# A Coupled Approach to Evaluate the Dynamic Linkage between Fuel Treatment Effects on Fuel Matrices and Effectiveness at Reducing Wildfire Intensity and Spread Rate.


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## Introduction

Over the past ten years, ≈ $5.6 billion has been spent on hazardous fuel reduction to treat an average of ≈ 1 million ha $yr^{-1}$ across the United States (Gorte 2011, NIFC 2011). These expenditures represent one of our nation's primary strategies for the mitigation of catastrophic wildland fire events. However, a recent Government Accountability Office study illustrates the paucity of research in this area stating: "The agencies, for example, still lack a measure of the effectiveness of fuel reduction treatments and therefore lack information needed to ensure that fuel reduction funds are directed to the areas where they can best minimize risk to communities and natural and cultural resources (GAO, 2009)." Our study takes a synthetic approach to blend field-based experimentation, landscape-scale fuels quantification, and multiple-scale, computational fluid dynamics modeling to examine both the effect of fuel reduction treatments and the effectiveness of these treatments at mitigating fire spread and intensity across a range of conditions.

## Objectives

1. Quantify the effect of fuel reduction treatments on three-dimensional canopy and forest floor loading.
2. Implement and evaluate the Wildland-urban interface Fire Dynamics Simulator (WFDS) using coupled laboratory and *in situ* observations of the fire environment.
3. Simulate and evaluate the effectiveness of resultant fuel structures at mitigating fire spread rates and intensities over a variety of meteorological scenarios.

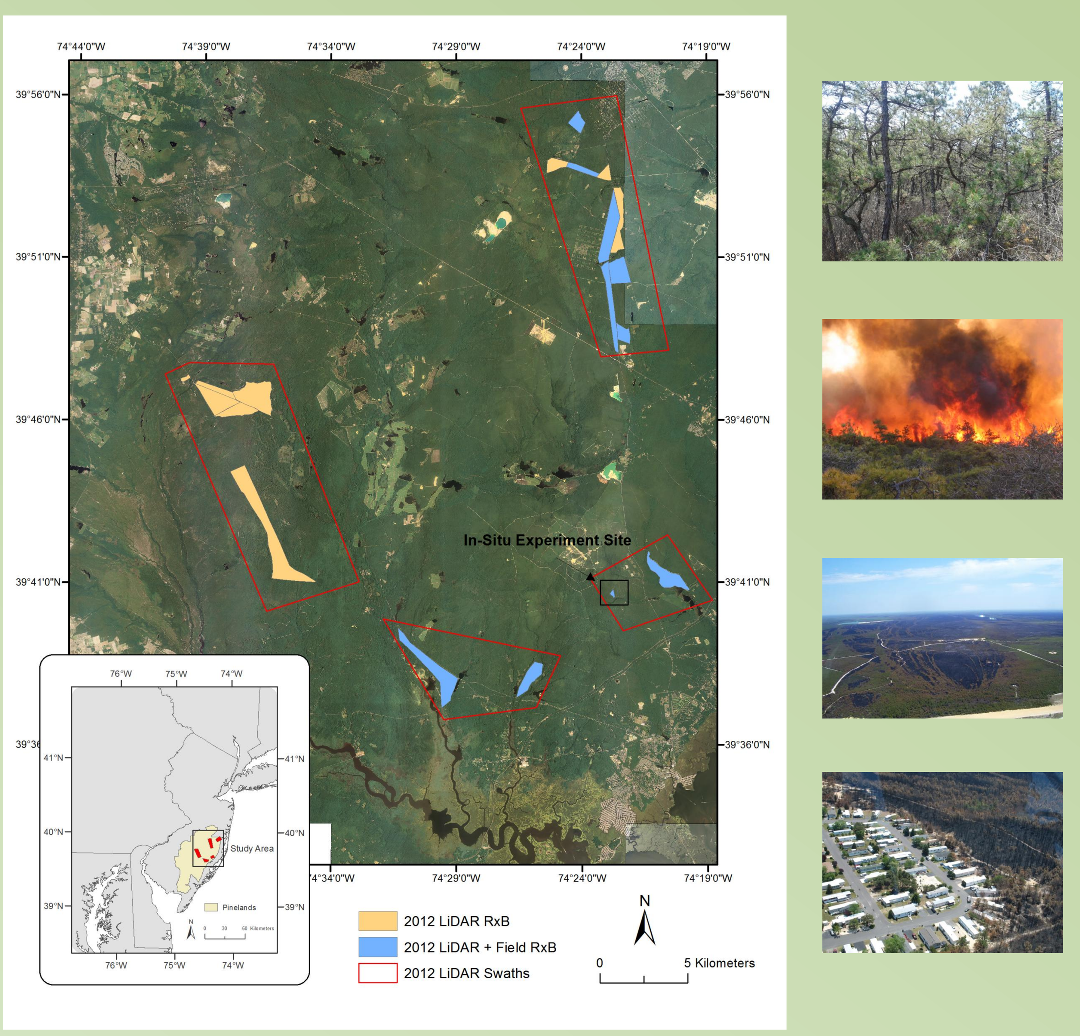


**Figure 1.** The New Jersey Pine Barrens (NJPB) cover 0.5 million ha, 23% of the state. These flammable forests occur adjacent to dense Wildland Urban Interface (WUI) and key transportation corridors. The NJPB averages 1500 wildfires per year, typically burning ca. 3000 ha. A wind driven wildfire in 1963 burned 74,000 ha over the course of 2 days. Recent fires in 1995 and 2007 burned 7,700 and 6,250 ha, respectively. The landscape is actively managed by state and federal agencies who treat ca. 8,000 ha $yr^{-1}$ with prescribed fire annually. Mechanical treatment is a typically unsupported option because of the rigid environmental restrictions in this area, but small pilot treatments have recently been conducted.

## Fuel Treatment Effects

We are sampling fuel treatment effects on 3-D and forest floor fuel properties in ≈ 20 parcels (Fig. 1 shows the Year 1 sampling, ca. 100 ha each). We are using a combination of:

### *Field Sampling* (10 parcels $yr^{-1}$, pre- and post- treatment)

- Forest Floor bulk sampling
- Long-term Biometric plot installation
- Terrestrial LiDAR profiles and scans (TLS)

### *Airborne Laser Scanning (ALS)*

- $T_0$ : 2000 km$^2$ Base Area (completed 12/12)
- $T_1$ : 10 post-treat parcels (Fig. 1; 4/2013)
- $T_2$ : $T_1$ remeasure and 10 additional post-treat (4/2014)

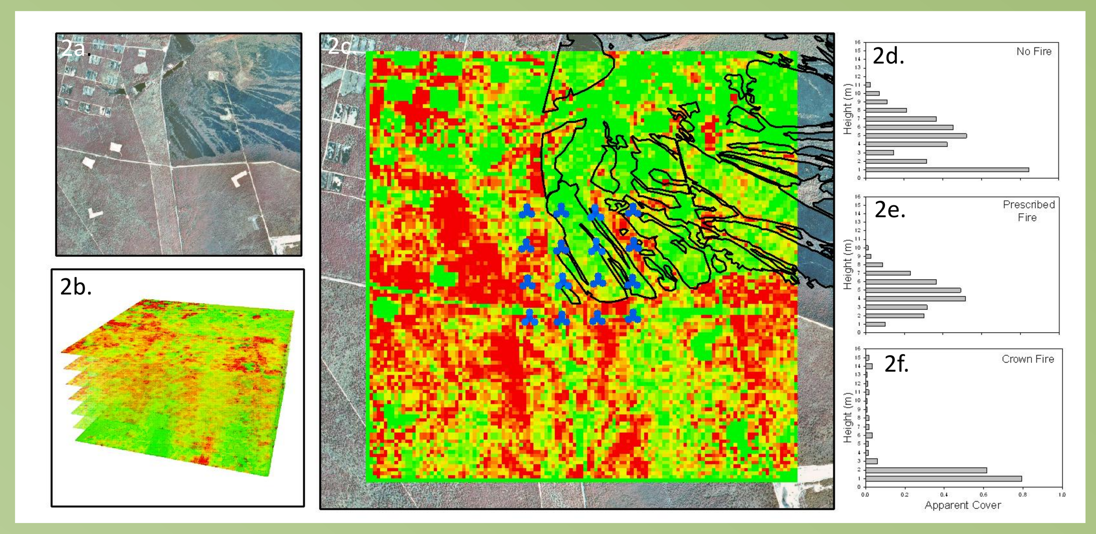


**Figure 2.** Example of an ALS-based 3-D representation of canopy fuels (Canopy Bulk Density, CBD) over a 3 x 3 km domain burned by a highly variable crowning wildfire in 1995 (Fig. 2a). Fig. 2b illustrates a raster stack of canopy bulk density with 25 x 25 m vertical and 1 m horizontal resolution (field calibrated; see Clark et al.: "Assessing Canopy Fuels Across Heterogeneous Landscapes Using LiDAR" poster at this conference) . Fig. 2c shows $CBD_{sum}$ (sum of raster stack fuels for each pixel). Figs. 2d-f are examples of canopy fuel distribution for individual cells. LiDAR data was collected 10 years post-fire.

## WFDS Implementation and Evaluation

To implement WFDS in a relevant way, we are combining extensive observations that scale from individual fuel particles in a laboratory environment to parcel-scale operational burns.

### *Laboratory Observations*

Our laboratory evaluation focuses on characterizing the physical properties and burning dynamics of the fuels that are most commonly combusted in the NJPB. Bulk physical properties for these fuels include: Particle density, surface/volume, bulk Density and porosity. Burning dynamics include heat release rates, time to ignition, time of flaming combustion, time of smoldering after flameout and ignition temperature.

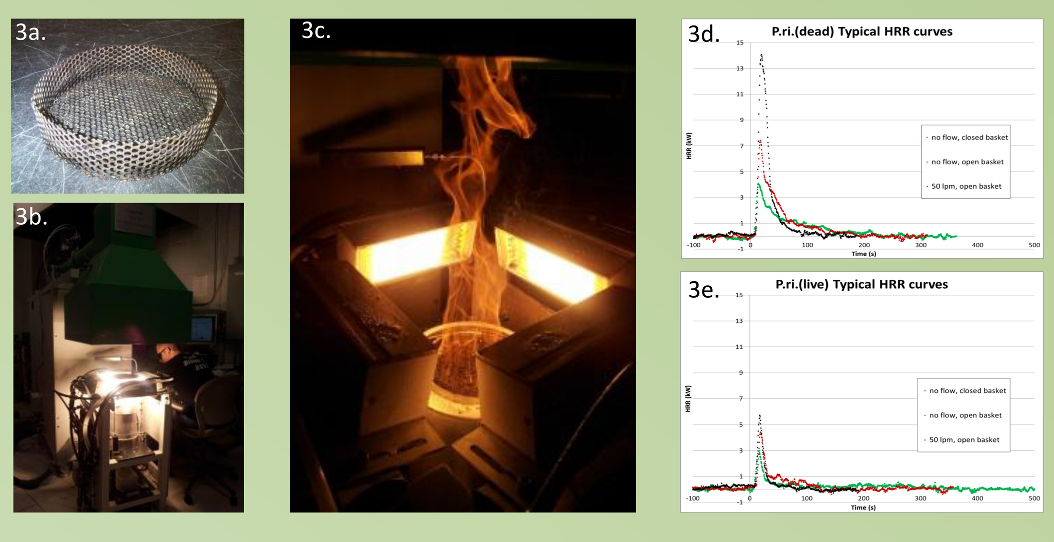


**Figure 3.** Figs. 3a-c are examples of experimentation with the FM Global Fire Propagation Apparatus. Figs. 3d-e are examples of temporal heat release from dead (Fig. 3d) and live (Fig. 3e) pitch pine needles over numerous experimental configurations.

## *In situ Observations*

We are making fire-environment observations on 2 contrasting prescribed fires. The first, in early-march of 2013, is a site with high loading and extensive ladder fuels and thus has a considerable probability of experiencing crowning behavior.

### *Fuels*

Fuel characterization has been done at this site with a large-scale ALS acquisition that is informed by nested TLS and field sampling at 12 fixed plot locations (Fig. 4a). These measurements will be repeated following the burn providing measures of combustion and fire intensity.

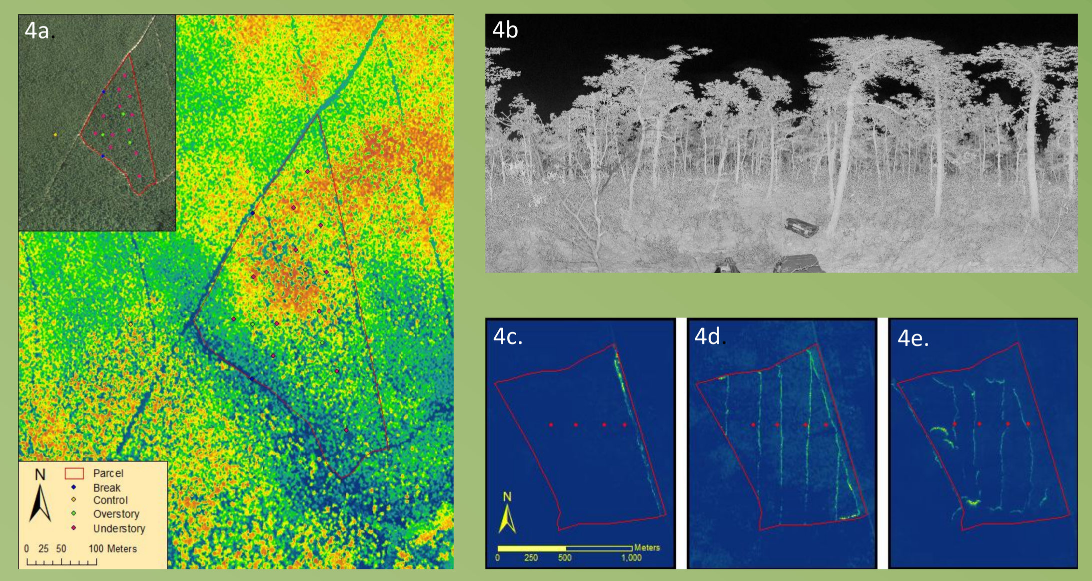


**Figure 4.** Fig. 4a illustrates the 2013 RxB experimental parcel as a RGB image (inset) and as a 1m horizontal resolution, ALS-derived, canopy height model. The spatial arrangement of the tower array is also illustrated in Fig. 4a. Fig 4b is a scan from a Faro TLS at a single understory plot location. Figs. 4c-e are a sequential example of the images provided by the RIT WASP infrared sensor (left to right, ≈ 30 minute timestep). The red dots are provided as reference to illustrate the progression of the fire. The vertical features are plowed fire breaks that were used to divide the parcel for control purposes and lit sequentially against the wind.

### *Fire Environment*

The fire-environment will be monitored extensively using measurements from an array of overstory and understory towers (Table 1). The spatial arrangement was designed for a NW prevailing wind but will accommodate other directions (Fig. 4a). We will also be collecting time-resolved airborne multi-spectral images via the RIT WASP instrument. This overhead data will provide information on thermal heat release at ≈ 1 m resolution over the fire ground (Figs. 4c-d).

**Table 1.** Measurements for RxB Experiments.

| Measured aspect | Quantity | Device |
|---|---|---|
| Fire behavior | Rate of spread and fire shape | Airborne Infrared camera |
| | | Visible cameras |
| | Temperature | Thermocouples |
| | Radiant Flux Density | Dual band infrared radiometers (12 per fire) |
| | | Heat flux meters |
| | Flame height | Visible cameras |
| Fuel properties and fuel consumption | Fuel load pre- and post-fire | Airborne and Terrestrial LiDAR |
| | | Destructive sampling of vegetation and litter |
| | Geometry of vegetation | Visible camera |
| | Fuel Moisture | In situ collection and laboratory weighing and drying |
| Meteorological conditions | Turbulence and meteorological measurements. | Sonic anemometers and standard meteorological equipment. |

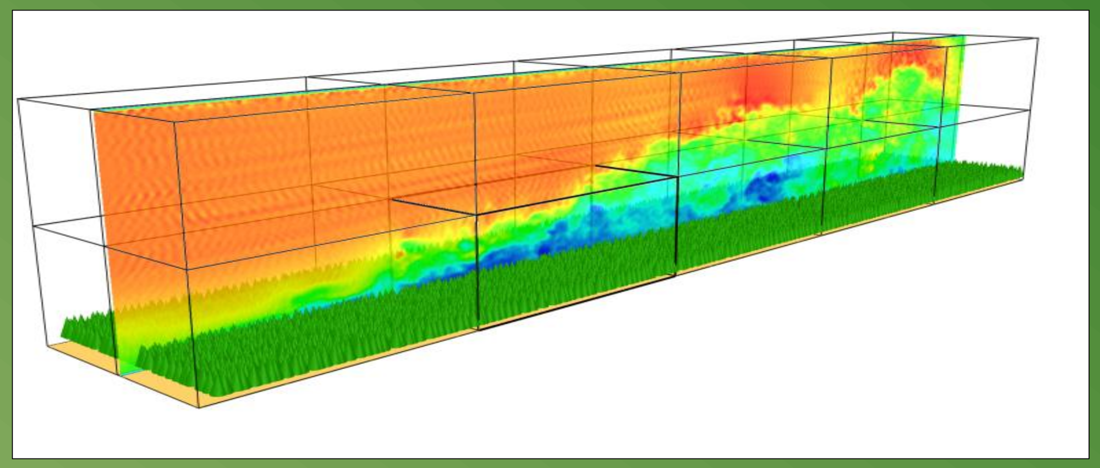

**Figure 5.** Sample Smokeview visualization of WFDS output. Stream-wise velocity component at the edge of a densely forested area.

## Simulation of Treatment Effectiveness

The final step of this project will consist of an integration and synthesis of the quantified treatment effects and observational experimentation. WFDS will be configured to perform a set of sensitivity analyses designed to integrate measured canopy and forest floor loadings with a range of climactic and meteorological conditions. These analyses will be designed to assess the efficacy of measured fuel treatments at mitigating fire spread and intensity, while determining theoretical thresholds at which the treatments become ineffective. This integrated approach provides an opportunity to inform both pressing management and theoretical knowledge gaps. The advantages and limitations of the approach will be compared to commonly used semi-empirical models.

## References


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US Government Accountability Office. 2009. *Wildland fire management—Federal agencies have taken important steps forward but additional strategic action is needed to capitalize on those steps*. GAO-09-877. 45 pp.


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