**NASA DEVELOP National Program**



National Centers for Environmental Information (NCEI)

*Summer 2015*

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**

Rough Draft – June 25, 2015

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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 flooding events have fatigued land management teams in the Southwest United States as the cyclical events increase in intensity and frequency across the region. While wildfires and subsequent floods 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 Burn 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, USGS Landslide Hazards program incorporate 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, this tool only assesses the impact of a debris flow hazard as opposed to general flooding events.

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, as satellite imagery has the potential to identify change 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 to monitoring vegetation dynamics. In “Monitoring post-wildfire vegetation response with remotely sensed time-series data in Spain, USA, and Israel,” 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 fire occurred to establish long term trends in vegetation response. Thus, remotely sensed NDVI products have successfully measured trends in post-fire phenology.

**Objectives**

This project seeks to establish a spatio-temporal relationship between vegetation regrowth as a function of NDVI and post-fire flood 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 on a per-pixel basis. The additional measure of vegetation regrowth will enhance the usefulness of the current USGS Landslide Hazards Program Post-Fire Debris Flow Hazards tool by incorporating it with the current parameters of rainfall history, soil type, morphology, and burn severity. 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**

The Lower Colorado River is one of several climatic planning areas within Arizona. The region typically has the highest average annual temperature in the state, with annual precipitation hovering around 4.6 inches (Arizona Water Atlas, p 19). While the Lower Colorado is best characterized by extreme aridity, it also experiences a summer monsoon season, El Niño, and La Niña events, leading to high decadal variability in both precipitation and temperature (20). In general, the Colorado River serves as the only perennial water source in the basin, and coupled with little or erratic precipitation, in-situ rainfall data is limited across the region (15). Several USGS teams across the Southwest United States, then, have expressed the need for alternative measures of precipitation and flooding to better assess post-burnout hazards.

**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 events.

**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-one 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.

* Data Acquisition: What data did you get, what level products are they, for what dates did you get images, where did you get the images from, etc.
  + Modis is level 3
  + PERSIANN-CDR, GridSat-B1 – Infrared water vapor
  + CMORPH-CDR, Passive microwave and infrared from several geostationary satellites – Precipitation rate
* Data Processing: What did you do to the data? Were there conversions needed to be able to analyze it? Did you have to mosaic images? Did you have to normalize anything to fit other datasets? Did you run an NDVI, change detection, etc?

**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. ]

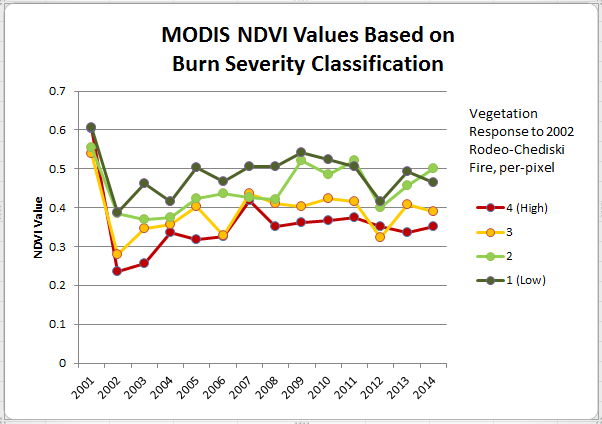


Figure 1 Initial identification of NDVI values pre- and post-burn in relation to burn severity classes based on the 2002 Rodeo-Chediski fire, suggesting a relationship between vegetation regrowth and burn severity.

**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)

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

# 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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# IV. Appendices

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