**Bandelier Ecological Conservation**

*Mapping Invasive Species Along the Rio Grande Corridor in Bandelier National Monument*

**Project Team**

***Project Team:***

Evan Barrett (Project Lead)

Megan Rich

Nusrat Zahan Jarin

Chloe Johnson

***Advisors & Mentors:***

Dr. Marguerite Madden (University of Georgia, Center for Geospatial Research)

Joseph Spruce (Science Systems and Applications, Inc.)

***Fellow:***

Sarah Payne (Georgia – Athens)

***Team Contact:*** Evan Barrett, evan.p.barrett.24@dartmouth.edu

***Partner Contact:*** Sarah Milligan, sarah\_milligan@nps.gov

**Project Overview**

***Project Synopsis:***

Bandelier National Monument has experienced invasive species spread along the Rio Grande, which has negatively impacted native species and the overall biodiversity of the region. In partnership with the National Park Service, this project used a random forest classification algorithm applied to hyperspectral and multispectral satellite data from 2019 to 2023 to map the extent of invasive species within the region. The resulting maps and associated time series will inform the park staff about sites for environmental remediation to protect the area’s ecosystems from invasive species.

***Abstract:***

The Southwest U.S. has experienced a growth of invasive riparian species, specifically *Elaeagnus angustifolia* (Russian olive), *Tamarix ramosissima* (saltcedar), and *Ulmus pumila* (Siberian elm), which alter local soil chemistry and outcompete native species. Locating these exotic species is critical for ecological conservation; however, field identification can be resource-intensive and difficult. NASA DEVELOP partnered with the National Park Service (NPS) at Bandelier National Monument (BAND) to assess the feasibility of using Earth observation data to map invasive species along the Rio Grande corridor of the park. The team used Landsat 8 OLI, Sentinel-2 MSI, and ISS DESIS imagery to compute principal components based on spectral bands, vegetation indices, and terrain indices through a principal component analysis. Using the first five components, the team created classification maps using both a k-means classification algorithm and a random forest algorithm to differentiate between native and non-native species. The team derived maps for the three invasive riparian species in the region for the last five years along with native vegetation and other land cover classes. The team found that invasive species covered 33% of the park's river corridor in 2023, and the downstream species extent has increased by 5.7% from 2019 to 2023. The methods will serve as a guide for aiding historic and present invasive species identification in riparian regions, and the NPS staff at BAND will use the results to inform local mitigation practices and advocate for invasive species removal.

***Key Terms:***

Bandelier National Monument, remote sensing, invasive species, random forest, principal component analysis, hyperspectral, multispectral

***National Application Area Addressed:*** Ecological Conservation

***Study Location:*** Bandelier National Monument, NM

***Study Period:*** June 2019 – June 2023

***Community Concerns:***

* BAND has seen various land disturbances through the years such as homesteading, overgrazing, and wildfires, which have introduced many non-native species to the area. All three species (Russian olive, saltcedar, and Siberian elm) are labeled as noxious weeds in New Mexico and are a significant threat to native riparian trees such as cottonwoods and willows.
* These non-native species tend to replace natives, alter the existing watershed, cause soil degradation, and threaten biodiversity in the region.
* The NPS staff removed thousands of stems of these species along the park’s Rio Grande corridor, and in the years immediately following, existing native riparian vegetation recovered greatly. However, re-establishment of these invasive tree species is a major concern for park staff, as well as for Pueblo communities living downstream of the monument.

***Project Objectives:***

* Determine the extent of invasive species (Russian olive, saltcedar, Siberian elm) in the Rio Grande corridor over the past 5 years
* Produce vegetation classification maps
* Visualize vegetation change using maps and time series analysis
* Assess the feasibility of using hyperspectral data to identify invasive species

**Partner Overview**

***Partner Organization:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **National Park Service, Bandelier National Monument** | Sarah Milligan, Natural Resource Project Manager;  Laura Trader, Fire Ecologist;  Anna Wheeler, Invasive Plant Management Specialist;  Kay Beeley, Ecologist; Priscilla Hare, Biological Technician; Cassandra Suddath, Recreation Fee Technician | End User |

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

The NPS staff at BAND bases restoration and invasive species removal decisions primarily on in situ data collection, much of which is collected by the invasive plant management team associated with the park. The partners have familiarity with GIS and remote sensing having previously mapped vegetation in 2011. While staff at BAND have experience using GIS to visualize land cover, they have yet to integrate current multispectral or hyperspectral data into their invasive plant management plans or decision-making practices.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | True Color Composites (RGB), NDVI, EVI, NDMI, LAI, MSAVI, Tasseled Cap Indices (Brightness, Greenness, Wetness) | Landsat 8 OLI spectral indices were used to identify invasive species through a random forest classification. |
| **Sentinel-2 MSI** | True Color Composites (RGB), NDVI, EVI, NDMI, LAI, MSAVI, Tasseled Cap Indices (Brightness, Greenness, Wetness) | Sentinel-2 MSI spectral indices were used to identify invasive species through a random forest classification. |
| **ISS DESIS** | Surface Reflectance, NDVI, EVI, MSAVI, LAI | DESIS hyperspectral imagery was used to identify invasive species along the Rio Grande corridor of the park through a random forest classification. |

***Ancillary Datasets:***

* Bandelier National Monument, Park Boundary, Roads, and Trails – Provide geographic context to end products
* National Agricultural Imagery Program – 1-meter spatial resolution data for creating training data
* 2011 Bandelier NM Vegetation Mapping Project – Provide background context for the team’s classification
* MERIT Hydro, Global Hydrography Datasets – Hand Above Nearest Drainage data for BAND

***Modeling:***

* Random forest (Contact: Sergio Bernardes, University of Georgia) – Generate vegetation classification

***Software & Scripting:***

* Harris Corporation ENVI 5.3 - DESIS derived classification, pan sharpening
* QGIS 3.3 - Hyperspectral image preprocessing, data post-processing and analysis, map creation
* Google Earth Engine: Multispectral (Landsat 8 OLI, Sentinel-2 MSI) classification modeling, PCA, indices (NDVI, EVI, NDMI, LAI, MSAVI, Tasseled cap, HAND)
* Esri ArcGIS Pro 3.1 - Making study area map, performing data analysis on classified maps, map creation

***End Products:***

|  |  |  |
| --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** |
| **Annual Vegetation Maps** | Landsat 8 OLI, Sentinel-2 MSI, ISS DESIS | The vegetation maps will allow the partners to observe where invasive species are located within BAND and surrounding areas. The staff can then use the location data to identify areas for treatment and mitigation. |
| **Vegetation Time Series & River Transect Graph** | Sentinel-2 MSI | The partners will use the time series to observe trends in the spread of invasive species along the river corridor, thus allowing them to make predictions as to where the species will spread in the future. The park staff will use the projections to mitigate the risk of the species spreading. |

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

The partners will utilize the maps and methodologies produced by the DEVELOP team to identify areas for invasive species treatment. The partners will use the 2023 map to locate invasive species and identify where treatment plans are effective or ineffective within BAND. Furthermore, the staff at BAND will use the time series analysis and river transect graphs to understand trends associated with the invasives and mitigate future spread of the species. With these tools, the partners will be able to advocate for funding to aid in ecological restoration of the Rio Grande corridor and other areas within BAND. Mechanical, chemical, and biological control measures may be used to remove the invasive species and protect the native plants, watershed, and local communities.

**References**

New Mexico Department of Agriculture. (2020). New Mexico Noxious Weed List. <https://www.invasive.org/species/list.cfm?id=30>

National Park Service. (2015). Foundation document: Bandelier National Monument. <http://npshistory.com/publications/foundation-documents/band-fd-2015.pdf>