**Colorado Ecological Forecasting**

*Monitoring Post-Fire Cheatgrass* (*Bromus Tectorum*) *Distribution to Inform Management Planning*

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**Project Overview**

***Project Synopsis:*** In the American West, cheatgrass (*Bromus tectorum)* is a growing concern due to its ability to outcompete local vegetation and exacerbate fire risk. This project, in partnership with the United States Forest Service (USFS), employed machine learning algorithms along with satellite-derived predictors to create habitat suitability and cheatgrass detection models across the area impacted by the Cameron Peak Fire in Colorado. Maps generated from these models, along with an associated technical report, will help partners manage invasive species to promote recovery of native vegetation in the fire-impacted areas.

***Abstract:***

Cheatgrass (Bromus tectorum) is a species of concern across the western United States as it has the potential to outcompete native plant species, reduce biodiversity, and diminish nutrient availability for ungulates. Furthermore, because cheatgrass can quickly dominate disturbed landscapes it has the potential to exacerbate wildfire risk by increasing fuel loads. In 2020, the Cameron Peak fire burned more than 200,000 acres on the Arapaho and Roosevelt National Forests in Colorado and is unique for two reasons: (1) it is Colorado’s largest fire on record and (2) it burned later into the year than is typical. These issues are of imminent concern for our partners at the Forest Service (USFS), as they are tasked with wildfire risk and invasive species mitigation and disturbances such as wildfires can substantially increase the rate and extent of cheatgrass spread. Current cheatgrass mitigation methods rely on field crews to physically locate cheatgrass on the landscape, which takes time, money, and extensive manpower. Here, we developed two Random Forest (RF) models within the Software for Assisted Habitat Modeling (SAHM) using remote sensing predictors one of suitable cheatgrass habitat and one to detect cheatgrass presence during the 2021 growing season. Maps derived from these models provide natural resource managers the ability to implement early detection and rapid response (EDRR) to prevent the spread of cheatgrass to new locations.

***Key Terms:*** Random Forest, remote sensing, SRTM, Sentinel-2, invasive, habitat suitability analysis, detection model

***National Application Areas Addressed:*** Ecological Forecasting, Disasters

***Study Location:*** Burn areas of Cameron Peak Fire, CO

***Study Period:*** March 2021 – June 2021

***Community Concerns:***

* Cheatgrass is an invasive species that has spread to over 101 million acres in the western United States; managing invasive species in the United States costs taxpayers 120 trillion dollars annually.
* Cheatgrass can create a positive feedback loop, increasing the frequency and severity of fires which pose a growing threat to local communities and ecosystem biodiversity.
* Cheatgrass outcompetes native vegetation and creates monocultures which decrease forage for wild and domesticated ungulates, causing ranchers to supplement livestock diet.

***Project Objectives:***

* Create cheatgrass detection model to aid in early detection and rapid response (EDRR) of burned and unburned areas
* Develop model to predict suitable cheatgrass habitat for future establishment and spread to inform monitoring strategies
* Design an interactive StoryMap as public-facing representation of this project

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, US Forest Service, Arapaho and Roosevelt National Forests and Pawnee National Grassland** | Tom Bates, Forest Plant Ecologist | End User | No |

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

Invasive species are often treated at the state or county level and given priority for management. In Larimer County, cheatgrass is a species that is recommended for management., but not required. Within the burned area, the Colorado Department of Agriculture has specified that treatment of Cheatgrass will be prioritized for monitoring and management. Currently, the USFS relies on ground data from field biologists and volunteers to locate and treat cheatgrass stands mechanically and chemically within the project area. Within the Arapaho and Roosevelt National Forest Noxious Weed Management Plan cheatgrass is considered a priority species and is to be treated mechanically, chemically, biologically, or with prescribed burns. But with the widespread nature of cheatgrass presents, it often becomes difficult to allocate money and resources to mitigation efforts. Fortunately, recent updates to treatment methods, such as the herbicide Indaziflam and rotational grazing, have made treatment options more practical at the large scale that needs to take place. The Arapaho and Roosevelt National Forest also follows an integrated weed management process (IWM) that helps minimize the spread of Invasive Species.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Sentinel-2 MSI** | Differenced Normalized Burn Ratio (dNBR), Relative Differenced Normalized Burn Ratio (RdNBR), Relativized Burn Ratio (RBR), Normalized Differenced Vegetation Index (NDVI), Modified Soil Adjusted Vegetation Index 2 (MSAVI2), Enhanced Vegetation Index (EVI), Normalized Differenced Wetness Index (NDWI), Tasseled Cap Brightness (TB), Tasseled Cap Greeness (TG), Tasseled Cap Wetness (TW) | This dataset provided the temporal (5 days) and spatial (20 m) resolution needed to derive spectral indices used to detect cheatgrass via phenological features, as well as burn-related indices used to develop the suitability model. |
| **SRTM** | Elevation, Northness, Eastness, Slope Northness, Slope Eastness, Topographic Diversity (TD), Continuous Heat Insolation Index (CHILI), Multi-Scale Topographic Position Index (mTPI), Landform | This dataset will provide the spatial (30 m) resolution needed to derive topographic variables to map cheatgrass occurrence in the suitability model. |

***Ancillary Datasets:***

* USDA, USFS field data – Spatial data providing locations of cheatgrass, abundance and co-occurring species at the site of the Cameron Peak Fire used to help train and evaluate detection and suitability models
* Natural Resource Ecology Laboratory Cameron Peak Fire shapefile – Shapefile used to delineate fire extents in analysis
* NASA DEVELOP Spring 2021 Colorado Front Range Disasters team burn severity raster for the Cameron Peak Fire – Predictor used for in the suitability model creation and analysis
* PRISM Monthly Spatial Climate Dataset – Raster data used to derive climatic variables (temperature and precipitation) to model cheatgrass occurrence
* US Census Bureau Tiger/Line Shapefiles 2019 – Shapefile of roads to derive dispersal corridors of cheatgrass
* Colorado Parks & Wildlife COTREX Dataset – Shapefile of trails throughout the study area used to derive dispersal corridors of cheatgrass

***Modeling:***

Comparative cheatgrass habitat suitability and detection modeling

* Random Forest (RF) (POC: Dr. Anthony Vorster, Colorado State University)
* Generalized Linear Model (GLM) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center)
* Boosted Regression Tree (BRT)

***Software & Scripting:***

* Esri ArcGIS Pro version 2.8.29751 – Image processing and end product generation
* Google Earth Engine Application Programming Interface (API) version 0.1.263 – Access to remotely sensed imagery and raster datasets, large-scale image analysis, and generation of modelling predictor variables
* RStudio version 1.4.1106 – Statistical analyses and data visualization
* Software for Assisted Habitat Modeling (SAHM) version 2.0.1 – Habitat suitability and detection model builder and map generation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Cheatgrass Occurrence Map** | Sentinel-2 MSI | These maps of cheatgrass locations within the study area will be a guiding resource to the partners to direct field resources for EDRR of invasive species, specifically cheatgrass. They will also provide an estimated scope of the problem. | N/A |
| **Cheatgrass Habitat Suitability Map** | Sentinel-2 MSI, SRTM | In addition to detection mapping of cheatgrass, it is important to identify where conditions might be suitable for cheatgrass before the species establishes. This cheatgrass suitability map will be a product the partner can use to target monitoring efforts each year to detect new populations early. | N/A |
| **Cheatgrass Occurrence Masked by Suitable Habitat** | Sentinel-2 MSI | Overlaying the cheatgrass detection map with the suitability map will highlight which regions of the suitability map are most likely to support cheatgrass populations. This will further help isolate areas for the partners to survey and treat if needed, saving valuable resources and time. | N/A |

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

The window to restore native plant communities post-fire is short due to the rapid colonization of invasive species such as cheatgrass, and this is especially true for large burn areas such as the Cameron Peak fire. Using this project's results, our partners will be able to make faster and more informed post-fire management decisions. Cheatgrass occurrence maps will provide support to focus on areas of the Cameron Peak Fire and similar fires to implement early detection and rapid response efforts to control the spread of invasive cheatgrass. As the landscape recovers, habitat suitability models will inform future monitoring efforts.

**References:**‌

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