Spring 2020 Project Summary

Gila Water Resources II
Using Earth Observations to Identify Wildfire Impacts on Hydrologic Functions and Recovery in the Gila National Forest

VPS Title: Fire and the Flood: Watershed Response to Wildfire in Gila National Forest

Project Team

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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 wildfires have caused drastic changes in stream flow, stream morphology, water quality, vegetation cover, soil moisture, and ecological communities within the semi-arid national forest. This study used NASA Earth observation (EO) sensors from the Landsat and Global Precipitation Measurement missions to assess watershed recovery within the Gila NF following wildfires from 2000 to 2020. The team provided the United States Forest Service Gila National Forest with maps, analyses, and tools that inform future management practices and restoration efforts.

Abstract:
Wildfires have the potential to cause devastating and long-lasting impacts on ecological systems. In the Gila National Forest (Gila NF), wildfire events have occurred with increasing frequency and severity over recent years. These disturbances, such as the historic Whitewater Baldy Complex Fire (2012) and Silver Fire (2013), have raised concerns over post-fire flooding, debris flows, and vegetation recovery. Understanding connections between burn events and ecological functions is crucial for developing effective land management practices within the Gila NF that ensure conservation of the watershed. The Gila Water Resources II team worked in partnership with the US Department of Agriculture (USDA) US Forest Service's (USFS) Gila National Forest and Region 3. This project provided insight into the influence of wildfires on increased flooding events and determined if restoration efforts in the Gila NF are having a beneficial impact on vegetation regeneration. To understand recovery trends and hydrologic impact in the Gila NF between 2000-2019, this project used Landsat 5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper Plus, Landsat 8 Operational Land Imager, Global Precipitation Measurement Integrated Multi-satellite Retrievals for GPM precipitation, along with ancillary data from USGS stream gauges and data provided by USDA USFS's Gila National Forest and Region 3. Based on these data, the team identified burn areas that received restorative treatments and compared Normalized Burn Ratio for different land cover types

to better inform land management decisions. Additionally, the team analyzed the relationship between precipitation and streamflow from stream gauges to investigate the impact wildfires have on hydrology within the watershed.

Keywords:
hydrology, watershed, post-fire recovery, wildfire, vegetation, Landsat, Normalized Burn Ratio (NBR), New Mexico

National Application Areas Addressed: Water Resources
Study Location: Gila National Forest, NM
Study Period: September 2000 to January 2020

Community Concerns:

- Wildfire events are correlated with other ecological changes, including vegetation loss, soil erosion, flooding, sedimentation, and debris flows.
- These ecological changes in upstream ecosystems can result in reduced water quality and increased streamflow and sedimentation downstream.
- Wildfire disturbances drive change in the Gila NF and can negatively influence ecosystem function and provision of goods and services, such as access to clean water for communities downstream.
- Recovery efforts, such as seeding an area of land, can be negatively impacted by the interrelated ecological responses to disturbances, like post-fire flooding. Without knowledge of the watershed-level wildfire impacts, forest managers are limited in their ability to plan effective restoration efforts and prepare for these impacts.

Project Objectives:

- Examine the influence of restoration efforts, land cover, elevation, and initial burn severity on Normalized Burn Ratio results and vegetation recovery post-wildfire
- Compare the efficacy of different recovery methods implemented by the US Department of Agriculture (USDA) US Forest Service's (USFS) Gila National Forest through examining treated and untreated burn areas
- Inspect the hydrological impacts of several New Mexico fires including Dry Lake 2003, Bear 2006, Wallow 2011, Miller 2011, Whitewater Baldy 2012, and Silver Fires 2013
- Produce research that can inform restoration efforts, specifically aimed to answer when to begin land and stream restoration post-wildfire

Previous Term: 2019 Fall (GSFC) – Gila Water Resources

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	End User	Yes
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; Kathleen Hawkos, GIS Specialist	End User	Yes

Decision-Making Practices & Policies:
The USFS Gila National Forest has used Landsat data provided by the USFS Region 3 office and US Geological Survey (USGS) data for vegetation mapping and other natural resource analyses and inventory. On a national level, the US Forest Service also has a host of analysts and cartographers, mapping and cataloging fire disturbances and restoration areas. The USDA USFS Gila National Forest and Region 3 are especially interested in making cost-effective decisions related to ecosystem and stream restoration following burn events and accumulating documentation to track potential patterns related to the increasing rates of wildfire occurrence. Most condition assessments and land management decision-making practices at the present are site-specific and informed by local knowledge, observational survey, and some *in situ* restoration monitoring and data collection. While the USFS Gila National Forest and Region 3 have several methods for documenting immediate landscape changes following wildfires, relatively few operational tools are in place to look at medium to long-term recovery. The USFS Gila National Forest also lacks a method for estimating recovery at the watershed scale and identifying differences in recovery based on treatments or land cover types.

Project Benefit to End User:
Tools that enable more informed decision-making at the watershed scale will allow for more effective land management and planning, such as vegetation and stream restoration within the Gila NF. These efforts benefit both the forest and downstream users. The USFS Gila National Forest can use this project's resulting recovery maps and spatial analysis to identify recovery trends across different land cover types and treatment areas along with fire-related hydrologic impacts on the sub-watershed scale. With these results, inferences may be made about the efficacy of seeding, mulching, and other restoration practices. Understanding some of the factors that significantly impact recovery will allow managers to proactively manage or plan mitigation efforts. Moreover, recognizing the complex interactions between wildfire burns, streamflow, and precipitation among other factors in semi-arid regions like the Gila NF will give our partners a grasp on how these variables relate and enable them to continue investigating the impacts independently.

Earth Observations & End Products Overview

Earth Observations:

Platform & Sensor	**Parameters**	**Use**
Landsat 5 TM	Surface reflectance	Landsat 5 TM data were used to identify the change in historical vegetation presence at the watershed scale. The Normalized Burn Ratio (NBR) was calculated and used as a proxy for changes in vegetation and soil condition.
Landsat 7 ETM+	Surface reflectance	Landsat 7 ETM+ data were used to identify the change in historical vegetation presence at the watershed scale. The NBR was calculated and used as a proxy for changes in vegetation and soil condition.
Landsat 8 OLI	Surface reflectance	Landsat 8 OLI data were used to identify the change in historical vegetation presence at the watershed scale. The NBR was calculated and used as a proxy for changes in vegetation and soil condition.
GPM IMERG	Precipitation	The Integrated Multi-satellite Retrievals for GPM (IMERG) product from Global Precipitation Measurement (GPM) mission was used alongside stream discharge data to identify the hydrologic impacts of wildfire.

Ancillary Datasets:

- USGS National Land Cover Database (NLCD) Land Cover Collection – Shapefiles used to isolate different land cover classifications in the Gila NF in order to better understand vegetation recovery trends and select control plots to compare with the restoration treatment plots
- USGS Digital Elevation Model (DEM) – Elevation data were used to determine the flow direction, flow accumulation, and boundaries of the sub-watersheds of interest
- USGS National Water Information System – Twenty years of stream gauge data used in conjunction with precipitation data to analyze the hydrologic impact of wildfire disruption on the sub-watershed scale
- USFS Terrestrial Ecological Unit Inventory (TEUI) – Description, classification mapping, and interpretation of ecological types used in conjunction with the NLCD Land Cover Collection to isolate land cover types and areas within the Gila NF for vegetation recovery analyses
- USFS Monitoring Trends in Burn Severity Data (MTBS) – Used burn severity data as a variable when selecting control areas to examine the impact of restoration efforts
- USFS Burned Area Emergency Response (BAER) Treatment Dataset – The vegetation recovery within the treatment areas for the Bear Fire (2006), Silver Fire (2012), and Whitewater Baldy Fire (2013) were compared to vegetation recovery within control areas in order to evaluate the effectiveness of restoration efforts

Software & Scripting:

- Google Earth Engine API – Large-scale image processing and analysis, land cover classification, platform creation
- Esri ArcMap 10.7.1 – Map creation, watershed delineation, and imagery analysis for land cover, burn severity, and vegetation regrowth comparisons
- RStudio 1.2.5033-1 – Statistical computing and graphics for the dissemination of results related to vegetation regrowth

End Products:

End Products	Earth Observations Used	Partner Benefit & Use	Software Release Category
Graph Visualizations Displaying the Difference in Vegetation Regrowth Between Treated and Untreated Areas	Landsat 8 OLI Landsat 7 ETM+ Landsat 5 TM	Partners can use this graph to understand the impacts of restoration efforts by USFS Gila National Forest post-wildfire. Together with the map visualization this will be used to inform future management decisions	I
Map Visualization Displaying Change Detection Analysis Between Treated and Untreated Areas	Landsat 8 OLI Landsat 7 ETM+ Landsat 5 TM	Partners can use this map to supplement the graph visualization to inform future management decisions concerning post-fire restoration actions	I
Map Visualizations and Step-by-Step Methodology	N/A	Partners can use the map as a visual aid to understand the methodology behind control plot selection. Additionally, this	n/a

Displaying Selection Process of Control Areas for Treatment Comparison Analyses		will provide a methodology for any future treatment comparison analyses.	
Graph Visualizations Identifying Patterns in Post-Fire Streamflow	GPM-IMERG	Partners can utilize this graph to inform restoration efforts by USFS Gila National Forest in riparian areas and understand the effects of wildfires on flooding in the watershed.	I
Geospatial Repository of all Shapefiles, Raster Classes, and Feature Classes Related to ArcMap Analyses	N/A	Partners can utilize this repository as a foundation for future analyses concerning specific fires, land cover types, burn severity, etc.	n/a

Project Handoff Package

Transition Plan: The team presented the Gila Water Resources II project virtually to a WebEx audience including representatives from partner organizations and other stakeholders. Team members presented the project video and results. Other data and deliverables were transferred to partners via online file sharing.

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Handoff Package:

- Project Summary
- Technical Paper
- Poster
- Presentation
- Project video
- Study Area Shapefile
- Graph Visualizations Displaying the Difference in Vegetation Regrowth Between Treated and Untreated Areas
- Map Visualization Displaying Change Detection Analysis Between Treated and Untreated Areas
- Graph Visualizations Identifying Patterns in Post-Fire Streamflow
- Map Visualizations and Step-by-Step Methodology Displaying Selection Process of Control Areas for Treatment Comparison Analyses
- Geospatial Repository of all Shapefiles, Raster Classes, and Feature Classes Related to ArcMap Analyses

References

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