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Leveraging Google Earth Engine to Couple Landsat and MODIS for Detecting Phenological Changes in Semi-Arid Ecosystems

Megan Gallagher
Boise State University

Josh Enterkine
Boise State University

Nancy Glenn
Boise State University

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Author: Megan Gallagher
Co-Authors: Josh Enterkine, Nancy Glenn
https://bcal.boisestate.edu/ @BCAL_Boise
Department of Geosciences, Boise State University, Boise, ID, USA; contact: megangallagher@u.boisestate.edu

INTRODUCTION

Spectral classification over dryland regions is difficult because of the similar spectral responses of the plants. The reflectivity of the soil, and the quick senescence of plant species creates large errors when they are viewed through satellite imagery. Most public satellites do not have the ability to have fine resolution – either temporally or spatially- to distinguish between the many different species that exist. As semi-arid regions have quick green-up immediately after rain fall, it is difficult to get properly timed imagery for best classification practices.
This causes complications when faced with issues such as the invasion of Cheatgrass (*Bromus Tectorum)* in areas that were historically Wyoming Sagebrush (*Artemisa Tridentata)* and native grass dominated. Cheatgrass is known for its quick spread over regions, especially after fires have occurred, and creates a positive feedback loop for more frequent fires in the future.
Fusion methods between multiple satellite systems will allow us to get higher temporal and spatial resolution views on these systems, which will aid with vegetation classification and monitoring.

BACKGROUND

	Landsat 8	MODIS
Spatial (m)	30, 15 panchromatic	250 ,500, 1000
Temporal(day period)	16	1-2
Blue Band Wavelength (nm)	450-510	459-479
Green Band Wavelength (nm)	530-590	545-565
Red Band Wavelength (nm)	640-670	620-670
NIR Band Wavelength (nm)	850-880	841-867

Figure 1: Landsat 8 and MODIS spatial, temporal and wavelength comparisons.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a NASA instrument aboard both the Aqua and Terra satellites. MODIS has 36 bands and a revisit period of one to two days.

Landsat-8 has a 16 day period, and 30 m bands. This satellite has two instruments on board: the Operational Land Imager (OLI) covers the bands from visible light to shortwave infrared, and the Thermal Infrared Sensor (TIRS) which receives information for thermal infrared.

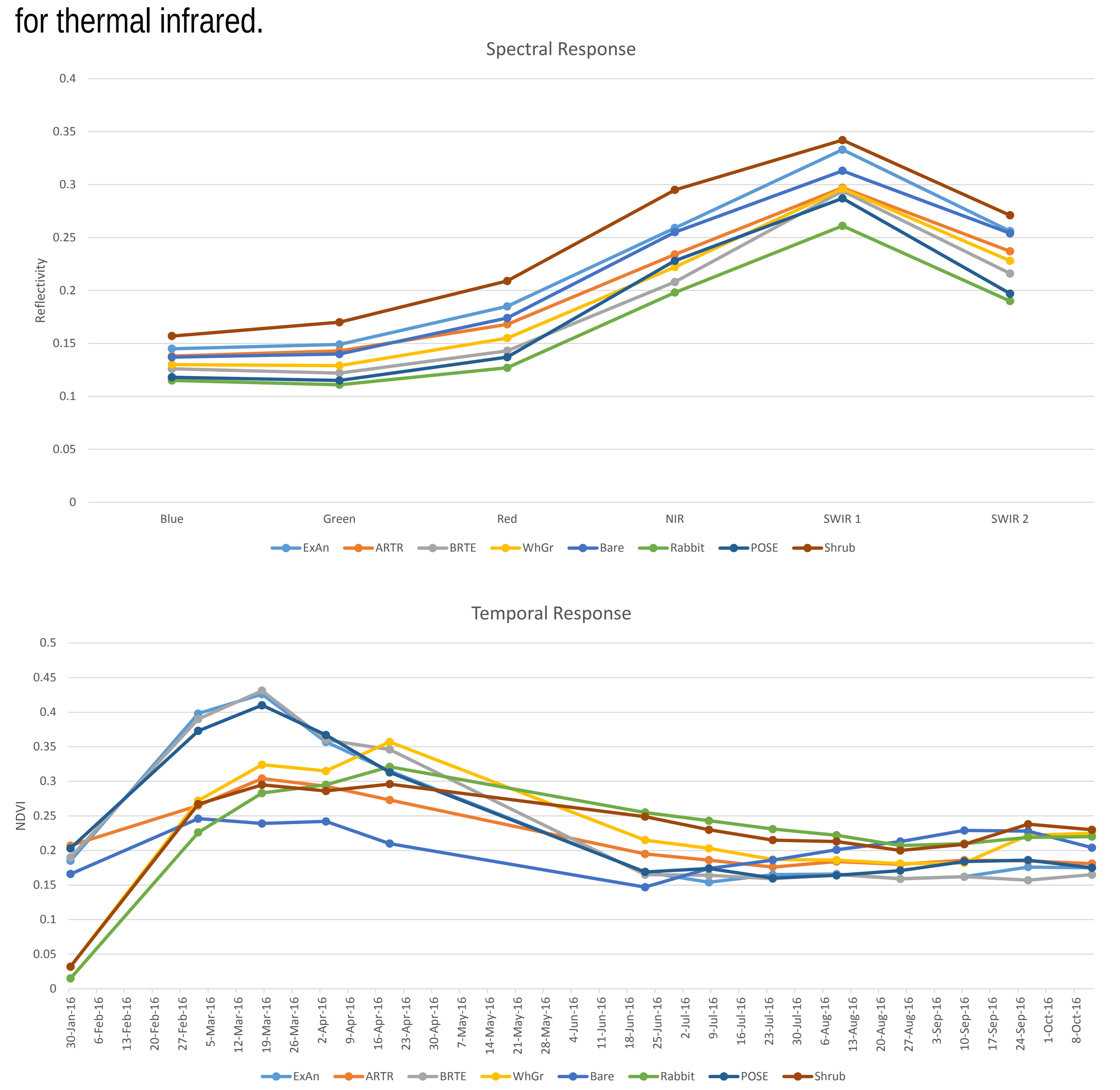

Figure 2: Top image: Spectral indices between many samples of sagebrush (*ARTE,Shrub),* cheatgrass (*BRTE*) , exotic annuals (*ExAn*), wheat grass (*WhGr*), bare ground (*Bare*), rabbit brush (*Rabbit*), and sandberg bluegrass (*POSE*) taken from one Landsat image with bands from Blue to Short Wave Infrared 2.
Bottom Image: Time series response of the same regions of vegetation in 2016 using the Normalized Difference Vegetation Index (NDVI). Larger variation in plant response is visible in the changes over time.

GOOGLE EARTH ENGINE

Google Earth Engine (GEE) is an online repository and code engine that is used extensively in this project. GEE holds petabytes of remote sensing information, and allows you to go through all of it quickly and easily without having to use your own memory or processors.

GEE is used for all preprocessing, registration, and interpretation of the inputs and outputs for STARFM. This allows work that usually would have taken hours to be done in less then 10 minutes, and for large data sets to be easily included.

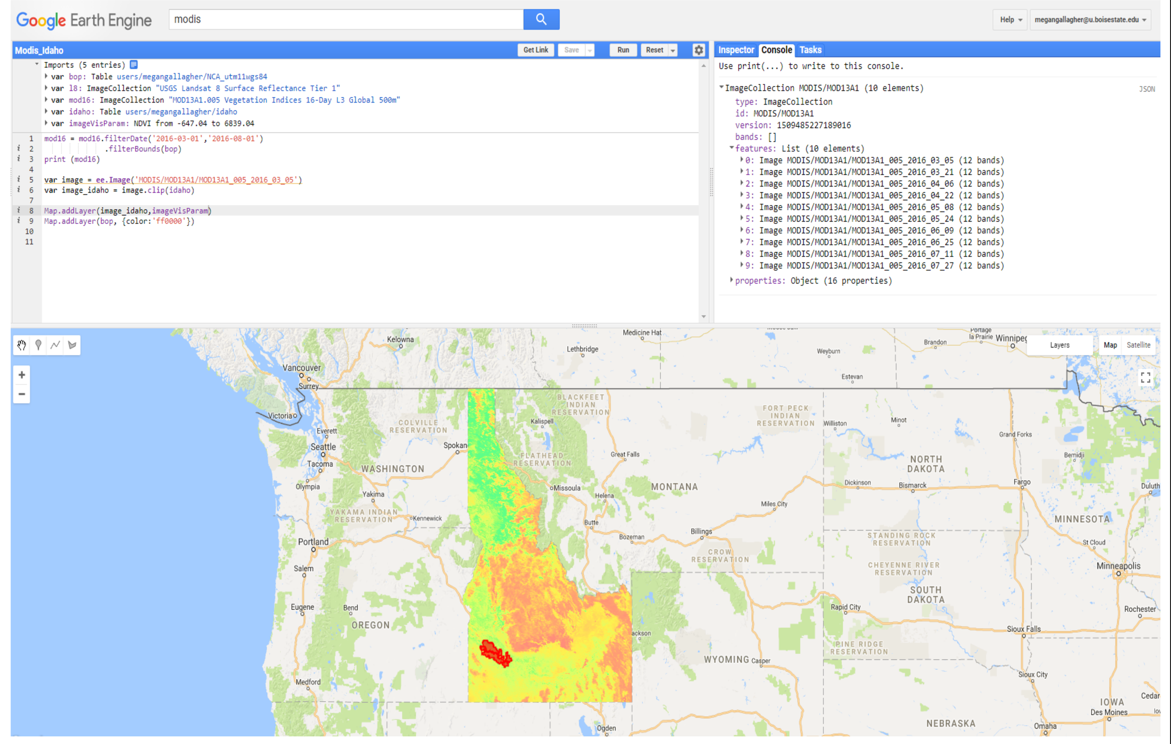

Figure 3: Google Earth Engine Code Editor, with full code listed for MODIS NDVI Imagery over Idaho, and the Morley Nelson Snake River Birds of Prey National Conservation Area highlighted.

STARFM

STARFM produced by the USDA uses the band similarities between MODIS and Landsat to create an interpolation between the two. This allows for interpolated images to be created on a higher temporal scale and with a higher spatial resolution.

The MODIS 250 m pixels are comprised of many Landsat 30 m pixels. An image from both systems on the same day is used to create a percentile map of similarities between the pixels. MODIS images are then used along with the percentile map to create the simulated Landsat image. This image's pixels are weighted by the input image pixel percentage, the amount of time from the original image set, and the time since the input data.

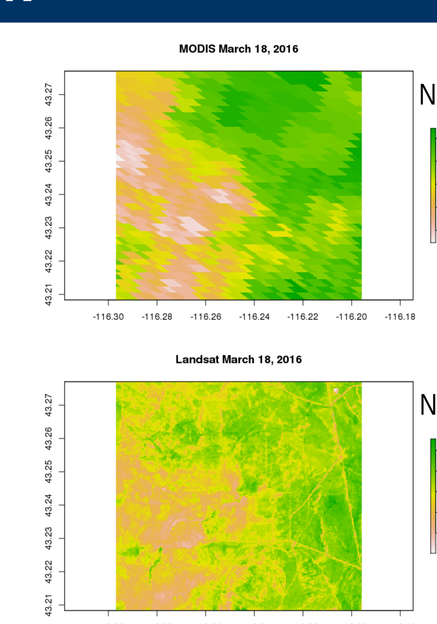

Figure 4 : An example of two of the input images, the top is the MODIS and the bottom Landsat 8.

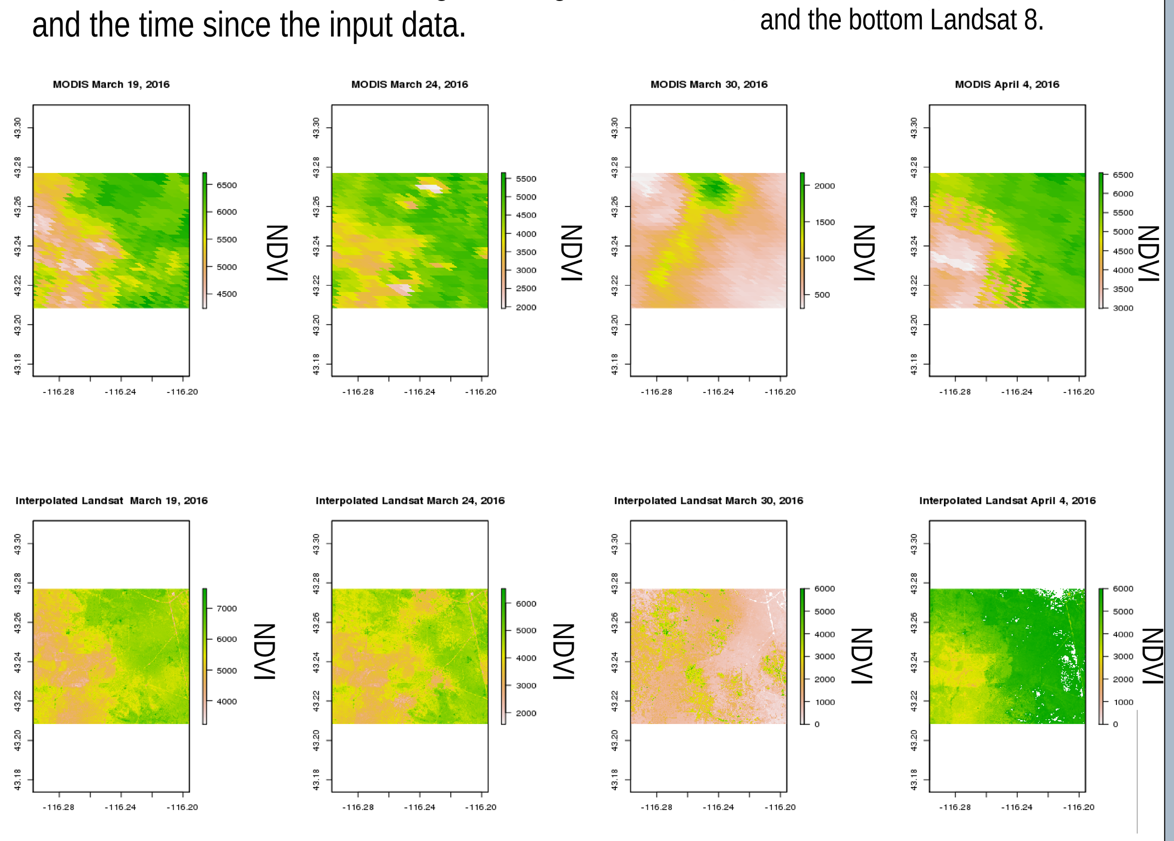

Figure 5: The top layer has the original MODIS images, and the bottom the interpolated Landsat images that are created from them using STARFM.

RESULTS

The GEE STARFM system was run on a study area in the Birds of Prey from March 2, 2016 to October 13, 2016. This used over 11 Landsat Images and 225 MODIS images for interpolation.

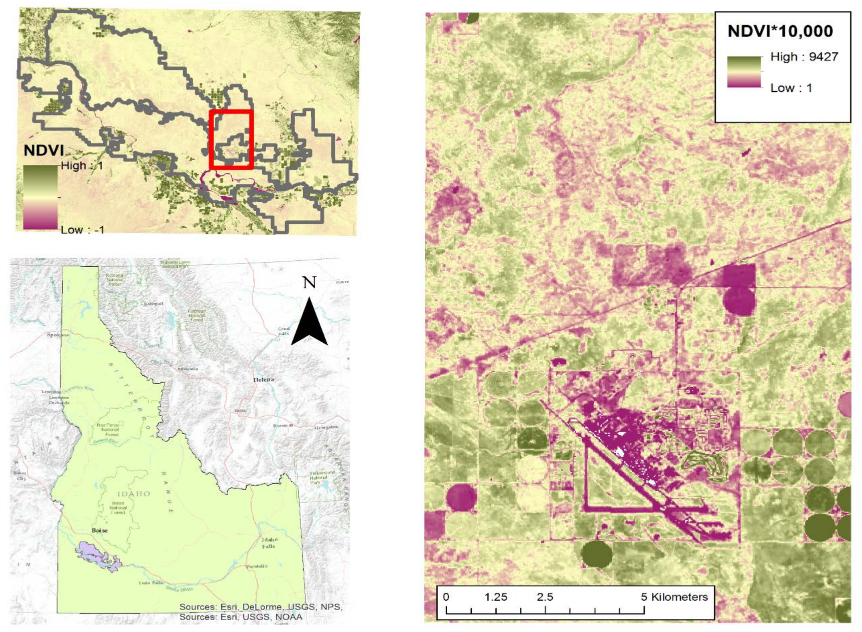

Figure 6: Map of the Morley Nelson Snake River Birds of Prey National Conservation Area with the area of interest highlighted. This area has known plots of vegetation coverage, as well as asphalt and concrete responses for error analysis.

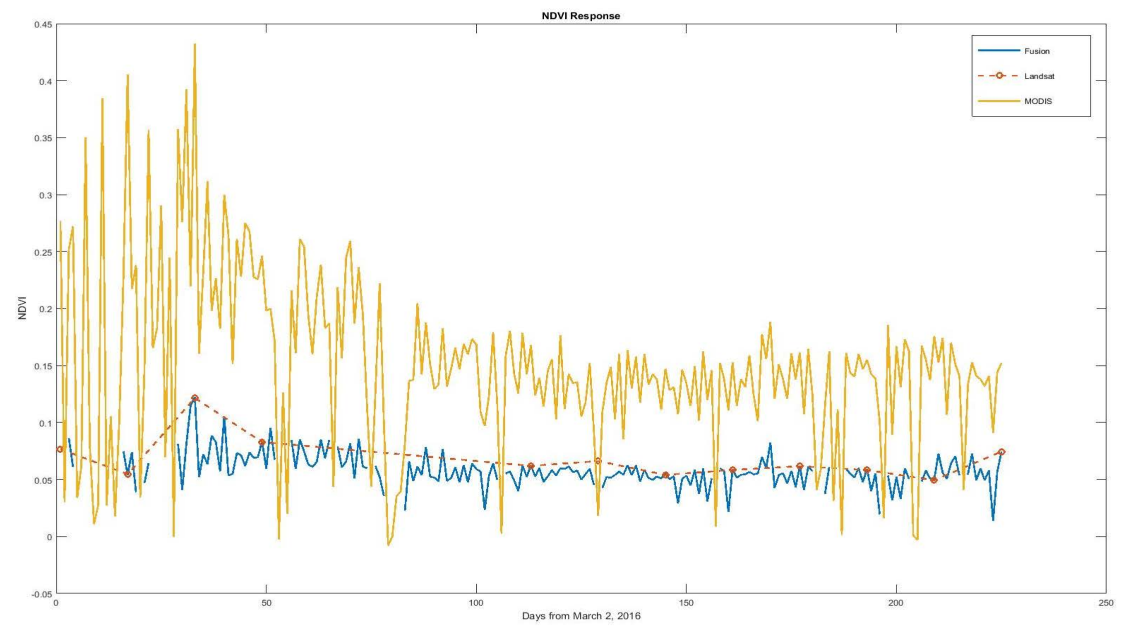

Figure 7: A test using black asphalt was done to see how well the interpolation method worked as it should be stable year round. It can be seen that the MODIS response over this chosen patch of asphalt is high, which is caused by the large footprint of the MODIS covering other kinds of ground cover, such as nearby plants. The Landsat response (red) is more stable but has much fewer point responses. The Fusion approach stays well within the range of the Landsat response, but pattern leftovers from the MODIS imagery are present.

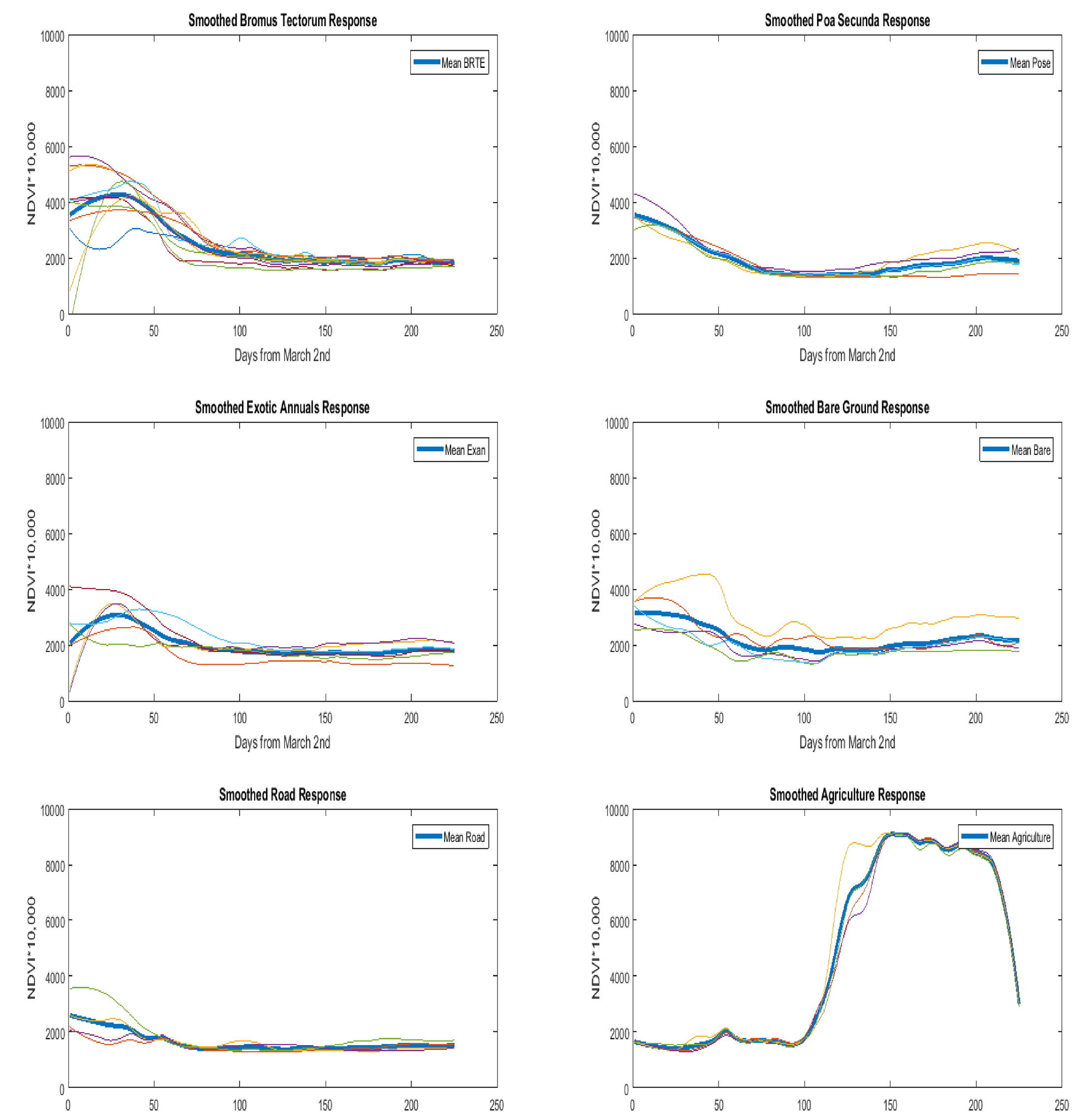

Figure 8: Known plant plot points were used to get generalized phenological responses over the time series. These series were smoothed to help dampen noise, and the overall mean response of the plants is shown in blue. This time series allows us to see major differences between plant growth cycles and types, which can make classification and mitigation of invasive species easier to define.

FIRE WORK

A secondary use for this system is in depth tracking of fire responses over long period of time for better understanding of cheatgrass and shrub regrowth cycles. This system uses a secondary program called bfastSpatial to build off of historical knowledge to find major changes that have occurred in vegetated areas.

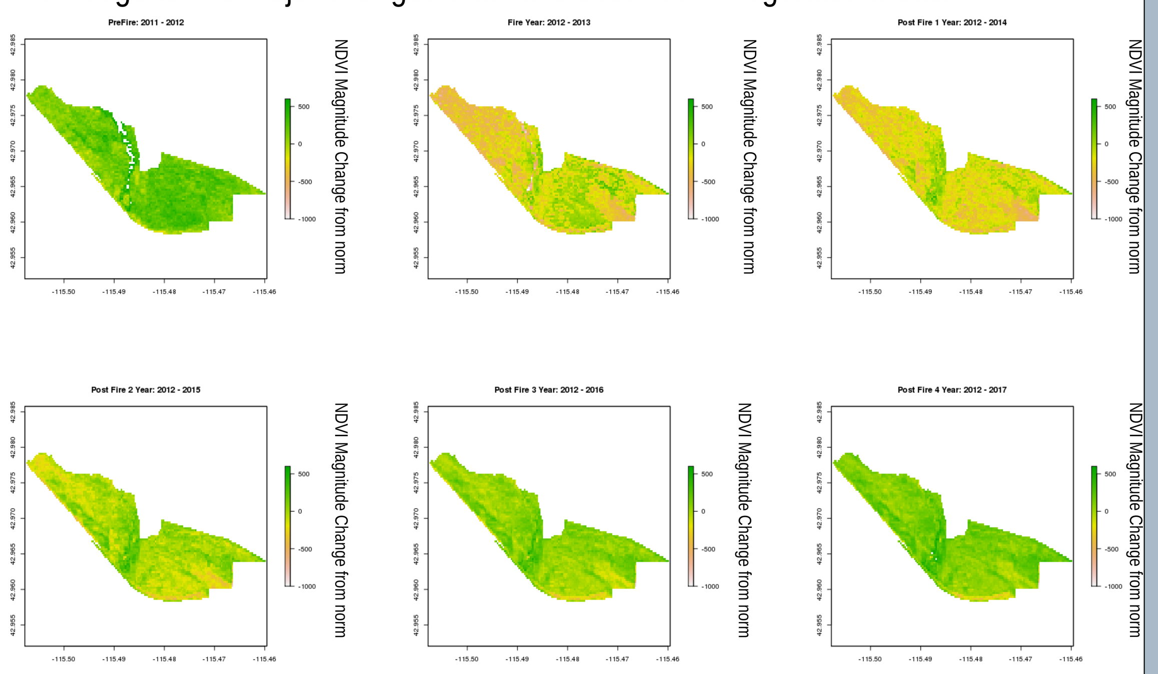

Figure 9: The MM109I84 fire occurred between May 18, 2012 and June 3, 2012, making it an early season fire in a Cheatgrass dominated area. Using the fusion system we can get daily responses to regrowth after the fire event has occurred, and monitor that growth over time. A decade of information was created, with 5 years pre fire and 5 years post to find changes that are out of the norm. It can be seen in the figure above that the first two years after the fire had low regrowth, but the third and fourth year had higher responses.

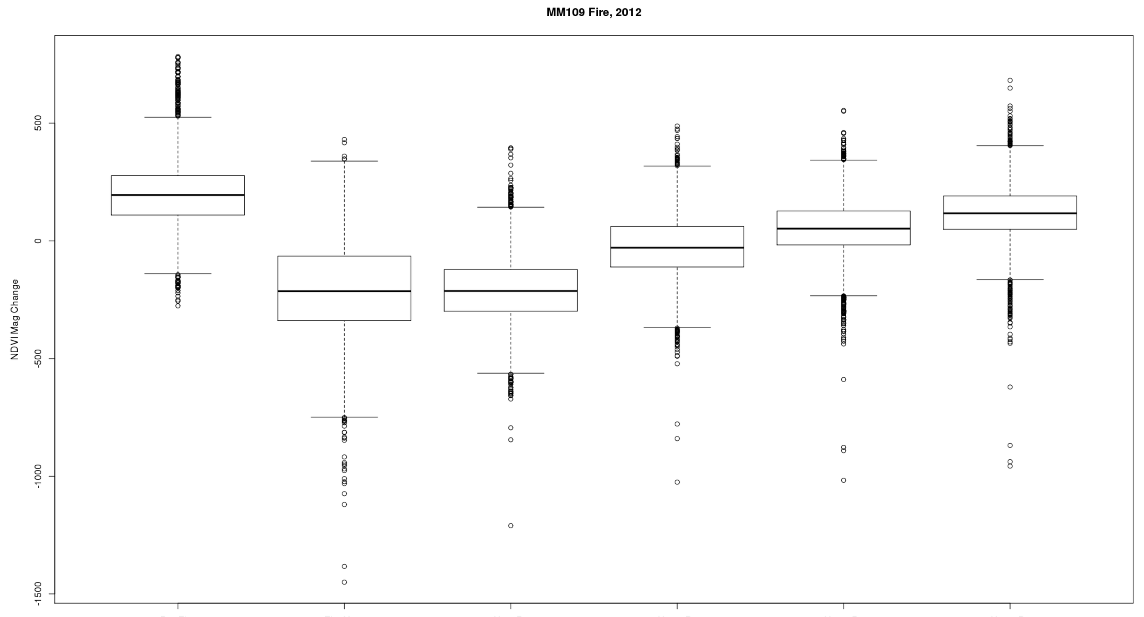

Figure 10: A different view on the vegetation responses gives an overall trend, with low but steady regrowth occurring over the 5 year time period, but it has not yet reached it's previous norm.

CONCLUSIONS

- STARFM facilitated with GEE allows for easy and quick computation of large datasets for interpolation.
- Phenological differences of plants with similar spectral responses can be characterized in the time domain.
- Cheatgrass has a markedly different response from sagebrush, which can be used for classification at multiple time steps.
- Vegetation response to fire can be easily tracked and quantified, allowing for better understanding of regrowth and possible management tactics.

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REFERENCES

Enterkine, Josh, et al., Plot point information, & "Vegetation Mapping in a Dryland Ecosystem Using Multi-temporal", Poster Number B31F-2060, 12/13/2017 8:00-12:20
Sentinel-2 Imagery and Ensemble Learning
Gao, F., Masek, J., Schwaller, M., & Hall, F. (2006). On the blending of the landsat and MODIS surface reflectance: Predicting daily landsat surface reflectance. *IEEE Transactions on Geoscience and Remote Sensing*, 44(8), 2207–2218. http://doi.org/10.1109/TGRS.2006.872081
Gao, F., Hilker, T., Zhu, X., Anderson, M. A., Masek, J., Wang, P. and Yang, Y. Fusing Landsat and MODIS data for vegetation monitoring, I*EEE Geoscience and Remote Sensing Magazine*. 3(3): 47-60. doi: 10.1109/MGRS.2015.2434351. 2015.
Google Earth Engine Team, 2015. Google Earth Engine: A planetary-scale geospatial analysis platform. https://earthengine.google.com
Peters, Faye, "Analyzing the phenologic dynamics of kudzu (Pueraria montana) infestations using remote sensing and the normalized difference vegetation index." (2016). Electronic Theses and Dissertations. Paper 2437. https://doi.org/10.18297/etd/2437
Verbesselt, J., R. Hyndman, G. Newnham, and D. Culvenor. 2010. "Detecting Trend and Seasonal Changes in Satellite Image Time Series." Remote Sensing of Environment 114 (1): 106–115. doi:10.1016/j.rse.2009.08.014.
Verbesselt, J., A. Zeileis, and M. Herold. 2012. "Near Real-Time Disturbance Detection Using Satellite Image Time Series." Remote Sensing of Environment 123: 98–108. doi:10.1016/j.rse.2012.02.022.