**NASA DEVELOP National Program**

**2020 Spring Project Proposal**

**Maryland – Goddard**

**Gila Water Resources II**

*Implementing a Watershed Recovery Model to Assess Wildfire-Induced Watershed and Streamflow Changes in New Mexico*

**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. This project will create a predictive model of watershed recovery following wildfires, built from a previously created database of environmental variables, for Gila NF and the US Forest Service Region 3. This model will incorporate soils, soil moisture, and vegetation condition assessed using Normalized Burn Ratio (NBR) following wildfires derived from Landsat, SMAP, GRACE, and GPM satellites. High-resolution aerial imagery, National Agriculture Imagery Program (NAIP) imagery, and Monitoring Trends in Burn Severity (MTBS) maps will also be used to predict recovery. Additionally, this project will use USGS streamflow data, GPM precipitation data, and MODIS MOD16 evapotranspiration data to create a post-fire flood correlation model, which will identify if wildfire events trigger post-fire flooding events. This model will also be used to assess the rate of recovery of stream dynamics.

***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 a growing demand for its water resources from downstream users. Wildfires can significantly impact watershed hydrologic functions, as well as water and sediment yields, further complicating water rights challenges. Additionally, wildfires can result in significantly increased streamflow due to changes in soils and vegetation cover. The Gila NF land managers have observed significant flooding events following large wildfires. These flooding events can slow natural recovery processes and disturb downstream communities.

***Source of Project Idea:*** This project is part of a 2017 request by Dr. Raha Hakimdavar, a Hydrologist at the US Forest Service’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 National Science Foundation forest management and planning as well as new projects in the NASA Western Water Applications Office (WWAO). During the first term, the Gila NF expressed interest in improving their understanding of the connection between wildfires and flooding events.

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

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

***Study Period:*** September 2001 – January 2020, Forecasting to 2030 and 2040

***Advisors:*** Dr. Sebastian Martinuzzi (University of Wisconsin – Madison), 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 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 of natural resource analysis and inventory. More recently, high-resolution aerial imagery was made available to the Gila NF by Region 3. Otherwise, condition assessments are carried out using expert knowledge, surveys, and existing environmental data collected in the forest. The Gila NF and US Forest Service, in general, have several programs to assess immediate hydrology and soils impacts following wildfires, however, relatively few operational tools are in place to look at long-to-medium term recovery of watershed hydrological processes. While small-scale assessments of wildfire damage are conducted immediately following fires, the Gila NF does not utilize Earth observations for watershed-level assessments of wildfire impacts.

***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 to utilize remote sensing with advanced techniques to address challenging problems. The Gila NF does not have a remote sensing expert but does have a GIS analyst.

*USDA, US Forest Service, Region 3 –* USFS Region 3, which provides support to the Gila NF, has a Photogrammetry Program Specialist. Region 3 has the ability to provide technical support for the Gila NF, but would also benefit from the outcomes of this project, 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 to disseminate information on assessments and scientifically relevant information. The Gila NF also promotes opportunities for input related to decisions that are being made on the management of the Gila NF. There is great interest from recreational users and downstream communities in the allocation of water resources, forest restoration and fire risk, range production and conditions, 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. Any products requiring Software Release will be described, but the actual platform foundation will not be shared until after the project term and the completion of the NASA Software Release Process.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Spectral vegetation index (NBR) | Landsat 5 TM data will be used to identify the change in historical vegetation presence at the watershed scale. NBR will be calculated and used as a proxy for changes in the watershed and soil conditions. |
| **Landsat 7 ETM+** | Spectral vegetation index (NBR) | Landsat 7 ETM+ data will be used to identify the change in historical vegetation presence at the watershed scale. NBR will be calculated and used as a proxy for changes in the watershed and soil conditions. |
| **Landsat 8 OLI** | Spectral vegetation index (NBR) | Landsat 8 OLI data will be used to identify the change in historical vegetation presence at the watershed scale. NBR will be calculated and used as a proxy for changes in the watershed and soil conditions. |
| **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** | 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. |
| **~~GRACE~~** | Changes in total water storage | GRACE data will be used to assess watershed hydrological processes using total water storage to track the movement of water through the watershed. |
| **Terra MODIS** | Evapotranspiration | The MOD16 global evapotranspiration product to calculate the regional water balance. |

***Ancillary Datasets:***

* 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.
* NASA 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 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, 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 Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Post-fire Flood Correlation Model** | This model will serve to identify the correlation between flooding events and wildfire disturbance. Clear evidence of a relationship between fires and flooding events will allow the partners to mitigate flood damage following fire events and anticipate the recovery of stream dynamics. | This model will be derived from USGS stream gauge data, GPM precipitation data, and MODIS MOD16 evapotranspiration data. This model will be used to predict the rate of recovery of stream dynamics. | III |
| **Gila National Forest Model of Predicted Watershed Recovery** | This model will use results from the previous database of environmental variables affecting watershed recovery to predict future recovery trends in the Gila NF watershed 10 and 20 years following a wildfire event. This will allow partners to prioritize restoration projects for further watershed recovery. | The model will build from the previous term’s Database of Environmental Variables Influencing Recovery Dynamics. It will use NBR and spectral vegetation indices derived from Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI. Landcover data from LANDFIRE and soil data from SSURGO will supplement the model. | III |
| **Map of Predicted Watershed Recovery** | This visualization will demonstrate the predicted recovery of the watershed 10 and 20 years in the future using NBR as a proxy. This will visualize results from the Gila National Forest Model of Predicted Watershed Recovery. The resulting maps will help the partners direct future management efforts in the Gila NF. | Maps displaying land cover/vegetation recovery using NBR and spectral vegetation indices derived from Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI. Landcover data from LANDFIRE and soil data from SSURGO will supplement the model. | N/A |

***End User Benefit*:** The Gila NF is prone to frequent wildfires, which are increasing in rate and severity. 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 post-fire flooding events. These results will help the Gila NF anticipate stream recovery following wildfire events. 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:** 2019 Fall (GSFC) – Gila Water Resources
  + This term explored a watershed recovery classification of the Gila NF. 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. In preparation for a subsequent term, this project created a database of environmental variables influencing percent recovery and NBR values, which can be used to predict future recovery. This term 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
  + A second term will utilize the database of variables influencing recovery to create a predictive model of watershed recovery 10 and 20 years in the future. This term will also complete the model of post-fire flood correlation dynamics to explore the relationship between wildfires and post-fire flooding events. USFS will use the results of the model of recovery to guide further restoration efforts. The USFS will also use the post-fire flood correlation model to mitigate ahead of post-fire flooding events. All products will be handed off at the end of the term via web training, allowing the USFS to replicate the methodologies implemented.

***Previous Terms:***

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:**

Donato, D. C., Campbell, J. L., & Fontaine, J. B. (2015). Ten years after the Biscuit Fire: Evaluating vegetation succession and post- fire management effects. Internal report shared by Dr. Matt Reeves from USFS Rocky Mountain Research Station.

Frazier, R. J., Coops, N. C., Wulder, M. A., Hermosilla, T., & White, J. C. (2018). Analyzing spatial and temporal variability in short-term rates of post-fire vegetation return from Landsat time series. *Remote Sensing of Environment, 205*, 32–45. <https://doi.org/10.1016/j.rse.2017.11.007>

Potyondy, J., & Geier, T. (2011). Watershed Condition Classification Technical Guide. United States Department of Agriculture, Forest Service.

Soulard, C. E., Albano, C. M., Villarreal, M. L., & Walker, J. J. (2016). Continuous 1985-2012 Landsat monitoring to assess fire effects on meadows in Yosemite National Park, California. *Remote Sensing,* *8*(5), 1–16. <https://doi.org/10.3390/rs8050371>

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>