scientific and management perspective. The NASA DEVELOP Massachusetts Water Resources team created an interactive monitoring tool capable of identifying beaver-induced flooding events in order to assist the Massachusetts Audubon Society in detecting these floods and managing the outcomes.

***Abstract:***

North American beavers (*Castor canadensis*) are returning to Massachusetts after overhunting decimated their populations in the 1700s. Current regulations have allowed this species to recolonize, resulting in increasingly prevalent human-beaver conflicts. These ecosystem engineers can quickly change their environment through the creation of dams, leading to floods that can adversely affect human infrastructures, such as basements, roads, or septic systems. Conversely, beaver dams can positively influence their environment, modifying the physical and chemical properties of streams and providing crucial habitats to a variety of wildlife. The 2020 Spring Boston NASA DEVELOP team collaborated with the Massachusetts Audubon Society to support their efforts in monitoring beaver impacts and managing human-beaver conflicts. The project-utilized data from Landsat 5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper Plus, and Landsat 8 Operational Land Imager to map the spectral signature created from beaver-induced flooding. The team created a tool called Beaver-Flood Event Detector (B-FED) in Google Earth Engine using imagery from 1985 to 2019. Ancillary datasets were incorporated into B-FED that allow the tool to highlight flood events in wetland areas and in situ observations of beaver presence. Beaver observations in or near flooded areas indicated likelihood that the flood was beaver induced. Time series and animations were also produced to display key regions of landscape change across Massachusetts. B-FED will allow the partner to identify and assess potential ecosystem changes and infrastructural impacts from beavers across Massachusetts and inform future management practices.

***Keywords:***

Landsat, remote sensing, *Castor canadensis*, beaver, Google Earth Engine, flooding, citizen science

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

***Study Location:*** Massachusetts

***Study Period:*** January 1985 to December 2019

***Community Concerns:***

* The beaver population has been steadily growing in Massachusetts after nearly 200 years of local extinction. They were first reintroduced in the first half of the 20th century in western Massachusetts. By 1998, the beaver population was over 58,000 in the state and believed to be increasing. Their return has led to the creation of dams, changing the extent of water bodies and physical properties of the landscape.
* The increased flooding caused by beaver dams can lead to positive impacts for humans such as wetlands that mitigate storms and have greater biodiversity.
* Flooding caused by beavers can also cause inconveniences for humans in the form of physical and economic damage to infrastructure including roads, wells, and septic tanks.
* Beaver dams cause changes in aquatic biogeochemical cycling, water quality, and habitat availability, which in turn increases plant, animal, and aquatic invertebrate diversity.
* Beaver activity can pose long-term issues that require management and close monitoring; therefore, understanding the spatial and temporal response of their activity is of great interest to local communities and environmental conservation agencies.

***Project Objectives:***

* Create a user-friendly Google Earth Engine flood detection tool to detect flooding events likely caused by the North American beaver
* Correlate direct beaver observations from a citizen science platform to remotely sensed flood events
* Produce flood extent time series, maps, and animations to show how beavers have impacted the Massachusetts landscape through time

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Massachusetts Audubon Society** | Joshua Rapp, Regional Scientist; Cameron Piper, TerraCorps Landscape Stewardship Coordinator; Jeff  Collins, Director of Conservation  Science; Elissa Landre, Sanctuary Director of Broadmoor Wildlife Sanctuary | End User | Yes |

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

The Massachusetts Audubon Society (Mass Audubon) is a non-profit organization dedicated to the protection and conservation of Massachusetts wildlife. The organization stresses the importance of conserving wildlife sanctuaries and manages over 38,000 acres of land under its purview. In order to promote the protection of natural Massachusetts wildlife, Mass Audubon collaborates with academic institutions, local government organizations, summer camps, wildlife sanctuaries and more. Much of their environmental decision-making comes from data acquired from the field and materials from outside organizations, residents, or academic institutions. They have not yet integrated remote sensing into their decision-making, but they are familiar with spatial analyses. Mass Audubon is currently responding to community concerns about beaver-induced flooding and is attempting to inform the public on how to manage human-beaver conflicts. Presently, their beaver disturbance management procedures vary from site-to-site, adjusting their approach according to landscape and infrastructure.

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

The Beaver-Flood Event Detector (B-FED) will facilitate the detection of potential beaver-related flooding events and help the end user better monitor and manage the impacts of growing beaver populations. This will allow for the assessment of beavers’ impact on human infrastructure, water quality, and wetland ecosystems. Maps, animations, and analyses of high-impact areas will aid in the understanding of the size and spatial extent of Massachusetts beaver populations. These products can be used to inform ongoing research, expand public awareness and help manage human-wildlife interactions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Surface reflectance | Surface reflectance was used to examine and map flooding events. |
| **Landsat 7 ETM+** | Surface reflectance | Surface reflectance was used to examine and map flooding events. |
| **Landsat 8 OLI** | Surface reflectance | Surface reflectance was used to examine and map flooding events. It also provided a baseline comparison for years in which flooding events did not take place. |

***Ancillary Datasets:***

* Global Biodiversity Information Facility, Massachusetts Beaver Observations – Integrate direct beaver observations into the Google Earth Engine tool to distinguish between regular flooding and beaver-induced flooding
* USGS National Land Cover Database – Land cover data selected for wetlands

***Software & Scripting:***

* Google Earth Engine API – Data and time series analysis of imagery
* Esri ArcGIS Pro 2.1.10257 – Production of maps
* Adobe Illustrator CC 2020 – Creating graphics
* Adobe After Effects CC 2020 – Creating animations

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Beaver-Flood Event Detector (B-FED)** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | This tool will allow the partner to detect flooding events caused by beavers, allowing for improved management decision-making and assessment of potential negative impacts to human infrastructure and local ecosystems. | IV |
| **Flood Extent Time**  **Series, Maps, and**  **Animations** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | These visualizations demonstrate how beavers have changed the Massachusetts landscape through time. | N/A |
| **B-FED Tutorial** | N/A | This tutorial shows how to manipulate B-FED to change the parameters (years and location), produce time series, and input the latest in-situ data from the Global Biodiversity Information Facility website. | N/A |

**Project Handoff Package**

***Transition Plan:*** A virtual handoff took place in week 10 of the term. The team presented their methods and findings, performed a walkthrough of B-FED, and answered all questions. Maps and time series were electronically sent to partners for public dissemination and research integration. The code for the Google Earth Engine tool will be shared with the partner after it has completed the software release process.

***Software Release Plan:*** The partners were informed that the B-FED will undergo the NASA Software Release process and that this will cause a delay in their ability to gain access to the tool. The team POC will be in contact with the partner to answer questions or concerns during the delay. After the software release is complete, the tool will be shared with the partner through DEVELOP’s Github page.

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***Partner POC:*** Joshua Rapp, [jrapp@massaudubon.org](mailto:jrapp@massaudubon.org), Cameron Piper, [cpiper@massaudubon.org](mailto:cpiper@massaudubon.org)

***Handoff Package:***

* B-FED Tutorial
* Flood Extent Time Series, Maps, and Animations
* Technical Paper
* Poster
* Presentation
* Project Summary
* Study Area Shapefile

**References**

Bailey, D. R., Dittbrenner, B. J., & Yocom, K. P. (2019). Reintegrating the North American beaver (*Castor canadensis*) in the urban landscape. *Wiley Interdisciplinary Reviews: Water, 6*(1), e1323. https://doi.org/10.1002/wat2.1323

Pasquarella, V. J. (2016). *A conceptual and methodological approach to characterize beaver-related wetland disturbance using Landsat time series. In Utilizing the Landsat spectral-temporal domain for improved mapping and monitoring of ecosystem state and dynamics* [Unpublished Doctoral dissertation]. Boston University.