**Yellowstone Ecological Forecasting**

*Assessing Change in Aspen Extent in Northern Yellowstone National Park*

**Project Team**

***Project Team:***

Kyle Steen (Project Lead)

Vanessa Bailey

Gabriella Boodhoo

Barry McLaughlin

***Advisors & Mentors:***

Dr. Marguerite Madden (University of Georgia, Center for Geospatial Research)  
Dr. Kunwar Singh (William & Mary, AidData, Global Research Institute)

***Team Contact:*** Kyle Steen, kylejacobsteen@gmail.com

***Partner Contact:*** Daniel Stahler, dan\_stahler@nps.gov

**Project Overview**

***Project Synopsis:***

The gray wolf (*Canis lupus*) has played a significant role in shaping Yellowstone’s distinct ecosystem with its extirpation and subsequent reintroduction. In particular, wolf interactions with species such as elk and aspen have attracted significant scientific interest. In partnership with the National Park Service, Utah State University, and the University of Wisconsin–Stevens Point, this project utilizes remote sensing to investigate long-term trends in aspen extent with random forest modeling and phenological approaches. Maps and time-series will provide the partners with identification of aspen distribution and condition, thereby informing management practices, wildlife restoration, and rewilding decisions.

***Abstract:***

The removal and reintroduction of the gray wolf (*Canis lupus*) in Yellowstone National Park have shaped the ecological composition of this distinct landscape, representing a textbook example of trophic dynamics. With particular importance to conservation science, researchers have studied the trophic cascades between wolves and species such as elk (*Cervus canadensis*) and quaking aspen (*Populus tremuloides*). In conjunction with the National Park Service, Yellowstone National Park, Utah State University, and the University of Wisconsin–Stevens Point, this project utilized satellite remote sensing to investigate the long-term trends in aspen extent. Through random forest modeling and phenological approaches, Landsat 5 Thematic Mapper (TM; years 1986–2011) and Sentinel-2 Multispectral Instrument (MSI; years 2017–2019) datasets were used to derive color composites, Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Tasseled Cap Indices (Brightness, Greenness, Wetness). The International Space System (ISS) Global Ecosystem Dynamics Investigation (GEDI) provided canopy height data. The team consolidated results into maps and time-series which provide an in-depth depiction of aspen stand extent. The National Park Service will use these end products to assist in its management practices and inform wildlife restoration decisions within and beyond Yellowstone National Park.

***Key Terms***

*Populus tremuloides*, trophic cascade, NDVI, EVI, random forest, phenology, GEDI

***National Application Area Addressed:*** Ecological Forecasting

***Study Location:*** Elk Wintering Range in Northern Yellowstone National Park, WY and MT

***Study Period:*** July 1986 – July 2019

***Community Concerns:***

* Aspen contributes to ecosystem health, habitat creation, and biodiversity as one of the few deciduous species in the Yellowstone region. Increased elk browsing has potentially contributed to more mature aspen stands with few juveniles and saplings over the past decades. Aspen stands which lack a variety of age classes are more vulnerable to die-off and reduced biodiversity.
* Over the past few years, numerous reports and articles have explored cascading effects of wolf reintroduction in relation to aspen extent. Although many of these reports highlight the benefits of reintroduction, the scientific community has voiced some concerns with potential overestimation and inaccuracy within recent studies. More comprehensive research is needed to reduce these uncertainties.
* The National Park Service uses 113 (20 meters by 1 meter) transects to analyze trends in aspen extent and health. However, these transects may not fully reflect the overall extent or health of stands across the region. Incomplete aspen sampling may skew land management and decision-making within Yellowstone National Park.
* Multiple stakeholders have interests in Yellowstone and its aspen extent including tourists, wildlife enthusiasts, and the National Park Service. Millions of people travel to Yellowstone National Park every year to see the natural beauty, unique geological formations, and distinctive flora and fauna. If aspen declines, tourism and other wildlife within the ecosystem may be at risk.

***Project Objectives:***

* Assess aspen extent by performing landcover classification through a random forest model
* Identify aspen extent by contrasting peak and late senescence NDVI using a phenological approach
* Uncover long-term trends in aspen stand regeneration through the creation of maps and time-series
* Investigate the feasibility of using canopy height data from ISS GEDI to characterize aspen health

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **National Park Service, Yellowstone National Park** | Dr. Daniel Stahler, Wildlife Biologist | End User |
| **Utah State University** | Dr. Dan MacNulty, Professor Nicholas Bergeron, Researcher | Collaborator |
| **University of Wisconsin, Stevens Point** | Dr. Eric Larsen, Professor | Collaborator |

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

The absence and subsequent reintroduction of the gray wolf in Yellowstone National Park have significantly affected the ecological composition and trophic dynamics of the park’s landscape since the 1990s. Yellowstone National Park is interested in the indirect response of aspen to wolf reintroduction. Since 1999, researchers have annually monitored aspen regeneration in 113 transects across ~1500 km2 area in northern Yellowstone. The transects include information on canopy height, aspen presence, aspen health, and other vegetation presence. Long-term monitoring helps to assess trends in aspen stand regeneration and quantify the influence of several factors, including the indirect effects of the gray wolf. The park has used some aerial photography dating back to the 1950s to make observations of landcover change and aspen extent. They have not yet utilized satellite imagery, which will provide information about aspen recovery in the greater region. These results can be used for further analysis on the impact of wolf reintroduction and influence management decisions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Color composites, NDVI, EVI, Tasseled Cap Indices | Landsat 5 TM spectral indices were used to classify aspen stand extent through random forest modeling and phenological approaches. |
| **Sentinel-2 MSI** | Color composites, NDVI, EVI, Tasseled Cap Indices | Sentinel-2 MSI spectral indices were used to classify aspen stand extent through random forest modeling and phenological approaches. |
| **ISS GEDI** | LiDAR | ISS GEDI geolocated waveforms (Level 1) and canopy height and profile metrics (Level 2) were used to produce height and density graphs at locations within the study area. |

***Ancillary Datasets:***

* Utah State University and Yellowstone National Park, Landcover Data – Point locations of several landcover classes, including aspen, in the study area | for training of random forest model, generation of NDVI values, and validation with remotely sensed data
* USGS 3DEP LidarExplorer, DEM – Elevation data at 1/3 arc second | for elevation data and other terrain parameters
* Yellowstone National Park, Boundary of Elk Wintering Range – Elk wintering range boundary | for the spatial extent of the greater study region

***Modeling:***

* Random Forest (Contact: Dr. Marguerite Madden, University of Georgia) – Generate aspen classification

***Software & Scripting:***

* Google Earth Engine JavaScript API – Collect and analyze data from multiple sensors and satellites
* Esri ArcGIS Pro 2.9.0 – Map and visualize current aspen transects and the elevation of the greater study area
* QGIS 3.16.7 Hannover – Convert kml data points to shapefiles
* RStudio 2022.02.3 Build 492 – Utilize packages for processing, visualization, and manipulation of ISS GEDI data

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Aspen Stand Extent Maps & Time-Series** | Landsat 5 TM  Sentinel-2 MSI | The partners will use aspen stand extent maps and time-series to evaluate the impact of wolf reintroduction on aspen growth. The partners can validate the remotely sensed aspen outputs with plot-level data of aspen stands. End products will allow an assessment of the broader region, as field measurements are limited by person-hours and accessibility. | N/A |
| **Canopy Profile Transect** | ISS GEDI | The canopy profile transect provides information on height and other profile metrics. The partners can use this in combination with identified aspen extent to understand the health of stands. | N/A |

***Product Benefit to End User:***

The team will utilize the expertise and assets of the NASA DEVELOP program to assist our partners in understanding how the reintroduction of wolves in Yellowstone National Park has affected aspen extent. Our partners will benefit from increased understanding and awareness of what relevant data products are available; this project will improve their knowledge of remote sensing and satellite imagery applications. The maps produced give greater spatial context to aspen regeneration that cannot be obtained in the field alone due to time, money, or accessibility limitations. The final products enable our partners to validate findings at field sites. With a greater understanding of the effects of rewilding decisions, Yellowstone National Park can contextualize trends of vegetative change and the impacts of trophic cascades. Our partners may also compare with other datasets, such as elk and wolf population dynamics.

***Project Continuation Plan:***

This project will continue in the Fall 2022 DEVELOP term and build upon the previous team’s work. The team will focus the spatial extent on specific areas of interest within the elk wintering range. Spatial resolution will be improved using PlanetScope imagery for recent years. The team will improve the temporal resolution of aspen extent by increasing analysis to yearly increments. The team will perform further comparative analysis of the random forest and phenological methods and decide on which method(s) is most suitable. Once aspen extent is established, the team will analyze aspen health through NDVI and EVI time-series. Finally, the team will compare remotely sensed aspen extent and plot level data with ISS GEDI canopy height data to assess stand health.

**References:**

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