Evaluation of Satellite Imagery Based and Visual Estimation Methods for Quantifying Wildland Fire Severity in the New Jersey Pinelands

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1. Introduction

Extreme weather and increasing forest insect outbreaks can quickly prime forests for increased wildfire frequency and extreme fire behavior. Multiple studies suggest that fire regimes may already be changing, due to worldwide climate change. This represents an important challenge for managers who must deal with fire's important role in ecological resilience and as a serious threat to public safety. Quantifying fire impacts across broad spatial expanses is integral to advances in wildland fire research and to improve fire management strategies. Remote sensing techniques, using the middle and near infrared bands, are now commonly used by researchers and managers to assess fire severity; however multiple studies have yielded inconsistent results between systems. Many studies have not compared results however to physical change in forest mass, but rather visual criteria. Here we present our ongoing fire severity study in the high fire frequency New Jersey Pinelands (Figure 1)

2. Objectives

1) Evaluate the relationship between estimates of fire severity generated by satellite imagery, visually assessment, and field measurement methods.
2) Evaluate the relationship between fire intensity and satellite estimates of burn severity.
3) Estimate distributional patterns for wild and prescribed fire severity for the NJ Pinelands.

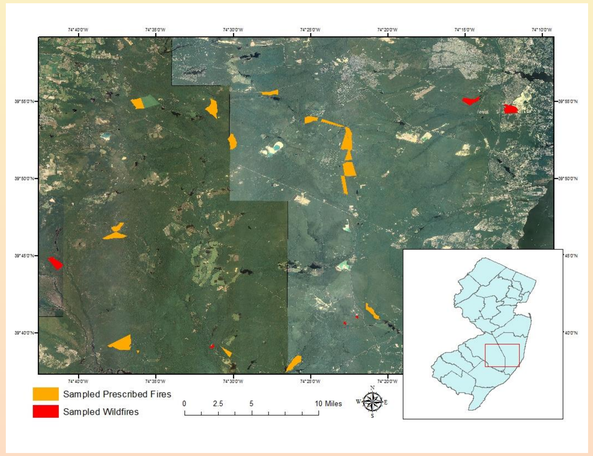


Figure 1. Study area in the northern New Jersey Pinelands, Burlington and Ocean Counties. Our study includes field measurements at 25 prescribed and wildfires that burned between February 2013 and July 2014.

3. Wildland Fire Severity Estimation

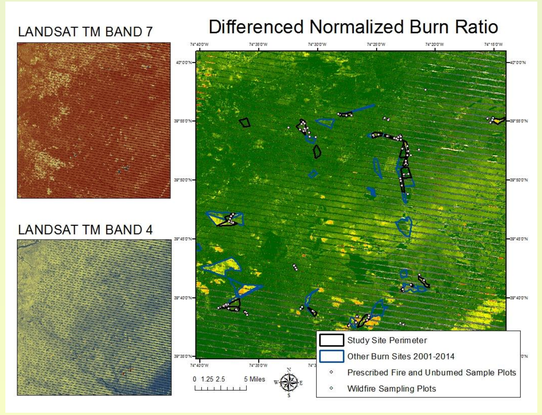


Figure 2. Differenced normalized burn ratio map of study area created using 2013 and 2014 leaf-on data. Wild and prescribed fire appear yellow and red, whereas very low severity and unburnt areas appear green.

3a. Satellite Imagery Based Methods

Multiple algorithms for estimating fire severity have been developed using satellite imagery. The most widely used employ near-infrared and mid-infrared bands, because each are sensitive to altered vegetation reflectance and exhibit low correlation between each other. We will be examining differenced normalized burn ratio (dNBR), the most commonly cited method used, as well as dNBR, RBR, and rdNBR (Figure 2).

3b. Visual Assessments using Composite Burn Index (CBI)

The Composite Burn Index is the most commonly used ground-based fire severity estimation method. CBI is generated by integrating visual estimations of vegetation change, or Burn Indices (BI), from multiple forest strata to develop the final CBI estimate (Figure 3). We have conducted CBI surveys at 52 prescribed fire plots, 38 wildfire plots, and 24 unburned 90m2 plots.

Figure 3. Severity estimates for 3 2014 Pinelands burn units. Low severity (CBI=1.3), Med. Severity (CBI = 1.85), High Severity (CBI = 2.66)

3c. Field Based Fire Severity Estimates

We have quantified pre- and post burn fuel at the same 114 plots where CBI surveys were conducted. Downward scanning LiDAR was used to estimate pre- and post burn canopy fuel load distributions (Figure 4a). Shrub, and forest floor fuels were estimated pre and post burn as oven dry weights of destructively harvested samples from three, 1m^2 sub plots per plot (Figure 4b). Duff loss was estimated using duff pins. Adjacent unburned areas were used to estimate pre-burn shrub, forest floor, and duff fuels at wildfire sites.

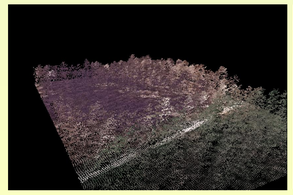
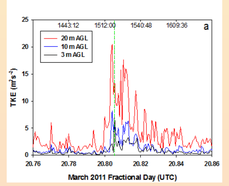
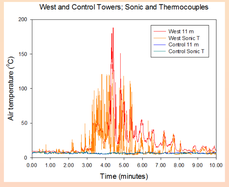


Figure 4a. 3D image of post burn canopy fuels generated using LiDAR,

Figure 4b. Destructive harvest of shrub and forest floor fuels and duff pin measurements.





3d. Wildland Fire Intensity Estimates

Wildland fire "intensity" relates to energy release and is correlated with wildland fire behavior (e.g. low intensity behavior vs. extreme fire behavior). We have measured fire behavior at 12 in-fire locations between 2011 and 2014 using custom meteorological towers (Figure 5). A fifth burn in 2015 will yield 3 more in fire estimates of fire behavior. Because these data are being repurposed from another project, we will be comparing only temperature and turbulence data with remotely sensed estimates of fire severity at these locations.

Figure 5. Custom meteorological towers measure conditions in New Jersey Pinelands prescribed burns

4. Preliminary Results

Our preliminary analysis has found strong relationships between remotely sensed severity estimates, visually assessed CBI, and at least one component of our fuel mass change estimates (Figure 6). Pre- and post burn forest floor fuel loading estimates suggest that fuel consumption is strongly proportional to pre-burn fuel loading (Figure 7). We analyzed average fire severity for wild and prescribed fires in 2014 in the northern NJ Pinelands and found that wildfires were on average more severe than prescribed fires, but also shared considerable overlap in severity distributions (Figure 8).

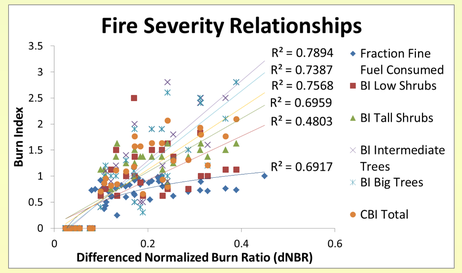


Figure 6. Relationship between dNBR, visual, and measured understory burn severity

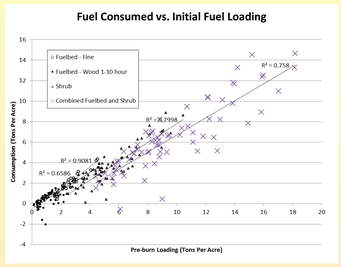


Figure 7. Pre- and post burn forest understory fuel loading relationships from wild and prescribed fire sites

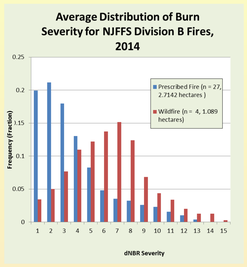


Figure 8. Frequency of fire severity in wild and prescribed fire, standardized by area.

5. Ongoing Research and Implications

We are presently analyzing canopy structural data, dNBR for 2013 burns, and fire intensity data. The ability to use satellite based severity estimates will enable researchers to objectively stratify future fire effects work on fire severity and better compare different burn units. This will also aid in management, by providing managers a better way to study conditions following severe fires, and to analyze effectiveness used in fire danger mitigation operations

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