**Southern Wyoming Ecological Conservation II**

*Improving Invasive Species Detection Mapping with Novel Phenology Approaches*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Accurate maps of cheatgrass (*Bromus tectorum*), an invasive annual grass, are a highly desired product to inform natural resource management in western U.S. landscapes, especially after large disturbances such as wildfires. This project aids USGS and USFS managers in mapping the current distribution of cheatgrass across the Mullen Fire burn scar in southern Wyoming using locally specific phenological information for the timing of green-up and senescence. The team analyzed remotely sensed imagery for the summer of 2021 and 2022. We compared these maps to results from habitat suitability models and on-the-ground cover measurements to examine the accuracy of the novel phenology-based maps.

***Abstract:***

Cheatgrass (*Bromus tectorum)* is an invasive species of grass across the United States, and due to its ability to establish itself in disturbed landscapes, outcompete native species, and generate novel fire regimes that benefit its reproduction, cheatgrass can quickly dominant the landscape, threatening an ecosystems’ integrity. Our partner, the United States Geological Services Fort Collins Science Center, is tasked with detecting and controlling invasive species through novel research methods that use remote sensing to detect cheatgrass presence across varied landscapes more accurately. Disturbed landscapes like the 2020 Mullen Fire burn scar (176,878 acres) in Wyoming, present both major concern due to vulnerability to invasive species and an opportunity to study the presence and spread of cheatgrass post-fire. We developed a detection method using a date-based approach to match satellite images captured on or near dates corresponding to the unique phenology of cheatgrass green-up and senescence phases. Phenology datasets provided by our partners were analyzed for the most common date pairs for the 2021 and 2022 growing season. We utilized the Normalized Difference Vegetation Index derived from Landsat 8 Operational Land Imager, Sentinel-2 MultiSpectral Instrument, and the Harmonized Landsat and Sentinel-2 surface reflectance dataset. NDVI differencing between greenness and senescence, produced both Scene-by-Scene and Pixel-by-Pixel maps predicting cheatgrass presence. Using the Pixel-by-Pixel approach, we found a negative correlation between cheatgrass cover and an increase in NDVI between predicted peak greenness and senescence dates. Our method considers the site conditions' impact on phenological timing giving it greater applicability over more diverse landscapes.

***Key Terms:***

Landsat 8, Sentinel-2, HLS, NDVI, CHILI, Phenology, remote sensing, greenness, senescence

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

***Study Location:*** Mullen Fire Burn Scar, WY

***Study Period:*** May to October 2021, May to October 2022

***Community Concerns:***

* Cheatgrass dominance may alter fire regimes, potentially increasing the frequency of large wildfires.
* More frequent fires prevent revegetation of native plants through continuous disturbance.
* Effective management requires reliable methods that accurately detect cheatgrass across a topographically diverse landscape.

***Project Objectives:***

* Compare NDVI values between images from peak greenness to peak senescence
* Compare satellite imagery between Landsat 8, Sentinel-2, and Harmonized Landsat 8/ Sentinel-2 (HLS) for accessing greenness and senescence dates
* Map cheatgrass coverage based on NDVI differences across a topographically diverse landscape

**Partner Overview**

***Partner Organization:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **USGS, Fort Collins Science Center** | Janet Prevey, Research Ecologist | End User |
| **USDA, US Forest Service** | Jacquilyn Roaque, Rangeland Management Specialist | Collaborator |

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

The United States Geological Survey (USGS) at the Fort Collins Science Center and land managers with the United States Forest Service (USFS) are interested in identifying and controlling cheatgrass in the Mullen Fire recovery area. They require accurate detection and identification maps of cheatgrass to monitor yearly changes in abundance to determine areas to focus treatments. USFS has been conducting aerial sprays of the herbicide Rejuvina to inhibit germination of cheatgrass and has a need for more accurate maps for better application practices. Work conducted by the USGS found peak greenness and senescence dates for cheatgrass within the study area derived from phenological data collected by camera traps and the landscape's varied topographic and climactic aspects. Our partner, Janet Prevey from the USGS, used these dates to create raster maps that show these dates across the study area. To validate these rasters, USFS field data was collected and compared to the USGS rasters. While field data is extremely valuable, it can be difficult to acquire spatially and temporally. Our partners have expressed that current methodologies to map cheatgrass are less effective across elevational variants due to differences in temporal phenology that vary with elevation and climate conditions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 8 OLI** | Spectral vegetation indices and bands | This dataset will provide the temporal (16 day) and spatial (30 m2) resolution needed to capture the phenology of cheatgrass and will be used to develop detection maps. |
| **Sentinel-2 MSI** | Spectral vegetation indices and bands | This dataset will provide the temporal (8 day) and spatial (10 m2) resolution needed to capture the phenology of cheatgrass and will be used to develop detection maps. |
| **Harmonized Landsat 8/Sentinel-2 (HLS)** | Spectral vegetation indices and bands | This dataset will provide the temporal (16 day for Landsat; 8 day for Sentinel) and spatial (30 m) resolution needed to capture the phenology of cheatgrass and will be used to develop detection maps. |

***Ancillary Datasets:***

* USGS Phenology Camera Data – Timelapse camera data from 2021 and 2022 to characterize cheatgrass phenology in the Mullen Fire.
* USGS CHILI/non-CHILI raster maps – These maps predict the peak greenness and trough senescence date per pixel for cheatgrass. Eight maps that both did and did not incorporate the heat load metric that combines elevation, slope, and latitude to estimate the average amount of sunlight exposure an area receives.
* USFS Field Data – 2021 and 2022 vegetation field data that was used as a comparison to model outputs.
* NASA Earthdata Search Harmonized Landsat and Sentinel-2 Data – Used to visualize the harmonized Landsat and Sentinel images by growing season within our desired years.

***Modeling:***

* SWY EC I Team RF Model (POC: Anthony Vorster, Natural Resources Ecology Lab at Colorado State University) – method comparison of results

***Software & Scripting:***

* ESRI ArcGIS Pro 3.1 – creating study area map
* Google Earth Engine – image acquisition and processing (specifically cloud masking and NDVI calculations)
* R 2023.06.0+421 – identifying most frequent date pairs and creating differenced NDVI rasters

***End Products:***

|  |  |  |
| --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** |
| **Scene-by-Scene Greenness/Senescence Date Pair Matching and NDVI Differencing Code** | Landsat 8 OLISentinel-2 MSIHarmonized Landsat 8/Sentinel-2 (HLS) | Takes satellite imagery and matches up all Scene-by-Scene date pairs for greenness and senescence photos and creates all NDVI difference maps based on those date pairs. |
| **Scene-by-Scene Greenness/Senescence for the most common Date Pair and NDVI Differencing Code** | Landsat 8 OLISentinel-2 MSIHarmonized Landsat 8/Sentinel-2 (HLS) | Takes two satellite images, one for peak greenness and one for peak senescence as the average for the entire study area and differences the two images to produce an NDVI difference map for the most common date pair. |
| **Pixel-by-Pixel Greenness/Senescence for the Most Common Date Pairs per Pixel and NDVI Differencing** | Landsat 8 OLISentinel-2 MSIHarmonized Landsat 8/Sentinel-2 (HLS) | Takes two satellite images from each pixel’s unique green up and senescence date and differences the two images’ NDVI values to create a difference map. |

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

The end results of the project will provide the partners with a method that analyzes satellite imagery to build a Pixel-by-Pixel raster map that provides the most accurate detection map of where cheatgrass could potentially reside during the growing seasons of 2021 and 2022. The R code that creates these raster maps will help end users better understand where cheatgrass resides on a year-to-year basis, allowing land managers to become more proactive in their cheatgrass management tactics. We have created a *read me* document for obtaining Harmonized Landsat 8 and Sentinel-2 imagery which increases imagery allotment across multiple satellites, which then allows for closer imagery to cheatgrass peak greenness and senescence dates.

**References**

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