**NASA DEVELOP National Program**



National Centers for Environmental Information (NCEI)

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Southwest United States Disasters

Incorporating CDRs and MODIS to Create a Predictive Model of Post-Burnout Vegetation Regrowth in Relation to Flood Risk

 **Technical Report**

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# I. Abstract

[Placeholder until the final draft submission.]

**Keywords**

Remote Sensing, Post-Wildfire Flooding, NDVI, Vegetation Regrowth, MODIS, PERSIANN, CDR

# II. Introduction

**Background Information**

Annual post-wildfire runoff events have fatigued land management teams in the Southwest United States as seasonal runoff events increase in intensity and frequency across the region. While wildfires and subsequent flooding and debris flows are an inevitable reality for the Southwest, the immediate and long-term effects of both events necessitate increasing preparedness for natural hazards in a changing climate.

Currently, the Burned Area Emergency Response (BAER) Imagery Support program, in coordination with the USGS Center for Earth Resources Observation and Science and USDA Forest Service Remote Sensing Applications Center, provide satellite imagery on burn severity. After a fire event, the USGS Landslide Hazards program incorporates the burn severity classifications, basin morphology, soil properties, and rainfall history for the affected area into the Emergency Assessment of Post-Fire Debris-Flow Hazards model to assess potential debris flow volumes. The inputs represent conditions, before or immediately following a wildfire, that most strongly influence debris flow potential. Although post-burnout environments are dynamic, the model generates a static image of debris flow hazards. Additionally, the USGS tool only addresses debris flow as opposed to determining the general impact of runoff hazards.

As the landscape begins to recover after a wildfire, the initial conditions used to predict hazards change at varying rates. Accordingly, the temporal component of hazard prediction can be difficult to capture. Research suggests vegetation regrowth may serve as an appropriate proxy for vulnerability to runoff hazards, and satellite imagery has the potential to identify change in vegetation over time.

**Previous Studies**

Numerous studies have assessed post-fire vegetation response using satellite imagery. Vegetation regeneration is determined by a number of natural and anthropogenic factors including topography, vegetation type, hydrology, and land management practices. Remotely sensed Normalized Difference Vegetation Index (NDVI) products are effective tools for monitoring vegetation dynamics. In “Monitoring post-wildfire vegetation response with remotely sensed time-series data in Spain, USA, and Israel,” van Leeuwen et al. explain that vegetation cover and pattern are among the most important aspects of analyzing ecological consequences of disturbances (75). One objective of their study was to monitor post-wildfire vegetation response using 250-meter Terra MODIS NDVI time-series data. Their study concluded that remotely sensed NDVI time-series data is beneficial in assessing post-wildfire vegetation response (91). In a similar study called “Using MODIS-NDVI for the Modeling of Post-Wildfire Vegetation Response as a Function of Environmental Conditions and Pre-Fire Restoration Treatments,” Leon et al. selected three wildfires that occurred in Bandelier National Monument in New Mexico between 1999 and 2007, and three adjacent control sites. A time-series analysis was performed by taking the average NDVI during monsoon season each year after a fire occurred, to establish long term trends in vegetation response. Thus, remotely sensed NDVI products have successfully measured trends in post-fire phenology.

A similar set of studies establish a relationship between runoff response and burned watersheds. In “Linking runoff response to burn severity after a wildfire,” Moody et al. note that runoff response is a function of rainfall and soil properties. Changes in runoff response are temporally and spatially variable and depend on factors such as vegetation, burn severity, climate, and topography. Runoff response and burn severity were measured in seven sub-watersheds in Rendija Canyon of New Mexico, USA. This study establishes a linear rainfall-discharge relationship in which a rainfall intensity greater than 8.5 mm h-1 is indicative of runoff potential. Furthermore, research has shown that remote sensing has the capability to simulate runoff at regional and global scales, although not yet directly linking runoff to disturbances such as wildfires. In “A first approach to global runoff simulation using satellite rainfall estimation,” Hong et al. explain that hydrological models used to predict runoff are not common decision support tools due to data requirements and complicated modeling processes. Remote sensing offers a supplemental tool in rainfall-runoff simulation where global satellite-based rainfall estimation is the main input parameter. Hong et al. use the USDA Natural Resources Conservation Service (NRCS) runoff curve number (CN) method to model rainfall-runoff, using the first nine years of rainfall estimates from the Tropical Rainfall Measuring Mission (TRMM) data.

Overall, numerous studies have successfully identified repeatable wildfire-vegetation and vegetation-runoff relationships, but less research assesses the impact of wildfire on runoff vulnerability over an extended period of vegetation regrowth.

**Objectives**

This project seeks to establish a spatio-temporal relationship between vegetation regrowth as a function of NDVI and post-fire runoff hazard, over a 10-year period, for Tucson, Arizona in the Lower Colorado River Basin. The MODIS NDVI product will be used to create a raster surface indicating vegetation regrowth rate after historical wildfires on a per-pixel basis. The additional measure of vegetation regrowth will then be compared to historical runoff events to establish a relationship between regrowth and runoff in order to enhance the predictive capabilities of current USGS Landslide Hazards teams. This study demonstrates the usefulness of these products by utilizing NOAA Climate Data Records (CDRs), NASA Earth Observations, and in-situ data as alternative sources for input parameters.

**Study Area**

This study analyzes twenty wildfires in the Lower Colorado River Basin, in central and south central Arizona, specifically within or adjacent to the Active Management Area (AMA) Planning Area of Arizona. The planning area ranges in geographic extent from Prescott to the Mexican border, including the major cities of Tucson, Phoenix, and Prescott. Over 80% of the state’s 6.2 million population lives within this planning area (AMA, p19). The climate within the AMA Planning Area varies significantly due to its large spatial magnitude (AMA, p34). Temperatures in Phoenix and Tucson are generally the warmest in the region, with the exception of the summer monsoon season in which Tucson receives most of its precipitation, producing cooler temperatures (AMA, p34). There are also strong year to year variations in precipitation due to El Niño events, as well as notable multi-decadal ocean variations linked to wet and dry periods for the Active Management Area.

**Study Period**

This study addresses post-burnout conditions from 2002 to 2014. The model looks specifically at monsoon season, from July through September, when extreme heat and wildfire events are most likely to be followed by rainfall conditions conducive to flooding.

**National Application Addressed**

The Southwest US Disasters project addresses Disasters by improving the long-term predictive capability of tools currently available for managing future post-fire hazards.

**Project Partners**

[More on partners will be included when the end-user is more specifically identified. Explain who the project partners are, why they are interested in this project, how they will use it, what decision making they have to do and is being addressed with this research and methodologies, etc. How will they benefit from this project and methodology? ]

Gregg Garfin (Investigator, Climate Assessment for the Southwest (CLIMAS)) serves as an advisor on the project. Dr. Garfin is an academic, who works at the interface between the research community and the stakeholder-practitioner community. Dr. Garfin is interested in this project because it shows promise to develop insights into understanding and predicting a critical natural hazard in his region – the post-fire flood. Dr. Garfin hopes to use the outputs of the project, when consulting with stakeholder-practitioners whose jobs require them to use the best available science in decision making. The benefits of the project to Dr. Garfin include: (a) it provides information and insights relevant to his region, (b) it intersects with one of his areas of investigation, i.e., increasing preparedness for natural hazards in a changing climate.

# III. Methodology

[This should be the focus of the paper - concise, yet explanatory, and highlight the NASA Earth observations utilized and its/their capabilities. Include a paragraph or more for each of the following items. No word cap, but be thoughtful and keep it in the two to six page range.]

**Data Used**

Terra - MODIS (Moderate Resolution Imaging Spectroradiometer) Vegetation Indices 16-Day L3 Global 250m SIN Grid (MOD13Q1) Version 5 data used in our study was acquired from the HTTP server, e4ftl01.cr.usgs.gov, using the Fetch\_MODIS dnppy function. MODIS-NDVI data was acquired every sixteen days from 2000 to 2014 for the study area. Using Python, the data was reprojected to NAD 1983 UTM Zone 12N, clipped to the state of Arizona, and the range of NDVI values was changed by applying the appropriate scale factor of 0.0001 (MODIS NDVI Metrics Table). Then, all MODIS NDVI scenes were clipped to the extent of each wildfire.

Wildfire data was acquired from the USDA Forest Service Burned Area Emergency Response (BAER) Imagery Support Data Download page. Twenty wildfires in the USFS Region 2 between the years of 2002 and 2004 within Arizona were downloaded from the BAER archives. These wildfires were formatted as burn severity raster images. Each image was reclassified to a common scale of 1-4, with 1 indicating low burn severity and 4 indicating high burn severity. Then, each reclassified burn severity raster was reprojected to NAD 1983 UTM Zone 12N, converted to a shapefile, and buffered by 5 kilometers. The final output was a series of wildfire polygons used to clip the MODIS NDVI scenes.

Forty-two Terra - ASTER (Advanced Spaceborne Thermal Emission and Reflectance Radiometer) Global Digital Elevation Model Version 2 tiles were downloaded from http://gdem.ersdac.jspacesystems.or.jp/ and mosaicked in ArcMap to produce one Digital Elevation Model (DEM) at 30 meter resolution for the study area. The DEM was reprojected to NAD 1983 UTM Zone 12N.

**Analysis**

[Data Analysis: How did you analyze the data? What methods did you use?]

First, an average rate of vegetation regrowth was computed for fires across the study area. All fires with associated BAER burn severity data that occurred within Arizona between 2002 and 2004 were chosen in order to also obtain ten years of NDVI data after each fire event. To create an NDVI regrowth rate, the “many\_stats” raster dnppy function was employed to calculate statistics across the series of input rasters, resulting in a single output raster. A set of pre-processed MODIS NDVI data was clipped to the extent of each wildfire. The “many\_stats” dnppy function was then used to find the average NDVI value on a per-pixel basis for each of the 10 years after the associated fire. Then, the “many\_stats” function was used again to calculate the average NDVI value across the 10-year span using only the annual averages. The result was a single raster surface indicating the average rate of NDVI regrowth for each pixel across the 10-year period following the wildfire. The process was repeated for each fire in the analysis.

# IV. Results & Discussion

[Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range. ]



Figure 1 Initial identification of NDVI values pre- and post-burn in relation to burn severity classes based on the 2002 Rodeo-Chediski fire, suggesting a relationship between vegetation regrowth and burn severity.

**Analysis of Results**

[What can you tell from your graphs, images, etc? What does this mean for your project?]

**Errors & Uncertainty**

[What factors could you not account for, what things didn’t work out like you expected they would, etc.]

**Future Work**

[If this project was to be selected for another term, what would be the focus? What other areas would be of interest?]

# V. Conclusions

[Final conclusions. Word count: 200-600 (~a page).]

# VI. Acknowledgments

[Insert here. Keep to a concise paragraph or bullets of names. End with the following sentence.]

* DeWayne Cecil (Chief Climatologist and Program Manager, Global Science & Technology (GST) National Centers for Environmental Information (NCEI))
* Gregg Garfin (Investigator, Climate Assessment for the Southwest (CLIMAS))
* Tim Brown (Director, Western Regional Climate Center (WRCC))
* Dennis Staley (Research Physical Scientist, USGS Landslide Hazards Program)
* Jason Kean (Research Hydrologist, USGS Landslide Hazards Program)

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# VII. References

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Insert references here. Only include articles/content cited in the body of text above. It’s great if you read many other articles, but they should not all be listed here unless they are being cited in this report.

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# VIII. Content Innovation

[Insert link to NDVI animation created in GRASS GIS]

[In preparation for DEVELOP’s coming microjournal, please select two content innovation features to support your paper. For each item, please list the name of the feature, and include the tool itself if possible (eg. glossary terms and definitions). If the tool does not work in Microsoft Word (eg. Interactive MATLAB Figure Viewer), please list the file name and upload the related file to the microjournal folder on the DEVELOP Exchange. If you choose to use Inline Supplementary Material, please also include where the material should appear in the text.]

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# IV. Appendices

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