**Gila Water Resources III**

Modeling the Impacts of Post-fire Restoration Methods on Vegetation Recovery in the Gila National Forest

**Project Team**

***Project Team:***

Henry Grover (Project Lead)

Ebony Williams

Darby Levin

Tyler Pantle

***Advisors & Mentors:***

Dr. John Bolten (NASA Goddard Space Flight Center)

Keith Weber (GIS Training and Research Center, Idaho State University)

Dr. Raha Hakimdavar (United States Forest Service)

***Past or Other Contributors:***

Terra Edenhart-Pepe

Abigail Barenblitt

Ariege Besson

Carli Merrick

Alia Giolitti

Madeline Allen

Sarah Hafer

***Team POC:*** Henry Grover, henrygrover@nau.edu

***Software Release POC:*** Tyler Pantle, tpantle13@gmail.com

***Partner POC:*** Carolyn Koury, carolyn.koury@usda.gov

**Project Overview**

***Project Synopsis:***

In recent years, the Gila National Forest (NF) in New Mexico has experienced an increasing frequency and scale of severe wildfires. These fires have dramatically altered the land cover and hydrology in the NF, often threatening human life, property, and critical natural and cultural resources. Research conducted by the Gila Water Resources I and II teams demonstrated the importance of post-fire vegetation regrowth for mitigating these threats. This project modeled vegetation recovery after the Silver Fire (2013) and created a proof-of-concept decision-support tool to help Burned Area Emergency Response (BAER) teams predict vegetation recovery in the Gila NF based on the restoration method used.

***Abstract:***
In recent years, wildfires in New Mexico’s Gila National Forest have become increasingly common and more severe. Wildfires can have powerful impacts on hydrology and soil stability, including erosion, flooding, and debris-flows that threaten lives and infrastructure downstream. Vegetation restoration treatments like seeding and mulching can mitigate these effects and facilitate ecosystem recovery. Understanding the effectiveness of various restoration methods is vital to planning a cost-effective and successful post-fire recovery strategy. The immediate response to a fire on US Forest Service land is coordinated by a Burned Area Emergency Response (BAER) team, a group responsible for mitigating immediate post-fire risks to human life, property, and critical natural and cultural resources. This study created a proof-of-concept methodology for a decision-support tool designed to help BAER teams identify the restoration treatments most likely to succeed in a given burned area. Leveraging random forest regression, Google Earth Engine, and Landsat 7 and 8 Earth observations, this study modeled vegetation recovery after the 2013 Silver Fire for seeded areas, seeded/mulched areas, and untreated areas. Treatment type and initial burn severity were the largest drivers of vegetation recovery across the landscape. Seeded/mulched areas showed higher recovery levels than untreated areas three months post-fire, but by four years post-fire, treated and untreated areas displayed similar recovery levels. To produce a robust predictive tool for the Gila National Forest, the model should be trained on many more fires and incorporate post-fire weather conditions into the process. Such a model will help partners ensure efficient resource use and plan effective post-fire restoration strategies.

***Key Terms:***

Wildfire, vegetation recovery, random forest regression, remote sensing, BAER teams, Landsat, Difference Normalized Burn Ratio, aerial seeding

***National Application Areas Addressed:*** Water Resources, Disasters

***Study Location:*** Gila National Forest, NM

***Study Period:*** 2013 – 2017

***Community Concerns:***

* Wildfire events can cause long-lasting ecological impacts, including vegetation loss, soil erosion, sediment transport, flash flooding, and debris flows. These often threaten human life, infrastructure, property, and natural and cultural resources downstream.
* The US Forest Service (USFS) Gila NF’s goal is to increase canopy and vegetative ground cover, while implementing post-wildfire recovery strategies as efficiently as possible. However, the effectiveness of different post-fire treatments is not clear across different landscape types in the Gila NF.
* Current monitoring of post-fire treatment methods only lasts three years, due to the USFS budget and protocol. Advanced understanding of mid- and long-term ecosystem recovery trajectories is needed for decision making on vegetative recovery.

***Project Objectives:***

* Utilize Earth observation data to assess the efficacy of several post-fire treatment methods targeting vegetation recovery
* Produce random forest model and model outputs that will predict the likelihood of vegetation recovery given different treatment methods and predictor variables; this model will also allow partners to better interpret the impacts of post-fire treatments both immediately and four years after a wildfire
* Create static maps of vegetation recovery that display projected difference Normalized Burn Ratio (dNBR) values for each treatment, which will extend beyond the three-year monitoring period currently in place by BAER teams
* Develop a proof of concept for modeling the effects of post-fire recovery treatments which could be replicated by the partners for further use

***Previous Terms:***

2019 Fall (GSFC) – Gila Water Resources

2020 Spring (GSFC) – Gila Water Resources II

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, US Forest Service, Gila National Forest** | Carolyn Koury, Hydrologist; Mike Natharius, Soil Scientist; Nessa Natharius, Soil Scientist/Ecologist | End User | No |
| **USDA, US Forest Service, Region 3** | Jack Triepke, Regional Ecologist; Bart Matthews, Photogrammetry Program Specialist; Anna Jaramillo, Regional Watershed Improvement Program and Burned Area Emergency Response Coordinator | End User | Yes |

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

The USFS Gila NF and Region 3 teams use expert knowledge, literature, and *in situ* data to conduct post-fire condition assessments. Treatment decisions are then made based on guidance from BAER teams relying on field data, remotely sensed burn severity data, institutional knowledge, and models. BAER teams determine critical values and model potential risks to them. Using inputs such as hillslope features and rainfall intensity, BAER teams predict the extent and risk of post-fire flooding and erosion. Treatments are then recommended to reduce those risks and a cost-benefit analysis is performed to justify those treatments. Watershed management efforts also rely heavily on fieldwork and expert knowledge, as well as some remote sensing data. The USFS Gila NF and Region 3 teams have used Landsat products provided by the regional office in conjunction with field data for both vegetation monitoring and watershed management. The USFS Gila NF and BAER teams do not currently use Earth observations or remote sensing decision-support tools to assess post-fire recovery, but they see a great opportunity to do so, especially to develop decision-making practices aimed at long-term recovery.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 7 ETM+** | Surface reflectance | Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data were used to identify the change in vegetation presence. The difference Normalized Burn Ratio (dNBR) was calculated and used as a proxy for changes in vegetation and soil condition. |
| **Landsat 8 OLI** | Surface reflectance | Landsat 8 Operational Land Imager (OLI) data were used to calculate vegetation health and recovery indices such as dNBR in order to characterize vegetation recovery post-fire. |

***Ancillary Datasets:***

* USGS National Elevation Dataset (NED) – Model predictor to determine the elevation and slope within the Gila NF
* USFS Terrestrial Ecological Unit Inventory (TEUI) – Description and interpretation of ecological types within the Gila NF; used to create a predictor of soil order and one of percent cover of vegetation that can resprout after a fire
* USFS Remote Sensing Applications Center (RSAC) Soil Burn Severity (SBS) Maps – Model predictor to find moderate and severely burned areas within the fire perimeter
* Conservation Science Partners Continuous Heat-Insolation Load Index (CHILI) – Model predictor to determine the impact of sun intensity on different hillslopes
* Landscape Fire and Resource Management Planning Tools (LANDFIRE) Vegetation Data – Model predictor to determine the impact of pre-fire vegetation cover
* USFS Burned Area Emergency Response (BAER) Treatment Dataset – Vegetation recovery within the treatment area for the Silver Fire (2013) compared to vegetation recovery within the control area to evaluate the effectiveness of restoration efforts
* NOAA Palmer Drought Severity Index (PDSI) – Select post-fire time frames for model predictions and contextualize model results in terms of post-fire weather conditions

***Modeling:***

* Random Forest Regression, Google Earth Engine (POC: Tyler Pantle) – Create multiple models of vegetation recovery based on restoration methods and burn severity in the Gila NF

***Software & Scripting:***

* Google Earth Engine – This platform was used to view, filter, and process data from Landsat and NED. It was also used to create the regression model.
* R 4.0.03 – This software was used for statistical data analysis and visualization
* Esri ArcGIS Online – This software was used to create the StoryMap

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Southwestern Post-fire Regrowth Observational Understanding Tool (SPROUT)** | Landsat 7 ETM+Landsat 8 OLI | This tool will allow BAER assessment teams on the Silver Fire to better understand the long-term impacts of post-fire seeding and mulching treatments on vegetation recovery which they do not currently have a way of assessing. | IV |
| **Graphs of Post-fire Recovery Drivers**  | Landsat 7 ETM+Landsat 8 OLI | This static output describes the major landscape-scale drivers of post-fire recovery on the Silver Fire. | I |
| **Map of predicted dNBR of treatments** | Landsat 7 ETM+Landsat 8 OLI | This map allows the USFS Gila NF to explore the impacts of each treatment type on the vegetation recovery after the Silver Fire. | I |
| **Graph of Palmer Drought Severity Index (PDSI)** | N/A | Temperature and precipitation data incorporated in the index will provide context to the USFS Gila NF to interpret the model predictions at different post-treatment time points. | I |
| **ArcGIS Online StoryMap**  | Landsat 7 ETM+Landsat 8 OLI | The project StoryMap will help the USFS Gila NF explain the process of post-fire recovery to forest users through an easily sharable format. | I |

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

A predictive model will allow BAER teams to better understand how restoration treatments affect post-fire recovery. This model serves as a proof-of-concept tool and will assist the USFS Gila NF in locating burn severities, elevations, and pre-fire vegetation conditions that are likely to recover naturally and ones where treatment interventions are justified. By using NASA Earth observations, we can increase both the spatial and temporal extent of post-fire monitoring, which is currently limited to on-the-ground vegetation surveys for up to three years post-fire. This tool augments *in situ* data, assisting BAER teams in monitoring post-fire recovery. Additionally, this model has the potential to be scaled beyond the Gila National Forest. The USFS could make vegetation recovery predictions throughout the Gila NF, or greater Southwest region, by training the model on additional data from other fires. In our model workflow, we stratified the landscape by locations where we expected different recovery trajectories and identified control areas comparable with known treatment areas. This methodology and shapefiles could be useful products when the USFS Gila NF is creating post-fire treatment monitoring survey locations for future fires. These products allow the USFS Gila NF to make more informed and targeted treatment decisions, increasing cost and implementation efficiency.

**References**

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