NASA DEVELOP National Program

**2020 Fall Project Proposal**

**Maryland – Goddard**

**Gila Water Resources III**

*Modeling Short-Term Impacts of Wildfire Restoration Methods on the Vegetation Recovery and Hydrologic Processes in Gila National Forest*

**Project Overview**

***Project Synopsis*:** Recent wildfires in New Mexico’s Gila National Forest (Gila NF) have significantly affected the landscape and stream dynamics in several watersheds. Studies of post-fire hydrology and erosion have shown that the first several years following a burn is the most critical period for the risks associated with high runoff and erosion. Building off of previous terms that investigated the relationship between wildfire events and flashiness of watersheds in the Gila NF, this project will quantify the success of vegetation recovery treatment methods. Using Terra MODIS, Suomi NPP VIIRS, Landsat 8 OLI, SMAP, and data from the Western Land Data Assimilation System (WLDAS), this project will build a decision-support tool which will employ a regression model to predict vegetation recovery for different restoration methods for a given set of environmental conditions. This will allow the partners to quantify the value and benefit of reseeding and mulching efforts in previously burned and high-risk areas of the watershed as well as empower them to make informed decisions for maximizing the impact of restoration work.

***Community Concern:*** The Gila NF Whitewater-Baldy Complex Fire of 2012 was the largest wildfire in New Mexico state history. US Forest Service (USFS) land managers and scientists expect that extreme events, such as the wildfires that occurred in 2012 and 2013, will become a more common occurrence in national forests across the country, including the Gila NF.y. This growing concern is reflected in the shift of USFS resource allocation. In 1995, approximately 16% of the USFS budget went towards fire prevention and recovery, but by 2016 over 50% of the budget was spent on fire mitigation efforts. For the Gila NF staff, how best to spend those fire resources is in question. While the restoration team uses several methods for restoring vegetation post-fire, the comparative success of these methods is unknown. Forest land managers could benefit from a tool that allows them to better understand the likelihood of vegetation regrowth after a major fire for each restoration technique they use. This will enable them to use available resources more efficiently to encourage healthy regrowth of the forest.

***Source of Project Idea:*** This project is part of a 2017 request by Dr. Raha Hakimdavar, a hydrologist at the USFS’s Washington Office, who was previously on detail at the NASA Goddard Space Flight Center. The Maryland – Goddard Lead Science Advisor, Dr. Bolten, continued to support the proposal after increased collaboration between NASA and USFS focused on NASA satellite applications for forest management and planning. During the second term of the DEVELOP project, the USFS Gila NF team expressed interest in understanding recovery rates for restoration methods and exploring the utility of WLDAS for hydrological impacts from the Gila fires.

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

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

***Study Period:*** September 2001 – January 2020

***Advisors:*** Dr. Sebastian Martinuzzi (University of Wisconsin – Madison), John Bolten (NASA Goddard Space Flight Center), Dr. Raha Hakimdavar (USFS)

**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 |

***End User Overview***

***End User’s Current Decision-Making Process:***The USFS Gila NF and Region 3 have used Landsat data provided by the regional office for vegetation mapping and other purposes for natural resource analysis and inventory. More recently, high-resolution aerial imagery was made available to the USFS Gila NF office by their colleagues at Region 3. Otherwise, condition assessments are carried out using expert knowledge, ground surveys, and existing environmental data collected in the forest. Currently, the USFS Gila NF Burned Area Emergency Response (BAER) team uses data collected on the ground as well as institutional knowledge to inform decisions for which restoration method to implement after a fire. They do not currently use Earth observations in these decisions, but they see a great opportunity to do so.

***End User’s Capacity to Use NASA Earth Observations:***

*USDA, US Forest Service, Gila National Forest* – Partnering with USFS Geospatial Technology and Applications Center (GTAC) has allowed the Gila NF staff to utilize remote sensing with advanced techniques to address challenging problems. Land managers for the forest do not have a remote sensing expert, but they do have a GIS analyst. Previous DEVELOP terms have bolstered the USFS Gila NF staff’s understanding of the capabilities of NASA Earth observations.

*USDA, US Forest Service, Region 3 –* USFS Region 3, which provides support to management efforts in the Gila NF, has a Photogrammetry Program Specialist. The region can provide technical support for the USFS Gila NF staff, but would also benefit from the outcomes of this project, as they could potentially scale the project in the Gila NF to other forests in the region.

***Collaborator & Boundary Organization Overview***.

***Dissemination by Boundary Organizations*:**

*USDA, US Forest Service, Region 3 –* The region is actively engaged with private and public partners, including regional universities and the GTAC, to develop and disseminate scientific information for purposes of scientific discovery and delivery. Region 3 would help to share the results from this project with other national forests located in the region, which includes 11 different national forests, through existing channels of communication.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** Weekly email updates and biweekly teleconference calls will be conducted throughout the course of the term. The Project Lead will serve as the main point of contact for communication with the project partners and advisors.

***Transition Plan*:** During week 10, end products and deliverables will be transitioned via virtual handoff to discuss results. A folder including all relevant results, data, and deliverables will be shared once the deliverables undergo NASA’s export control process.

**Earth Observations Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **SMAP** | Vegetative Optical Depth (VOD) | SMAP VOD will be tested as a vegetation index characterizing vegetation recovery post-fire. |
| **Suomi NPP VIIRS** | Active Fire | The Active Fire dataset will be used to highlight past fire areas. |
| **Landsat 8 OLI** | Normalized Burn Ratio (NBR), vegetation indices  | Landsat 8 OLI data will be used to calculate NBR and other vegetation indices to characterize vegetation recovery post-fire.  |
| **Landsat 8 TIRS** | Land Surface Temperature | Land surface temperature will be used as an environmental variable in the model. |
| **Terra MODIS** | Leaf Area Index (LAI), Evapotranspiration, Active Fire | The MOD16 LAI data product will be used to characterize vegetation recovery post-fire. Evapotranspiration will be used as an environmental variable in the model. The MODIS Active Fire dataset will be used to highlight past fire areas. |
| **GPM IMERG** | Precipitation | GPM IMERG precipitation will be used as an environmental variable in the model. |
| **SRTM** | Elevation, Slope, Aspect | The SRTM digital elevation model will be used to calculate environmental variables for the team’s model. |

***Ancillary Datasets:***

* NASA Western Water Applications Office (WWAO) High Resolution Soil Moisture– SMAP-based soil moisture
* NASA WWAO Land Data Assimilation System (WLDAS) Mosaic Precipitation, Soils, Surface Water – Environmental Predictor Variables Data (i.e. soil moisture and ET) for riparian mapping
* USGS National Elevation Dataset (NED) – Digital Elevation Model for riparian mapping
* USGS LANDFIRE Existing Vegetation Type (EVT) – Land Cover Classification for riparian mapping
* USGS National Water Information System – Historical and current water data, including *in situ* streamflow and groundwater measurements
* USFS LiDAR-based Digital Elevation Data – Digital Elevation Model for riparian mapping
* USFS Riparian Delineation Dataset – Comparison of riparian area to classified remotely sensed imagery
* USFS Terrestrial Ecological Unit Inventory – Description, classification mapping, and interpretation of ecological types
* USFS Historical Aerial Imagery/Orthophotography of Gila National Forest – Supplementation of remotely sensed datasets
* USDA National Agriculture Imagery Program (NAIP) – Aerial imagery for validation of riparian mapping
* PRISM (Parameter-elevation Regressions on Independent Slopes Model) Climate Data – Topographically corrected US rainfall data products for change analysis
* Monitoring Trends in Burn Severity (MBTS) Data – Comparison maps and inputs of burn severity and fire extent
* Natural Resources Conservation Service (NRCS) SNOTEL (Snow Telemetry) Precipitation Data – Supplementation and comparison of precipitation datasets for change analysis
* NRCS Soil Survey Geographic Database (SSURGO) – Soil type will supplement predictions of watershed recovery
* Western Regional Climate Center (WRCC) Climate Data – Supplementation and comparison of precipitation datasets for change analysis

***Software & Scripting:***

* Google Earth Engine API – Large scale image processing and analysis, model building, land cover classification, platform host/creation
* Esri ArcGIS Pro 2.3 – Map creation and imagery analysis, regression analyses and model construction

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Vegetation Recovery Regression Analysis**  | These general results will compare vegetation recovery rates from each treatment method and will highlight any trends observed for land and weather conditions. This can be used by the USFS Gila NF to understand the relationships that exist at large and can help explain past response to burns. | MODIS LAI and SMAP VOD will be used to derive a vegetation regrowth rate at a given time post-fire, previous burns are identified with Suomi NPP VIIRS Active Fires dataset. Regression analyses will be run between the vegetation regrowth rates and land and weather conditions from Landsat 8 OLI, WLDAS, GPM IMERG, and SMAP. | I |
| **Regression Model for Post-fire Vegetation Recovery**  | This model will be used by the partners to predict the likelihood of vegetation regrowth for a given treatment, considering current conditions of the burned area. The model will pull the relevant data for the burned area and can be run for each treatment type, so the USFS Gila NF can compare results and inform their decisions.  | The model will use the coefficients from the regression analyses to output a predicted vegetation regrowth based on the given area’s conditions from Landsat 8 OLI, WLDAS, GPM IMERG, and SMAP.  | IV |

***End User Benefit*:** The first two terms of this project provided the Gila NF staff with an understanding of the relationship between flash flooding and vegetation recovery after fire in the Gila NF. This term’s decision-support tool will quantify the likelihood of success for each restoration method for given land cover, vegetation, and weather conditions and will help inform the BAER team’s work and ensure that their budget is used efficiently and maximizes recovery rates. This tool will help the USFS appropriately respond to burns and support the short-term recovery of the watershed and holds the potential to be scaled for wider use within the USFS.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 3 Term: 2019 Fall, 2020 Spring, and 2020 Fall

***Multi-Term Objectives:***

* **Term 1:** 2019 Fall (GSFC) – Gila Water Resources
	+ The team explored a watershed recovery classification of the Gila NF. The Normalized Burn Ratio (NBR) served as a proxy to evaluate current recovery and to identify the impacts of the 2012 and 2013 wildfires on watershed dynamics. This project created a database of environmental variables influencing percent recovery and NBR values and laid the foundation for the analysis of stream dynamics in preparation for a Post-fire Flood Correlation Model. Results provided USFS with the groundwork for useful methodologies to supplement their current practices with NASA Earth observations.
* **Term 2:** 2020 Spring (GSFC) – Gila Water Resources II
	+ This term completed the analysis of post-fire flood correlation dynamics to explore the relationship between wildfires and post-fire flooding events and compared these dynamics across treatment areas, with a focus on vegetation recovery. The team also found potential for coupling Landsat-derived NBR with satellite precipitation and streamflow data. Additionally, they began exploring the integration of MODIS LAI data into the WLDAS model for use in modeling the impact of burn events on surface hydrology. The response of the vegetation analysis helped link NBR to stream flashiness and constructed recovery curves for different treatment and control areas within Gila NF.
* **Term 3 (Proposed Term)**: 2020 Fall (GSFC) – Gila Water Resources III
	+ The final team will build a model that predicts the likelihood of vegetation regrowth for different conditions. They will use derived vegetation indices including Terra MODIS LAI, Landsat 8 OLI NBR, and SMAP VOD to examine recovery curves for select fires across treatment and control areas as well as run regression analyses to quantify these relationships. The team will also compare these relationships for different land cover, vegetation, soil moisture, and precipitation conditions, derived from WLDAS and Landsat 8 OLI, to build a regression model that predicts the likelihood of short-term vegetation regrowth for each restoration technique and examine the likelihood of success for a treatment method for current post-fire conditions.

***Previous Terms:***

2020 Spring (GSFC) Gila Water Resources II: Using Earth Observations to Identify Wildfire Impacts on Hydrologic Functions and Recovery in the Gila National Forest

2019 Fall (GSFC) – Gila Water Resources: Using Earth Observations to Track Watershed Recovery after Wildfires in the Gila National Forest

***Related DEVELOP Work:***

2019 Spring (GSFC) – Chesapeake Bay Agriculture & Food Security III: Quantifying Wintertime Agricultural Land Use and Springtime Management of Winter Cover Crops using Landsat and Sentinel to Support Environmental Conservation in Maryland

2018 Spring (GSFC) – Kenai Ecological Forecasting: Mapping tree-line rise and wetland conversion in order to supplement resource management actions in a changing Alaskan climate

2018 Spring (CO) – Utah Water Resources: Utilizing Landsat to Detect Ephemeral Water Sources in Support of a USGS Feasibility Assessment and Management Strategy of Equids

2017 Summer (GSFC) – Chesapeake Bay Ecological Forecasting: Utilizing NASA Earth Observations to Monitor Marsh Health in the Chesapeake Bay to Support the Maryland Department of Natural Resources Coastal Resiliency Assessment

2014 Spring (MSFC) – Southeast U.S. Water Resources: Development of an Alternative Drought Monitoring System using NASA Earth Observation-Derived Drought Indices and Groundwater Storage Estimates for Improved Water Resource Monitoring in the Southeastern United States

**References:**

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Marque, M. A., & Mora, E. (1992). The influence of aspect on runoff and soil loss in a Mediterranean burnt forest (Spain). *Catena*, *19*(3-4), 333-344.

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Wine, M. L., & Cadol, D. (2016). Hydrologic effects of large southwestern USA wildfires significantly increase regional water supply: Fact or fiction? *Environmental Research Letters, 11*(8), 085006. <https://doi.org/10.1088/1748-9326/11/8/085006>