Determining Burn Severity in Forest Fires - Final Report

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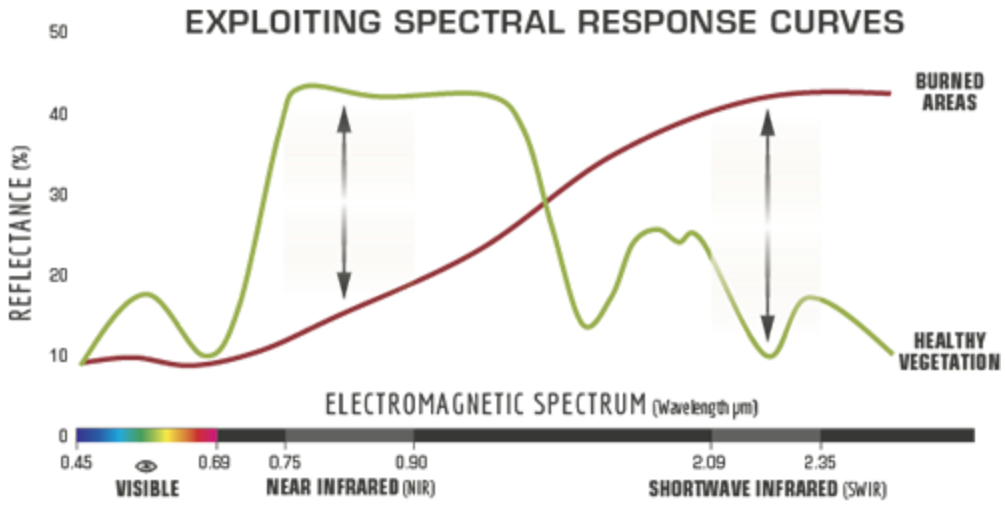
1) Background

Forest fires are an important issue in the Southwest region of the United States. Between 2012 and 2015 over 648,000 acres of land burned in New Mexico due to wildfire [1]. It is true that fires are a natural part of our ecosystem which is why man-made controlled burns are created as a natural "safety valve" solution. By determining the intensity of wildfires, we can learn where to prevent future unexpected natural fires by smartly targeting areas with controlled burns or other treatments.

How can we determine the severity of a forest fire? The Burned Area Reflectance Classification (BARC) methods developed by by the US Forest Service and US Geological Survey help us answer this question.

For the visible bands on the electromagnetic spectrum, there's very little difference between healthy vegetation and burnt vegetation because they're both fairly low in spectral reflectance. However there's big differences in the near-infrared (NIR) and the shortwave infrared (SWIR) bands. So in a forest fire, as the canopies are consumed, there is typically a substantial decrease in NIR reflectance as well as substantial increase in SWIR reflectance. These differences are caused by less canopy shadowing and a drier surface following a forest fire [2].



The Normalized Burn Ratio (NBR) is used to assess a fire's severity:

$$NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)}$$

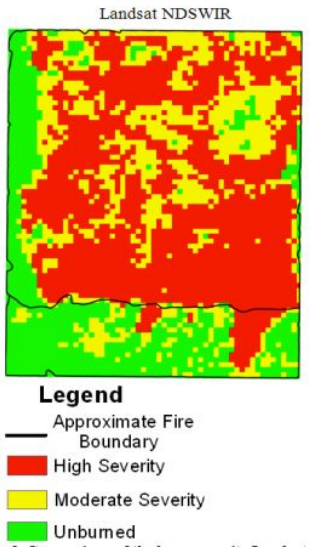
This formula is similar to NDVI, which we can also calculate to determine the health of the vegetation:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

If imagery from before the burn is available, we then can calculate the difference (dNBR):

Pre-fireNBR - Post-fireNBR = dNBR

If the dNBR is higher, the fire is more severe. A negative dNBR value can come from vegetation growth that comes after a wildfire [3]. Below we can see an example of raster data used to determine the severity of a forest fire in Clark County, Idaho calculated using dNBR [5].



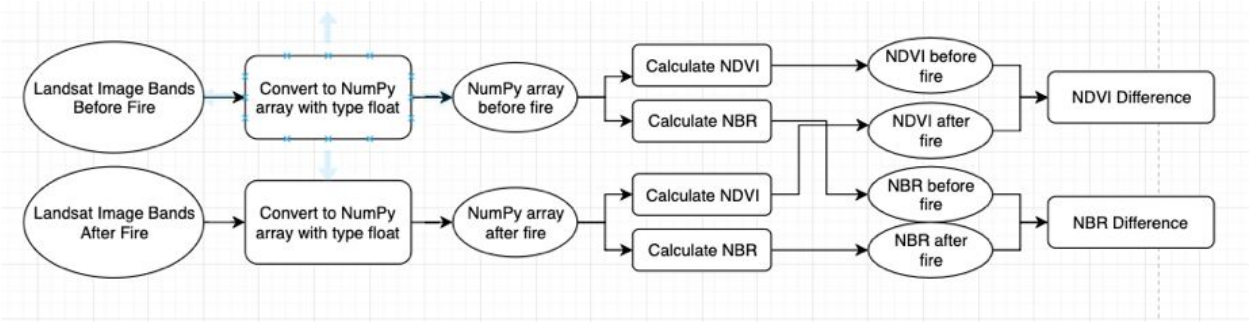
The US Forest Service's comparatively recent shift towards an open data policy has helped catapult the use of Landsat data among various science applications, including biomass burning. However the tools themselves are not open source (many use ArcGIS), but we can make a python-based tool utilizing the same NBR algorithm.

2) Methods

Burn severity is calculated using Landsat 5 imagery. Data was downloaded from USGS EarthExplorer. The bands extracted and analysed are:

Band 3 includes wavelengths from 0.63-0.69 µm (Red)
Band 4 includes wavelengths from 0.76-0.90 µm (NIR)
Band 7 includes wavelengths between 2.09-2.35 µm (SWIR) [4].

The flow chart of the application:



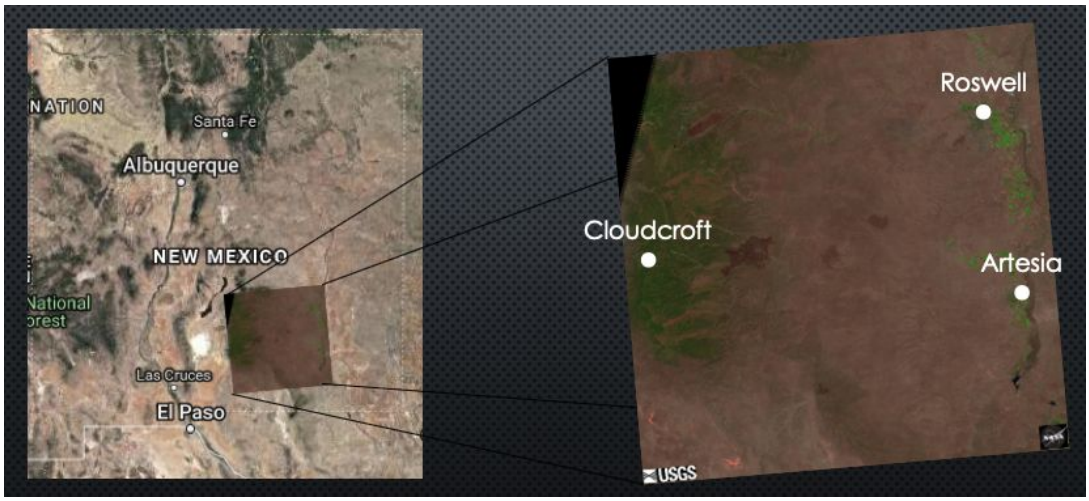
Analysis is done using python tools NumPy and Rasterio to create these images. Rasterio opens the .tif files for the desired bands and NumPy converts them through the .read() function. The NBR algorithm is run on the two bands, and then the dNBR algorithm is used on both the images before and after the fire. The NDVI algorithm is done similarly.

Code:

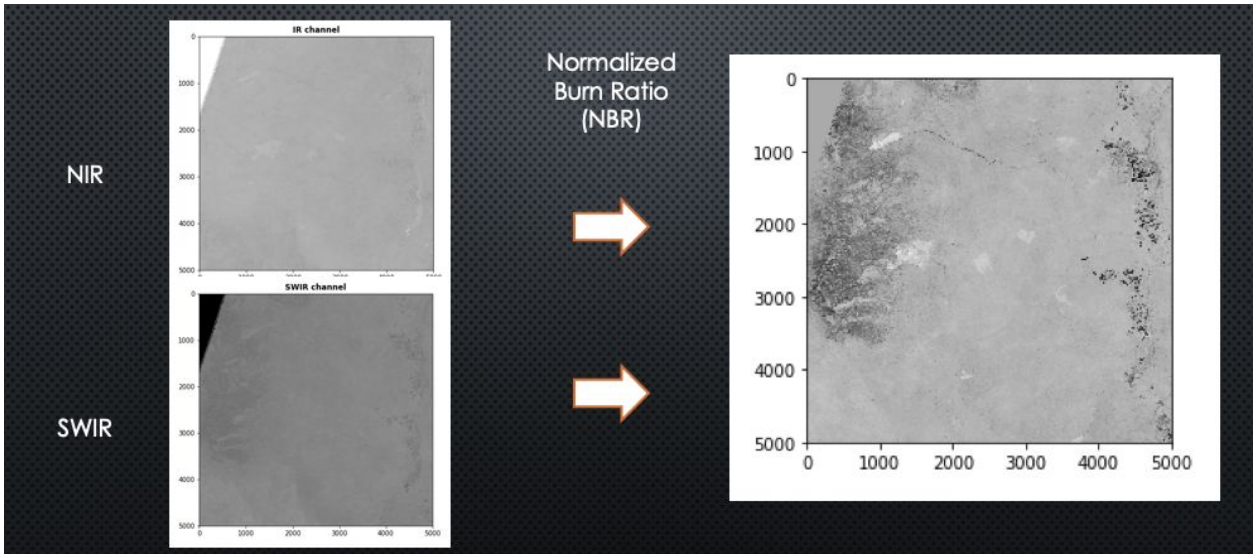
```
#Prefire - nbr
nir = rasterio.open("20030605/LT05_CU_006010_20030605_20190109_C01_V01_SRB4.tif")
swir = rasterio.open("20030605/LT05_CU_006010_20030605_20190109_C01_V01_SRB7.tif")

nir = nir.read()
swir = swir.read()
nir = nir.astype(float)
swir = swir.astype(float)
np.seterr(divide='ignore', invalid='ignore')
nbr_prefire = ((nir - swir) / (nir + swir))
plot.show(nbr_prefire, cmap = "Greys")
```

3) Demo and Results

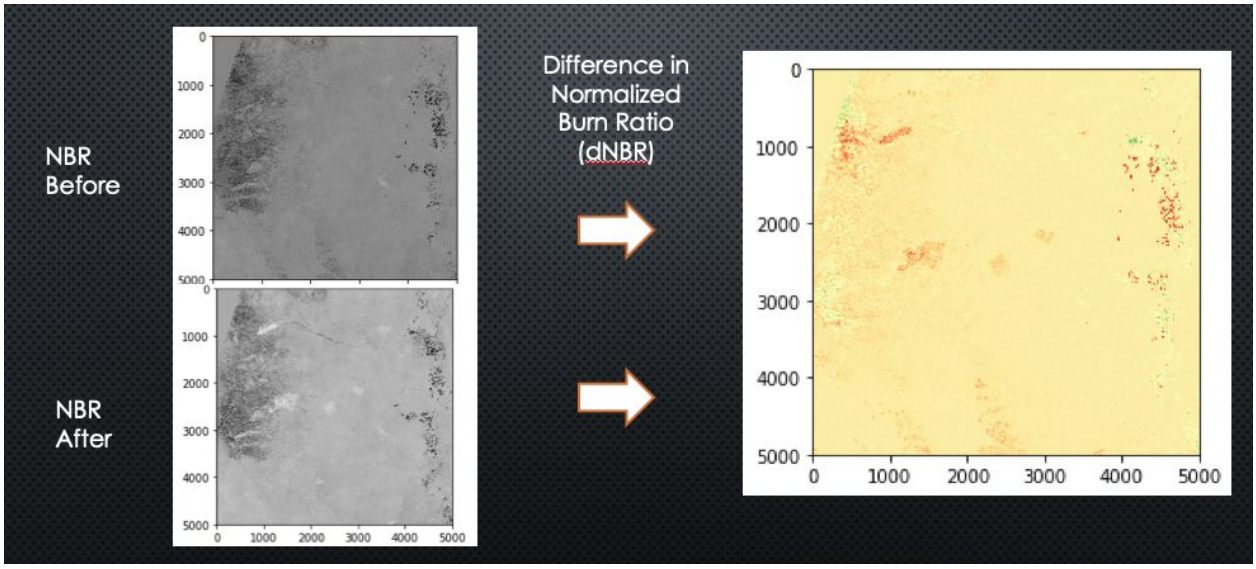
Demonstration (Southeast NM, 2011).



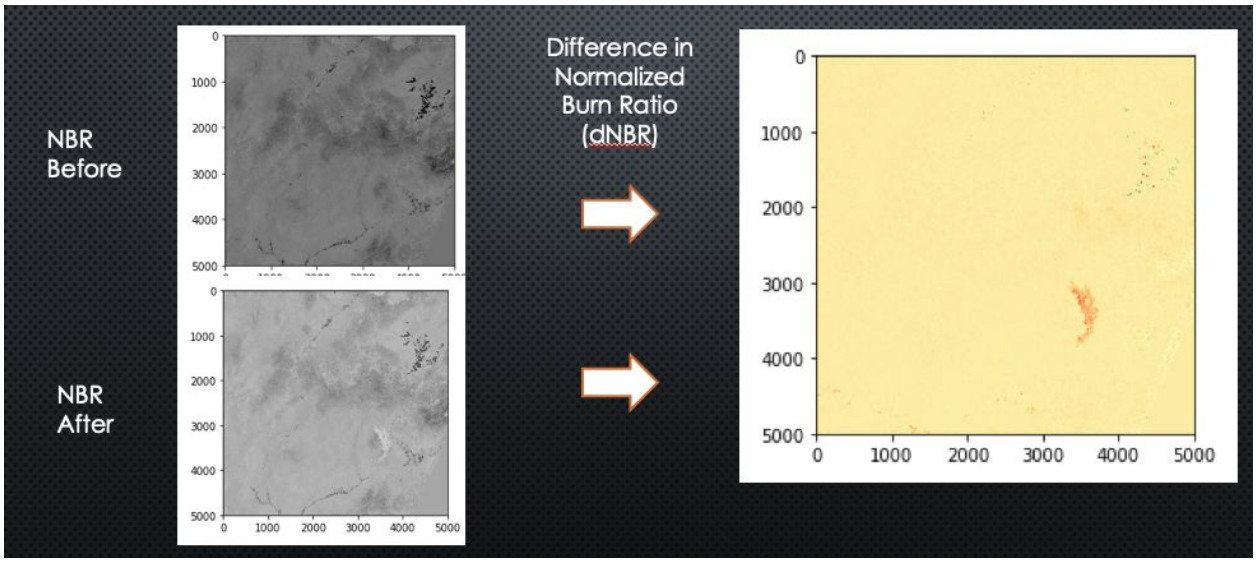
Take bands 4 (NIR) and 7 (SWIR) and calculate NBR.



Compare difference of NBR before and after the fire.



Demonstration (West Mountain Peak, Utah, 2003).
Another more clear example of burn utilizing dNBR.



4) Discussions and Conclusions

NDVI was also used, but didn't have the same results on the burn areas that NBR had. NDVI can isolate the areas lacking vegetation, but it cannot detect the barren rocky soil left behind because it does not utilize the SWIR band.

This tool is effective at isolating the differences in spectral curves to distinguish areas with vegetation and areas that are barren and use this data to determine burned and unburned areas as well as burn severity utilizing Python. This tool has the potential to be used in many areas outside of current US government analysis techniques that are limited to ArcGIS. Python's flexibility allows for analysis on many different platforms.

5) References

[1] RGIS. 2015. “How is Wildfire Affecting New Mexico?”. http://rgis.unm.edu/how-is-wildfire-affecting-new-mexico/

[2] US Forest Service’s Geospatial Technology and Applications Center. n.d. “BARC: Frequently Asked Questions”. https://www.fs.fed.us/eng/rsac/baer/barc.html

[3] The Landscape Toolbox. 2013. “Burned Area Reflectance Classification”. https://wiki.landscapetoolbox.org/doku.php/remote_sensing_methods:burned_area_reflectance_classification_barc

[4] USGS. n.d. “What are the band designations for the Landsat satellites?” https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

[5] Norton, Jill. 2006. “The use of remote sensing indices to determine wildland burn severity in semiarid sagebrush steppe rangelands using Landsat ETM+ and SPOT 5”. MS Thesis, Idaho State University. http://giscenter.isu.edu/research/techpg/nasa_tlcc/PDF/Ch6.pdf