**Rocky Mountain Disasters**

*Using NASA Earth Observations to Monitor Post-Fire Vegetation Recovery in the Colorado Front Range*

**Project Team**

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**Project Overview**

***Project Synopsis:***

This project partnered with the US Forest Service Rocky Mountain Research Station to evaluate post-fire vegetation recovery in the Colorado Front Range using Landsat data. The team quantified post-fire spectral recovery trajectories, analyzed relationships between spectral recovery and measures of forest condition, modeled contemporary forest cover percentages, and modeled post-fire seedling regeneration. In addition, the team analyzed drivers of post-fire seedling regeneration including topography, climate, fire, and soils. These products will help guide and define expectations for post-fire watershed recovery and forest restoration.

***Abstract:***

Forest composition and structure in the Colorado Front Range has been altered by changing wildfire regimes. In particular, increased moderate- and high-severity fire significantly reduces forest cover following fire and often results in reduced seedling regeneration. Reduced tree canopy regrowth has chronic effects on upland ecological function and downstream water quality. This project partnered with the US Forest Service to estimate long-term vegetation recovery following four Colorado Front Range fires between 1996 and 2002—the Bobcat, Buffalo Creek, Hayman, and High Meadows fires—using Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+), and Landsat 8 Operational Land Imager (OLI). The random forest algorithm was applied to produce maps of percent forest canopy cover for coniferous trees, deciduous trees, and all trees using time-series variables for pre- and post-fire as inputs. Similarly, maps of post-fire seedling regeneration were produced using random forest for coniferous trees, deciduous trees, and all trees using ecological drivers (soil, climate, fire, and topography) and pre-fire remote sensing predictors. Relationships between ecological drivers of post-fire vegetation trajectories were also evaluated. Additional analyses were conducted to (1) assess whether seedlings could be detected by Landsat or synthetic aperture radar (SAR) time-series analysis (2) assess pre-fire and post-fire Landsat variables against pre-fire and post-fire tree cover estimates to evaluate whether magnitude of forest change can be detected. Understanding variables that influence vegetative recovery, vegetation type conversion, and watershed characteristics will aid forest restoration efforts and water quality management.

***Key Terms:***

remote sensing, Landsat 8 OLI, Landsat 5 TM, Landsat 7 ETM+, wildfire, vegetation recovery, Random Forest, LandTrendr

***National Application Area Addressed:*** Disasters

***Study Location:*** Colorado Front Range

***Study Period:*** 1996 to 2019 (May to October)

***Community Concerns:***

* Communities within the boundaries of the catastrophic Bobcat Gulch (2000), Buffalo Creek (1996), Hayman (2002), and High Meadows (2000) fires along the Colorado Front Range have experienced multiple impacts and are facing a future with increased fire frequency and severity.
* Fires have direct impacts on infrastructure and local economies. For instance, the Hayman fire destroyed 600 structures, including 132 residences.
* Wildfires result in long-lasting forest ecosystem impacts, such as reduced forest cover and heterogeneity, reduced forest regeneration, and poor post-fire water quality from increased nutrient and sediment loads.

***Project Objectives:***

* Apply remotely sensed data to quantify spectral recovery and detect post-fire tree canopy cover
* Model suitability for post-fire tree seedling regeneration and evaluate spatial ecological drivers

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, US Forest Service, Rocky Mountain Research Station** | Dr. Charles Rhoades, Research Biogeochemist | End User | Yes |

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

The end user has extensive experience conducting field studies to measure burn severity, forest recovery, and watershed response. Field-based studies have been limited to transect and watershed scales after individual fires. Burn severity is typically mapped by the end user immediately post-fire using a combination of remote sensing and field observations. While these maps are useful in guiding more immediate soil erosion mitigation, they are not intended to capture long-term ecosystem response. Commonly used sensors like the Landsat series and LiDAR are effective in determining wildfire predictor and response variables over a large spatial-temporal scale. Additionally, remote sensing techniques can reduce field costs and improve site accessibility

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Surface reflectance, spectral vegetation indices | Time-series rasters derived from Landsat 5 data were used to track long-term post-fire vegetation recovery using a time series of surface reflectance and calculated spectral vegetation indices. |
| **Landsat 7 ETM+** | Surface reflectance, spectral vegetation indices | Time-series rasters derived from Landsat 7 data were used to track long-term post-fire vegetation recovery using a time series of surface reflectance and calculated spectral vegetation indices. |
| **Landsat 8 OLI** | Surface reflectance, spectral vegetation indices | Time-series rasters derived from Landsat 8 data were used to track long-term post-fire vegetation recovery using a time series of surface reflectance and calculated spectral vegetation indices. |
| **ALOS-2 PALSAR-2** | HV polarization band | Synthetic aperture radar (SAR) L-band data were used for characterizing post-fire vegetation structure. |
| **Sentinel-1 C-SAR** | VH polarization band | SAR C-band data were used for characterizing post-fire vegetation structure. |

***Ancillary Datasets:***

* USDA and United States Geological Survey (USGS) Monitoring Trends in Burn Severity, Burn Severity Maps – Assess initial burn severity as measured immediately post-fire
* Oak Ridge National Laboratory DayMet V3: Daily Surface Weather and Climatological Summaries – Calculate 30-year climate means and annual values for ecologically-relevant variables
* Duke University and USGS POLARIS Soil Properties rasters – Interpolate the Soil Survey Geographic Database (SSURGO) and State Soil Geographic Database (STATSGO) data to estimate soils variables like fractional sand, silt, and clay, soil moisture capacity, and others
* USGS National Elevation Dataset – Derive topographic variables such as slope and aspect which were used for modeling
* Conservation Science Partners (CSP) Ecologically Relevant Geomorphology (ERGo) dataset – Topographic variables such as heat load index and landform which were used for modeling
* US Forest Service Rocky Mountain Research Station, vegetation inventory field data – Vegetation inventory data to evaluate accuracy of vegetation recovery maps
* Google Earth imagery – Contemporary and historical imagery used to estimate tree canopy cover and regeneration prior to and following fires
* Pike San Isabel National Forest, Forest Restoration Areas – GIS data of tree planting after the Hayman fire used for the analysis of vegetation recovery patterns

***Modeling:***

* Random Forest (POC: Dr. Tony Vorster, Colorado State University) – Algorithm was used to model relationships between post-fire recovery and topography, land cover, forest restoration areas, initial burn severity, and burn severity patch size
* LandTrendr (POC: Dr. Tony Vorster, Colorado State University) – Algorithm was used to obtain post-disturbance recovery information

***Software & Scripting:***

* Google Earth Engine – View, filter, derive and export satellite imagery for analysis
* R Statistical Software – Organize and filter data and run random forest model
* Esri ArcGIS – Visualize model results, created map products
* Google Earth Pro – Collect pre-fire and post-fire training data

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Long-Term**  **Vegetation Raster Layers** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | These raster layers characterized spectral recovery in burned areas. This approach complements already-produced burn severity maps that evaluate impacts immediately after fires. | N/A |
| **Analysis of**  **Vegetation Recovery**  **Patterns** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | Partners and other decision makers will utilize field observations and initial burn severity maps to study post-fire vegetation recovery and associated water quality impacts. We evaluated the relationships between fire and vegetation at larger scales and across multiple fires. | N/A |
| **Maps of Post-Fire Tree Cover Percentage** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI  Sentinel-1 C-SAR  ALOS-2 PALSAR-2 | These maps of percentage cover of coniferous, deciduous, and all trees provide valuable spatially continuous data to partners for further watershed and forest condition analysis. | N/A |
| **Maps of Post-Fire Seedling Regeneration Probability** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | Partners and forest managers were interested in drivers of post-fire conifer, deciduous tree, and all tree regeneration. In the process of mapping regeneration probability, the team provided valuable information about environmental drivers of regeneration. | N/A |

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

Post-fire vegetation recovery maps and model-derived indications of which drivers influence wildfire patterns can provide large-scale insight into the smaller-scale work our partners have executed. Additionally, the proposed products can help adapt and target late-stage restoration treatments by evaluating the effectiveness of past restoration treatments and identifying critical areas with poor vegetation recovery.

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