Analyzing burn severity and vegetation regrowth following the Bastrop County Fire

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1. BACKGROUND RESEARCH

Wildfires occur naturally in many forest ecosystems and promote species diversity by clearing flammable undergrowth, thinning older trees, accelerating the carbon cycle, and replenishing soil nutrients. The aftermath of these wildfires varies widely depending on environmental variables including species and soil composition, weather, and seed production. Considering the impracticalities of surveying large areas through field work, remote sensing through satellite imagery allows for a more holistic overview of the entire region.

2. THE BASTROP COUNTY WILDFIRE

In **2011**, central Texas experienced its most extreme drought since the 1950s, as well as the hottest U.S. summer on record, with an average temperature of **86.8° F**. These already-extreme conditions created an environment ideal for the propagation of a spreading conflagration. After the original burns were ignited from sparks from fallen power lines, the wildfire converged from three smaller fires into one major entity over a period of several days in early **September 2011**.

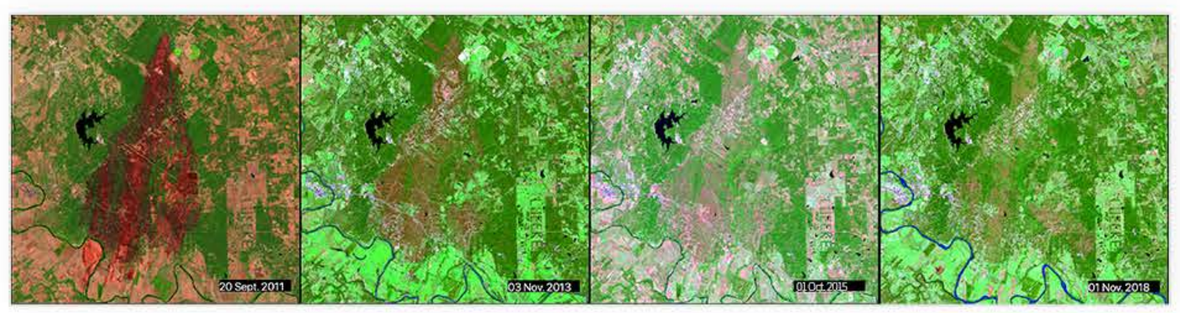

Fig. 1. False color composite images showing progression of vegetation recovery

Due to the winds of **Tropical Storm Lee**, the fire continued to spread for over a month, killing two people, destroying **96%** of **Bastrop State Park** (home to the indigenous **Loblolly Pine**), and burning **$325 million** worth of property before being fully extinguished on **October 29, 2011**.

3. RESEARCH OBJECTIVES

Although vegetation regrowth in the immediate aftermath of the wildfire is well-documented, longer periods of time are typically more effective in capturing the extended cycle of forest recovery. This investigation aims to explore the following topics:

- How can remote sensing techniques be used to evaluate the long-term effects of the **Bastrop County** wildfire and determine whether these trends are temporary or lasting?
- What are the relationships between burn severity and postfire vegetation recovery in the aftermath of a wildfire as tracked using **NDVI** and **dNBR**?
- What environmental factors influence the nature of post-fire vegetation dynamics?

4. DATA ACQUISITION AND PROCESSING

To survey the large **Bastrop Complex** fire region, we utilized and processed **18 Landsat 5 and 8 satellite images** from **2009** to **2018**. **Landsat** measures multispectral surface reflectance in the **Near Infrared (NIR)**, **Short Wave Infrared (SWIR)**, and **Visible Bands** bands. We selected the dates for our data using the **Landlook Viewer** and **USGS Earth Explorer** based on the image quality, cloud cover, and time of year in relation to the date of the 2011 fire.

The **Difference Normalized Burn Ratio (dNBR)** and **Normalized Difference Vegetation Index (NDVI)** are common indices used to quantify burn severity and vegetation growth, respectively. **dNBR** is calculated with **NIR** and **SWIR** bands from **Landsat** while **NDVI** incorporates the **NIR** and **Visible Red** bands. We quantified burn severity using the **dNBR** index, revealing patterns regarding the progression and impact of the fire.

$$NBR = \frac{NIR - SWIR}{NIR + SWIR} \cdot 1{,}000 \qquad dNBR = NBR_{Prefire} - NBR_{Postfire} \qquad NDVI = \frac{NIR - Red}{NIR + Red} \cdot 1{,}000$$

Data was processed using the following computational methods in **Python/QGIS**: clipping the raw imagery to the burn scar region, calculating a map of **dNBR** and NDVI, defining thresholds for burn severity based on dNBR value frequencies, and generating statistics (mean and standard deviation) and graphs of NDVI for each burn severity.

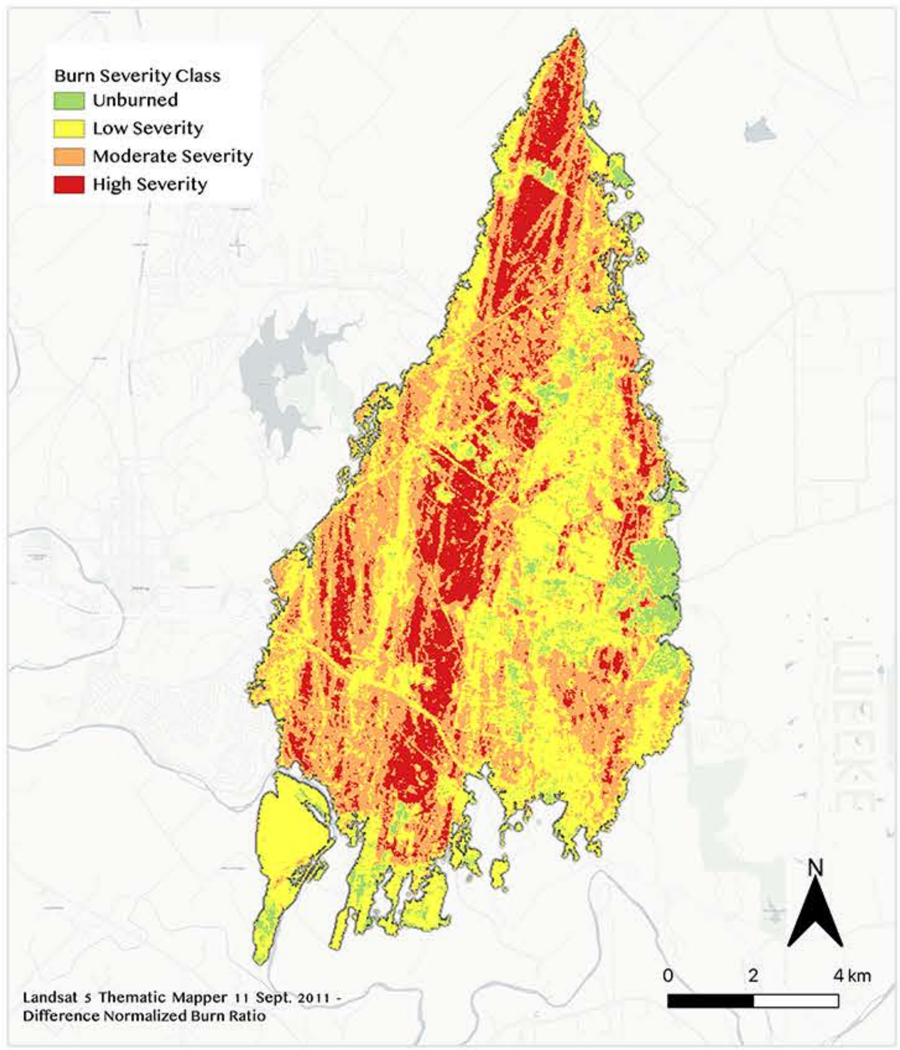

Fig. 2. The **dNBR** heat map exhibits a vertical strip of high severity, indicating a southerly direction of the wind that propagated the flames. Pockets of varying burn severity are influenced by other factors including species, geographic context, and fire movement.

5. VEGETATION REGROWTH

The resulting plot clearly illustrates the gradual decline in prefire **NDVI** values due to the worsening Texas drought, leading up to the significant drop in **NDVI** due to the **Bastrop Complex Fire** in 2011. The general trend also depicts fluctuations due to varying drought and precipitation levels, including drops in **2015** and **2018** due to hotter and drier conditions. The **2011** drop in **NDVI** is followed by a significant increase, with levels in **2013** and onwards appearing comparable to prefire **NDVI** levels, indicating a rapid rate of recovery.

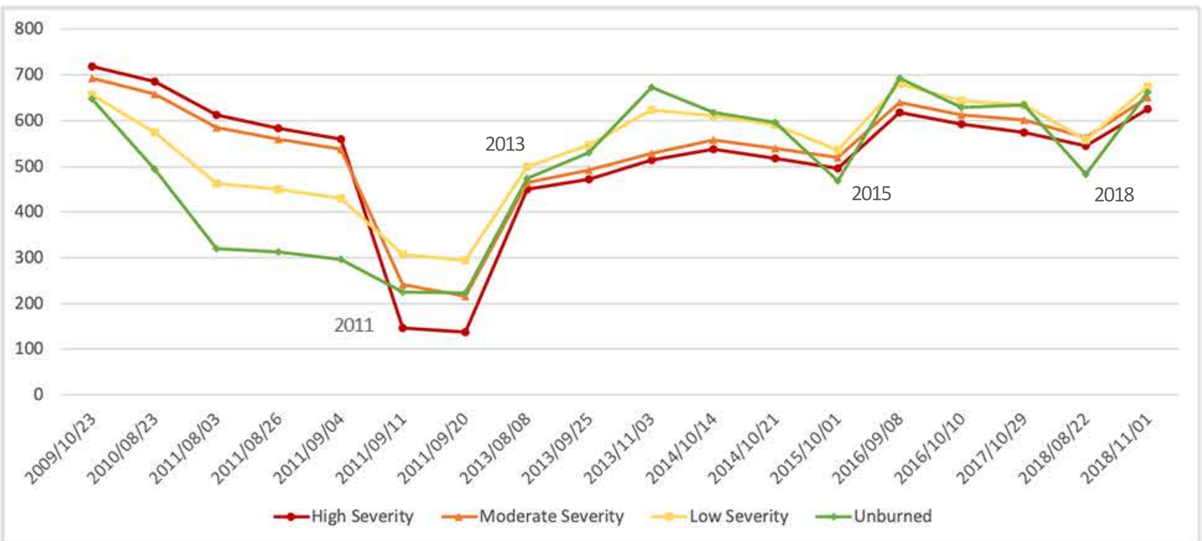

Fig.3. Plot of mean **NDVI** over time per burn severity. Each of the colored lines correspond to the defined burn severities of **Unburned**, **Low**, **Moderate**, and **High Severity**. The patterns displayed by the various burn severities are fairly similar to the general trend, but the **Unburned** and **Low Severity** lines appear to have many more fluctuations, indicating that they are more influenced by changes in heat and precipitation while more severely burned areas were more focused on regrowth.

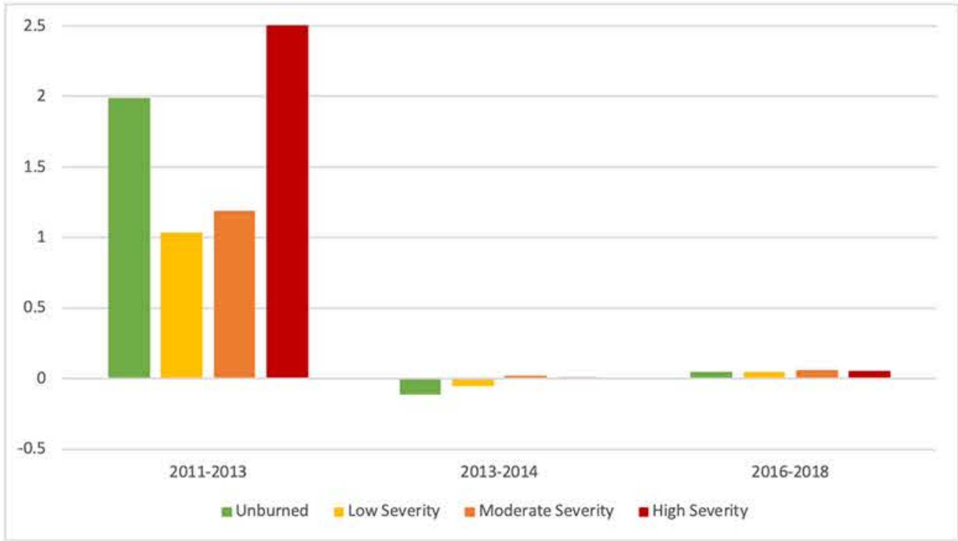

Fig. 4. Graph of percent change in **NDVI** over time per burn severity class for three chosen clusters of time. A clear trend can be observed with the first two clusters that the higher severity levels experienced greater percent changes in **NDVI**, but the most recent cluster shows the four severity levels experiencing similar percent changes, suggesting a plateau point.

6. GROUND TRUTHING

To confirm the geographical features observed by the spectral analysis of **Landsat** bands, qualitative field data was collected across various sampling points in the **Griffith League Scout Ranch.** The variance of vegetation regrowth appears to be largely consistent with predictions of **dNDVI** as classified by burn severity using satellite imagery.

Fig. 5. Sampling transect near edge of burn scar. Organized recovery efforts involving professional replanting were more effective than logging at expanding the area of regrowth, but clumps of natural regeneration experienced the most rapid rates of development in all.

7. CONCLUSIONS

Both the satellite analysis and field investigation **validate** the expected contrast of behavior between the burned versus unburned areas and the different levels of burn severity.

- Areas of higher burn severity tended to have greater changes in **NDVI**, although this may be temporary as the **NDVI** leveled off in more recent years.
- Mean **NDVI** over time indicated a rapid recovery, but the field study indicated that there are still drastic differences by burn severity in terms of the vegetation count and form. The longer rebound period can be attributed to the severity of the disaster.
- Natural and anthropogenic factors such as areas with targeted replanting, streams, and natural regeneration tended to recover faster than areas with post-fire logging.

8. FUTURE RESEARCH

The positive correlation between burn severity and vegetation regrowth opens up investigations regarding the severity of prescribed controlled burns best suited for maximizing ecosystem health. Similar ground-truthing methodologies may also provide scientists with avenues to explore the effects of species diversity on regrowth.

9. ACKNOWLEDGEMENTS

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