**Medicine Bow Disasters**

*Utilizing Remote Sensing to Evaluate Herbicide Treatment Efficacy on Invasive Cheatgrass in Medicine Bow National Forest, Wyoming*

**Project Team**

***Project Team:***

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***Advisors & Mentors:***

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**Project Overview**

***Project Synopsis:*** This project used Landsat 8 Operational Land Imager (OLI) and Sentinel-2 MultiSpectral Instrument (MSI) imagery to provide partners at the US Forest Service with a 2019 probabilistic map of cheatgrass post-herbicide treatment and an analysis of treatment efficacy relative to non-treated areas. This project built off methods explored by the Fall 2015 Wyoming Ecological Forecasting DEVELOP team. The team provided partners with a technical report that described the methods and results that quantify the cheatgrass treatment effects and progression after the Squirrel Creek Fire to help inform future invasive species management efforts.

***Abstract:***

The Medicine Bow National Forest (MBNF) consists of approximately 1,383,790 acres of forested land, grassland, and sagebrush steppe in southeastern Wyoming. Cheatgrass (*Bromus tectorum*), an invasive plant species in the Western US, occurs in the grasslands throughout MBNF. Cheatgrass is known to rapidly colonize disturbed sites and dramatically alter historic fire regimes and nutrient/water dynamics as well as outcompete native plant species that are important forage for mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*). In 2012, the Squirrel Creek Fire burned approximately 10,587 acres of land within MBNF, exacerbating the spread of cheatgrass. In 2015, the Wyoming Ecological Forecasting DEVELOP team identified areas of high cheatgrass abundance within the fire boundary in order to guide US Forest Service (USFS) herbicide spraying efforts to reduce cheatgrass in 2016. This research used Landsat 8 Operational Land Imager (OLI) and Sentinel-2 MultiSpectral Instrument (MSI) data to create a 2019 probabilistic cheatgrass occurrence map. This map allowed an analysis of the effectiveness of aerial spraying to inform future land management techniques for the USFS. Based on the results of the Generalized Linear Model, we found that treated areas decreased in cheatgrass cover by 36% while untreated areas increased in cheatgrass cover by 6%, suggesting that herbicide treatment has been effective.

***Keywords:***

machine learning, Landsat 8 OLI, Sentinel-2 MSI, invasive species, Boosted Regression Tree, Multi-Adaptive Regression Splines, Random Forest, Generalized Linear Model

***National Application Areas Addressed:*** Disasters

***Study Location:*** Medicine Bow National Forest, WY

***Study Period:*** May 2019 to October 2019

***Community Concerns:***

* Cheatgrass (*Bromus tectorum*) is known throughout the Western US as a problematic invasive species that can alter hydrologic and nutrient regimes, outcompete native grasses, and increase fire continuity while thriving in post-burn areas.
* The 2012 Squirrel Creek Fire in Medicine Bow National Forest, located in southeastern Wyoming, burned approximately 10,587 acres of land leaving the area susceptible to cheatgrass encroachment.
* This area is critical winter ground for mule deer and elk and the invasion of cheatgrass significantly reduces the available forage for these species.
* In 2016, the USFS treated areas with 40% or more cheatgrass occurrence (nearly 3,000 acres) via aerial herbicide spraying. After treatment, there has been a small number of point-sample efforts to monitor treatment effectiveness; however, there is a need to map cheatgrass across the study area to gain a better understanding of how it is responding in 2019

***Project Objectives:***

* Generate a probabilistic cheatgrass occurrence map for 2019
* Analyze the effectiveness of aerial herbicide spraying on cheatgrass populations

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, US Forest Service, Laramie Ranger District of Medicine Bow-Routt National Forests and Thunder Basin National Grassland** | Jacquilyn Roaque, Range Specialist | End User | No |

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

Currently, the USFS is managing the impact of the Squirrel Creek Fire and subsequent cheatgrass encroachment through targeted aerial spraying of the herbicide Imazapic at a volume of 6 oz/acre in a 2,986-acre area. The USFS targeted these areas as a result of cheatgrass occurrence likelihood maps that the Fall 2015 Wyoming Ecological Forecasting DEVELOP team created using remotely sensed and *in situ* data. On August 10th, 2016, the USFS treated areas where there was a high likelihood of 40% or more of cheatgrass land cover within the Squirrel Creek Fire boundary. The USFS repeated treatment on August 16th, 2019, as treatment must be applied every three years for a total of nine years. After treatment, there have been a number of point-sample efforts to monitor treatment effectiveness to provide data for post-herbicide cheatgrass occurrence maps. These maps will help managers understand how cheatgrass is responding to treatments in subsequent years.

***Project Benefit to End User:***

Providing partners with the 2019 cheatgrass occurrence map and the analysis of cheatgrass treatment will show the effectiveness of the 2016 aerial herbicide treatment and the progression of cheatgrass thereafter. These products will help elucidate the benefit the USFS’s management actions have had on the landscape. Lastly, this project will help guide the ways land managers will respond to cheatgrass expansion in the future.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | Surface reflectance | Generated spectral features (NDVI, etc.) of field data for training/testing models. |
| **Sentinel-2 MSI** | Surface reflectance | Generated spectral features (NDVI, etc.) of field data for training/testing models. |

***Ancillary Datasets:***

* USFS & DEVELOP Cheatgrass *in situ* field samples from 2019 – Used to train models and validate modeling efforts
* Colorado State University (CSU) Natural Resource Ecology Laboratory (NREL) Squirrel Creek fire shapefile – Used to delineate fire extent in analysis
* USFS Imazapic spray boundary shapefile – Used to delineate treated areas from untreated areas in analysis
* CSU NREL Pre-treatment cheatgrass probabilistic occurrence map – Used to evaluate the effectiveness of treatment in analysis

***Modeling:***

* Random Forest (RF) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Probabilistic classification map of pixels with ≥40% cheatgrass cover
* Generalized Linear Model (GLM) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Probabilistic classification map of pixels with ≥40% cheatgrass cover
* Multi-Adaptive Regression Splines (MARS) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Probabilistic classification map of pixels with ≥40% cheatgrass cover
* Boosted Regression Tree (BRT) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Probabilistic classification map of pixels with ≥40% cheatgrass cover
* Software for Assisted Habitat Modeling (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – Model generation and comparison

***Software & Scripting:***

* Esri ArcGIS 10.7 – Image processing and map product generation
* QGIS 3.4.1 – Image processing and map product generation
* Python 3.6.7 – Statistical analyses and raster processing
* Google Earth Engine API – Large-scale image analysis

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **2019 Cheatgrass Probabilistic Occurrence Map** | Landsat 8 OLI  Sentinel-2 MSI | The partners used the map of 2019 cheatgrass occurrence to inform and visualize the analysis of cheatgrass treatment. | N/A |
| **Analysis of Cheatgrass Treatment** | Landsat 8 OLI  Sentinel-2 MSI | An analysis of how effective aerial spraying of cheatgrass was assessed by comparing treated and untreated cheatgrass polygons and the progression of those patches through time to evaluate the effectiveness of current management techniques. | N/A |

**Project Handoff Package**

***Transition Plan:*** During week 10 of the term, the team visited partners at the USFS in person to present results and address final partner questions. Partners at the USFS received a 2019 cheatgrass probabilistic occurrence map, an analysis of the effectiveness of aerial herbicide spraying, and a technical report via NASA Large File Transfer (LFT) at the end of the term.

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***Partner POC:*** Jacquilyn Roaque, jacquilyn.roaque@usda.gov

***Handoff Package:***

* 2019 Cheatgrass Probabilistic Occurrence Map
* Analysis of Cheatgrass Treatment
* Technical Paper

**References**

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