**NASA DEVELOP National Program**

**2019 Fall Project Proposal**

**Maryland – Goddard**

**Gila Water Resources**

*Using Earth Observations to Track Watershed Recovery After Wildfires*

**Project Overview**

***Project Synopsis*:** Recent wildfires in New Mexico’s Gila National Forest (NF) have significantly affected the landscape and water resources in several watersheds. NASA DEVELOP will partner with the U.S. Forest Service’s (USFS) Gila NF, in collaboration with USFS Region 3. The aim of the project is to assess the short, medium, and long term changes to key watershed hydrological processes, namely looking at soils, soil moisture, riparian, and non-riparian vegetation condition (e.g. vegetation structure, composition), and streamflow following wildfires using Landsat, Sentinel, SMAP, GRACE, and GPM satellites. High-resolution aerial imagery collected by USFS Region 3, National Agriculture Imagery Program (NAIP) imagery, Monitoring Trends in Burn Severity (MTBS) maps, Terrestrial Ecological Unit Inventory (TEUI) data, USGS streamflow, and local weather station data will also be used. This project will lay the foundation for an adaptive and interactive data platform using NASA Earth observations and other geospatial data to evaluate the recovery of watersheds on the Gila NF following wildfires.

***Community Concern:*** The Gila NF Whitewater-Baldy Complex Fire of 2012 was the largest wildfire in New Mexico state history. 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 on the Gila NF and on many of the other National Forests across the country. In recent years, the Gila NF has also faced growing demand on its water resources from downstream users. Wildfires can significantly impact watershed hydrologic functions and water and sediment yields, further complicating water rights challenges. This project would provide information on the short, medium, and long-term watershed recovery following wildfires and support future targeted restoration activities on the Gila NF.

***Source of Project Idea:*** This project is part of an initial December 2017 request by Dr. Raha Hakimdavar, a Hydrologist at the US Forest Service’s Washington Office, who at the time was on detail at the NASA Goddard Space Flight Center. Lead Science advisor, Dr. Bolten, continued to support the proposal after increased collaboration between NASA and USFS focused on NASA satellite applications for NSF forest management and planning, as well as new projects in the NASA Western Water Applications Office (WWAO).

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

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

***Study Period:*** September 2001 – September 2019

***Advisors:*** Dr. Bruce Cook (NASA Goddard Space Flight Center), Dr. Douglas Morton (NASA Goddard Space Flight Center), Dr. John Bolten (NASA Goddard Space Flight Center), Dr. Raha Hakimdavar (USFS), Dr. Sinan Abood (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 | 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 | End User | Yes |

***End-User Overview***

***End Users’ Current Decision-Making Process:***The USFS Gila NF and Region 3 have used Landsat data provided by the regional office for vegetation mapping and for other purposes of natural resource analysis and inventory. More recently, high-resolution aerial imagery was made available to the Gila NF by the Region. Otherwise, condition assessments are carried out using expert knowledge, surveys, and existing environmental data collected on the forest. While the Gila NF and Forest Service in general have several programs to assess immediate hydrology and soils impacts following wildfires, relatively little operational tools are in place to look at long-to-medium term recovery of watershed hydrological processes.

***End Users’ Capacity to Use NASA Earth Observations:*** USFS Region 3, which provides support to the Gila NF, has a Photogrammetry Program Specialist. Partnering with USFS Geospatial Technology and Applications Center (GTAC) has allowed the Region to utilize remote sensing with advanced techniques to address challenging problems (e.g., mapping and inventory of select riparian areas using high-resolution aerial imagery). The Gila NF does not have a remote sensing expert but does have a GIS analyst. Region 3 is listed as a partner organization in this project because they have the ability to provide technical support for the Gila NF, but would also benefit from the outcomes of this project as an end user, as they could potentially scale the project on the Gila NF to other forests in the region.

***Collaborator & Boundary Organization Overview***

***Dissemination by Boundary Organizations*:**

*USDA, US Forest Service, Gila National Forest –* The Gila NF is continually connecting with an active community, including the local university, to disseminate information on assessments and scientifically relevant information, along with opportunities for input and decisions that are being made on the management of the Gila NF. There is great interest in the allocation of water resources, forest restoration and fire risk, range production and conditions, the protection of cultural resources, and other facets of how lands are managed.

*USDA, US Forest Service, Region 3 –* Region 3 is actively engaged with private and public partners, including regional universities and the GTAC, to develop and disseminate scientific information for purposes of science 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 maintained 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 and address questions regarding the products in preparation for term 2. Any products requiring Software Release will be described, but the actual platform foundation will not be shared until after the final project term and the completion of the NASA Software Release Process.

**Earth Observations Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 5 TM** | Spectral vegetation indices | Landsat 5 TM data will be used to identify change in historical vegetation presence at the watershed scale. The Normalized Difference Vegetation Index and Normalized Burn Ratio will be calculated and used as a proxy for changes in vegetation and soil condition. |
| **Landsat 7 ETM+** | Spectral vegetation indices | Landsat 7 ETM+ data will be used to identify change in historical vegetation presence at the watershed scale. The Normalized Difference Vegetation Index and Normalized Burn Ratio will be calculated and used as a proxy for changes in vegetation and soil condition. |
| **Landsat 8 OLI** | Spectral vegetation indices | Landsat 8 OLI data will be used to identify change in historical vegetation presence at the watershed scale. The Normalized Difference Vegetation Index and Normalized Burn Ratio will be calculated and used as a proxy for changes in vegetation and soil condition. |
| **Sentinel-2 MSI** | Spectral vegetation indices | Sentinel-2 MSI data will be used to identify change in historical vegetation presence at the watershed scale. The Normalized Difference Vegetation Index and Normalized Burn Ratio will be calculated and used as a proxy for changes in vegetation and soil condition. |
| **GPM IMERG** | Precipitation | GPM precipitation data products will be used to assess watershed hydrological processes as well as support the vegetation condition assessments using proxy spectral indices. |
| **SMAP V3** | Soil Moisture | SMAP soil moisture data will be used with NLDAS to assess watershed hydrological processes, including changes in water holding capacity and soil moisture dynamics due to wildfires. |

***Ancillary Datasets:***

* Western Water Application Office (WWAO) Data Sets and Tools - The NASA WWAO is developing SMAP-based soil moisture and other hydrologic tools and datasets that may be relevant to this work. Lead Science Advisor John Bolten will work with WWAO to discuss the availability of these tools and their application.
* North American Land Data Assimilation System (NLDAS-2) 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 U.S. 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
* 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, land cover classification, platform host/creation
* Esri ArcGIS Pro 2.3 – Map creation and imagery analysis

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Gila National Forest Enhanced Land Cover Classification Maps** | Maps of land cover classification that include burned area as well as hydrologic metrics will allow the partner to compare existing datasets to remotely sensed classification and analyze various changes over time. | Land cover classification maps using spectral vegetation indices and the Normalized Burn Ratio will be derived from Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, and Sentinel-2 MSI. These maps will also include hydrologic information from GPM, SMAP, and modeled datasets. | II |
| **Gila National Forest Land Cover/Vegetation Change Detection Maps** | A suite of static visualizations showing empirical rates of land cover/vegetation change between multiple time steps will help the partner efficiently direct management efforts in the Gila National Forest. | Maps displaying land cover/vegetation change using Normalized Burn Ratio and spectral vegetation indices will be derived from Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, and Sentinel-2 MSI. Precipitation data from GPM, and PRISM water extent data will supplement the change detection for comparison. | II |

***End-User Benefit*:** The Gila NF is prone to frequent wildfires, the rate and severity of which have been increasing. This project could help the Gila NF better understand and adapt to the short, medium, and long term recovery of watershed hydrological processes following wildfires. The outcomes from the project would strengthen the ability of forest managers to make crucial decisions around restoration prioritization and inform decisions around the reduction of fire and drought vulnerability. Findings from this work can potentially lead to the adoption of similar methods developed for other National Forests.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2019 Fall to 2020 Spring

***Multi-Term Objectives:***

* **Term 1 (Proposed Term):** 2019 Fall (GSFC) – Gila Water Resources
  + This term will produce a land cover classification of the Gila NF. Normalized Difference Vegetation Index (NDVI) and Normalized Burn Ratio (NBR) anomaly calculations will allow users to determine the amount of forest cover change throughout the study region and to identify the impacts of the 2012 and 2013 wildfires on vegetation recovery and watershed dynamics. Results will be compared against existing vegetation maps for validation, providing the USFS with useful methodologies to supplement their current practices with NASA Earth observations as well as feedback for future considerations. In preparation for a subsequent term, the foundation for a data-based watershed condition platform will plan to be established.
* **Term 2:** 2020 Spring (GSFC) – Gila Water Resources II
  + A second term will allow for more in-depth analysis, as well as completion of the data-based watershed condition platform. Utilizing the land cover classification, forest cover change, and condition maps created in term 1, this term would also allow for further assessment of the condition of riparian/non-riparian vegetation and soils on the Gila National Forest. The platform will help facilitate the intended goal to identify changes in watershed condition before and after the recent wildfires. All products will be handed off at the end of the term via web training, allowing the USFS to replicate the methodologies implemented.

***Related DEVELOP Work:***

2018 Spring (LaRC) – Amistad Ecological Forecasting: Using Landsat and Sentinel to Identify and Detect Giant Cane in Amistad National Recreation Area for Future Invasive Species Land Management

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

**Notes & References:**

***Notes:***

The water holding capacity of soils and vegetation will be assessed over time using listed EO and ancillary datasets to determine watershed metrics before and after major wildfire events. These metrics will be included and visualized on the land cover classification maps.

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