**Coronado Ecological Conservation**

*Assessing Vegetation Change Due to Border Wall Construction and Shifting Social Trails*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Coronado National Memorial has experienced the spread of invasive vegetation due to U.S.-Mexico border wall construction and the prevalence of social trails throughout the memorial. In partnership with the National Park Service, this project used remotely sensed imagery from 1990-2022 to assess vegetation change, generate classified images through random forest and k-means models, and produce vegetation health maps. The resulting classified images, maps, and time-series will inform the partners of the spread of invasive species and changes in vegetation health. They will additionally document the impacts of construction and social trails for management and restoration planning.

***Abstract:***

Species monitoring is essential for mitigating the impacts of plant invasion, such as radical changes in an area’s ecosystem, degraded soil health, increased wildfire severity, landslides, and increased flooding. For this project, NASA DEVELOP partnered with the National Park Service (NPS) to investigate invasive species in disturbed lands: specifically, areas affected by off-trail travel and U.S.-Mexico border construction activities. The team assessed how construction has impacted the distribution of Lehmann’s lovegrass and Russian thistle invasives throughout Coronado National Memorial, AZ (CORO) from 1986-2022. Using data from Landsat 5 and 8, Sentinel-2, NAIP, and PlanetScope, the team computed NDVI, NDMI, MSAVI2, EVI, and Tasseled Cap Wetness, Brightness, and Greenness transformations as vegetation health indicators to input into various machine learning algorithms. To minimize noise, the team conducted Principal Component Analysis on vegetation indices and spectral bands before running k-means clustering and random forest classification algorithms. Between all datasets, the team found that the median area fully overtaken by invasive plants was 5.37% of the park’s total area in 2022. DEVELOP’s end products will help increase the NPS’s restoration efforts in disturbed areas with high concentrations of invasive plants and serve as a jumping off point for future invasive species monitoring. The NPS’s collection of ground data for 2022-2023, in conjunction with future data collection, will notably improve the accuracy of classification models, leading to more precise monitoring of invasive spread over time.

***Key Terms:***

Coronado National Memorial, invasive species, border wall construction, social trails, random forest, k-means, principal component analysis

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

***Study Location:*** Coronado National Memorial, AZ

***Study Period:*** January 1990 – August 2022

***Community Concerns:***

* Coronado National Memorial is located at the intersection of four major biomes: the Chihuahuan Desert, the Sonoran Desert, the Rocky Mountains, and the Sierra Madre Occidental. As a result, the memorial harbors incredible biodiversity. However, due to border wall construction and shifting social trails, invasive species can outcompete native species. Native vegetation provides habitat and food for several threatened species; therefore, the loss of native vegetation could endanger other animal and plant species and the ecosystem.
* The invasive species of interest, Russian thistle *(Salsola tragus L.)* and Lehmann lovegrass *(Eragrostis spp.)* may contribute to elevated fire danger. Russian thistle is a tumbleweed that can facilitate a greater spread of wildfires once started. Lehmann lovegrass produces higher fuel loads than native species, increasing fire intensity which results in increased agave mortality. Agave is an important source of food for deer, squirrels, birds, insects, and the historically endangered lesser long-nosed bat.
* The spread of invasive species combined with potentially elevated incidences of wildfires can degrade soil health and lead to other natural disasters such as flooding or landslides.
* Coronado National Memorial protects important natural resources as part of the Sky Islands region and provides the area with unique economic and cultural value as a tourist destination. The loss of native vegetation and subsequent ecosystem impact, changes the aesthetic and conservation value of the memorial, negatively affecting recreation.

***Project Objectives:***

* Produce vegetation health maps and timeseries using remotely sensed imagery and spectral indices
* Visualize landcover change with random forest and k-means classification maps and timeseries
* Identify invasive species spread related to border wall construction and social trails using random forest and k-means classifiers

**Partner Overview**

***Partner Organization:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **National Park Service, Coronado National Memorial** | JoAnne Blalack, Integrated Resource Manager; Jessica Garcia, Physical Scientist; Robert Matthewman, GIS Intern; Nicole Gonzalez, Biologist | End User |

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

The NPS administers the policies governing Coronado National Memorial. Presently, the memorial uses remote sensing and spatial data for decision-making and management practices, including EarthExplorer satellite imagery, GPS and tablet collected field data, repeat photography, LiDAR registrations, and Unstable Slope Management protocols. The partners have expressed a need for an increased capacity for analysis and imagery classification, with particular attention to border-related resource impacts, which would inform future resource management and decision-making practices.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 5 TM** | True Color Composites (RGB), NDVI, MSAVI2, EVI, NDMI, Tasseled Cap Indices (Brightness, Greenness, Wetness) | Landsat 5 TM spectral indices were used to classify vegetation types through k-means and random forest approaches. |
| **Landsat 8 OLI** | True Color Composites (RGB), NDVI, MSAVI2, EVI, NDMI, Tasseled Cap Indices (Brightness, Greenness, Wetness) | Landsat 8 OLI spectral indices were used to classify vegetation types through k-means and random forest approaches. |
| **Sentinel-2 MSI** | True Color Composites (RGB), NDVI, MSAVI2, EVI, NDMI, Tasseled Cap Indices (Brightness, Greenness, Wetness) | Sentinel-2 MSI spectral indices were used to classify vegetation types through k-means and random forest approaches. |
| **NAIP** | True Color Composites (RGB), NDVI, EVI, MSAVI2 | NAIP spectral indices were used to classify vegetation types through k-means and random forest approaches. |
| **PlanetScope** | True Color Composites (RGB), NDVI, EVI, MSAVI2 | PlanetScope spectral indices were used to classify vegetation types through k-means and random forest approaches. |

***Ancillary Datasets:***

* Coronado National Memorial, Park Boundary, Roads, and Trails – Provide geographic context for end products
* Coronado National Memorial, Border Road – Focus area of analysis
* Coronado National Memorial, Unauthorized Social Trails 2009, 2020 – Focus area of analysis
* Coronado National Memorial, Invasive Species Point Locations 2022 – To train and test the team’s classification
* Coronado National Memorial, Invasive Species Point Locations 1999-2000 – To train and test the team’s classification

***Modeling:***

* Random Forest (Contact: Dr. Sergio Bernardes, University of Georgia) – Generate vegetation classification
* k-means (Contact: Dr. Sergio Bernardes, University of Georgia) – Generate vegetation classification

***Software & Scripting:***

* Google Earth Engine JavaScript API – Collect, analyze, and map data from multiple sensors and satellites
* QGIS 3.10 – Manage partner-provided vector datasets
* Esri ArcGIS Pro 2.9.0 – Manage partner-provided vector datasets and format maps

***End Products:***

|  |  |  |
| --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** |
| **Random Forest Landcover Classifications** | Sentinel-2 MSI, NAIP, PlanetScope, Landsat 5 TM, Landsat 8 OLI | These images will be used to provide our partners with an understanding of the classifier’s accuracy and the changes across all landcover classes within the park. |
| **Random Forest Invasive Species Classifications** | Sentinel-2 MSI, NAIP, PlanetScope, Landsat 5 TM, Landsat 8 OLI | These images will be used to prioritize targeted areas for invasive species mitigation and help in applying for restoration funding. |
| **Classification Timeseries GIF** | NAIP | These images will be used to create a gif depicting the change in invasive species extent from 2010 to 2019. |
| **Vegetation Health Timeseries** | Landsat 5 TM & Landsat 8 OLI | This chart will be used to demonstrate how vegetative health in the park has changed from 1986 to 2022 using median MSAVI2. |
| **k-means Landcover Classifications** | Sentinel-2 MSI, NAIP, PlanetScope, Landsat 5 TM, Landsat 8 OLI | These images will be used to compare classifier methodologies for determining the best way to gauge invasive species presence in the park. |
| **Border Impacts Buffer Analysis** | Sentinel-2 MSI | This image will be used to analyze and quantify the invasive species spread attributable to roads and trails in the park. |
| **Accuracy Assessment Data Tables** | Sentinel-2 MSI, NAIP, PlanetScope, Landsat 5 TM, Landsat 8 OLI | These data tables will inform our partners of the classes being confused by our random forest and k-means classifiers and provide feedback for future classifier refinement. It will also provide more detail on general classification accuracy. |

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

Though current border construction has halted, over 3 miles of wall have already been constructed in CORO and building materials left behind by previous federal construction crews have caused invasive species to proliferate along the border road, as well as other forms of vegetative damage. Since the future of the border wall’s construction is currently uncertain, CORO’s restoration and mitigation efforts have also come to a halt, so the park is creating documentation and plans for when they have the time and funding to resume construction. The partners will use the team’s work to bolster their documentation and provide evidence in their requests for funding. The vegetation classifications and maps of invasive species spread produced will also guide the implementation of invasive species mitigation efforts by helping the park managers identify and prioritize locations in need of restoration.

**References**

National Park Service. (n.d.). Foundation document overview: Coronado National Memorial, Arizona. <http://npshistory.com/publications/foundation-documents/coro-fd-overview.pdf>

Swetnam, T.L., Yool, S.R., Roy, S., & Falk, D.A. (2021). On the use of standardized multi-temporal indices for monitoring disturbance and ecosystem moisture stress across multiple earth observation systems in the Google Earth Engine. *Remote Sensing 2021, 13, 1448*. <https://doi.org/10.3390/rs13081448>