Assessing Canopy Fuels Across Heterogeneous Landscapes Using LiDAR

Kenneth L. Clark[1], Nicholas Skowronski[2], Michael Gallagher[1], Nicholas Carlo[1], Michael Farrell[1], and Melanie Maghirang[1]
[1]Silas Little Experimental Forest, USDA Forest Service, 501 Four Mile Road, New Lisbon, NJ 08064
[2] Carbon, Fire, and Climate Sciences, USDA Forest Service Northern Research Station, 180 Canfield St., Morgantown, WV 26505

Introduction

LiDAR (Light Detection and Ranging) systems are indispensable for estimating 3-dimensional structure of forest canopies. LiDAR data provide significant advantages over biometric, inventory-based approaches to quantifying canopy fuels, including the ability to conduct rapid, landscape-scale assessments at high resolution, and an accurate quantification of damaged, non-uniform crowns.

However, for a truly accurate determination of canopy fuels, it is essential to calibrate LiDAR signals against destructive harvest data, preferably with concurrent LiDAR acquisitions and sequential harvesting of trees to quantify fuels in 1-meter layers. This crucial step is frequently omitted from studies which have generated canopy fuel assessments using LiDAR technology.

We are improving estimates of canopy fuel loading in Pitch pine (*Pinus rigida* L.) stands for wildland fire managers in the New Jersey Pinelands by integrating sequential tree harvests with repeated upward-profiling LiDAR sampling in 20 m x 20 m plots (Figure 1). We then use wide-ranging Airborne Laser Scanning (ALS) data to scale canopy fuel estimates across a heterogeneous landscape consisting of stands of various age, structure, and wildfire history.

Here we report on; 1) our progress on the calibration of LiDAR data with biometric data derived from sequential harvests to quantify crown fuel weight (CFW) and canopy bulk density (CBD) in 1-meter height bins, 2) the comparison of profiling and scanning ALS data in Pitch pine stands of varying structure, and 3) the development of initial landscape-scale canopy fuel loading maps.

Acknowledgements: This research was supported by the Joint Fire Science Program and NRS-06, USDA Forest Service .

Figure 1. One of the 20 m x 20 m harvest plots containing wildfire-damaged Pitch pine in the New Jersey Pinelands. This stand was burned in the 2007 Warren Grove wildfire.

Results and Discussion

To date, we have harvested 180 live trees and 95 snags in five 20 m x 20 m plots, and separated, dried and weighed all needles and live and dead 1-hr, 10-hr, 100-hr and 1000-hr woody fuels in 1 meter height increments (Table 1).

Table 1. Biometric information for the five 20 m x 20 m calibration plots dominated by Pitch pine that were destructively harvested in 2010-2012.

Plot	#	Height m	DBH cm	BA m^2 ha^{-1}	Biomass t ha^{-1}	Needles g m^{-2}
HR3	32	10.3 ± 2.2	17.3 ± 4.3	19.9	78.4	441
HR1	57	7.6 ± 1.8	13.2 ± 4.1	21.5	67.0	422
HR2	45	10.0 ± 1.3	15.9 ± 4.1	23.7	91.7	528
DH1	19	14.6 ± 3.1	23.0 ± 7.1	21.5	107.9	498
DH2	27	12.2 ± 5.3	18.3 ± 9.5	22.4	106.7	509

An upward profiling LiDAR point cloud from one of the plots before harvest is shown in Figure 2a. The vertical canopy height profile and calculated canopy bulk density from biometric data are shown in Figure 2b.

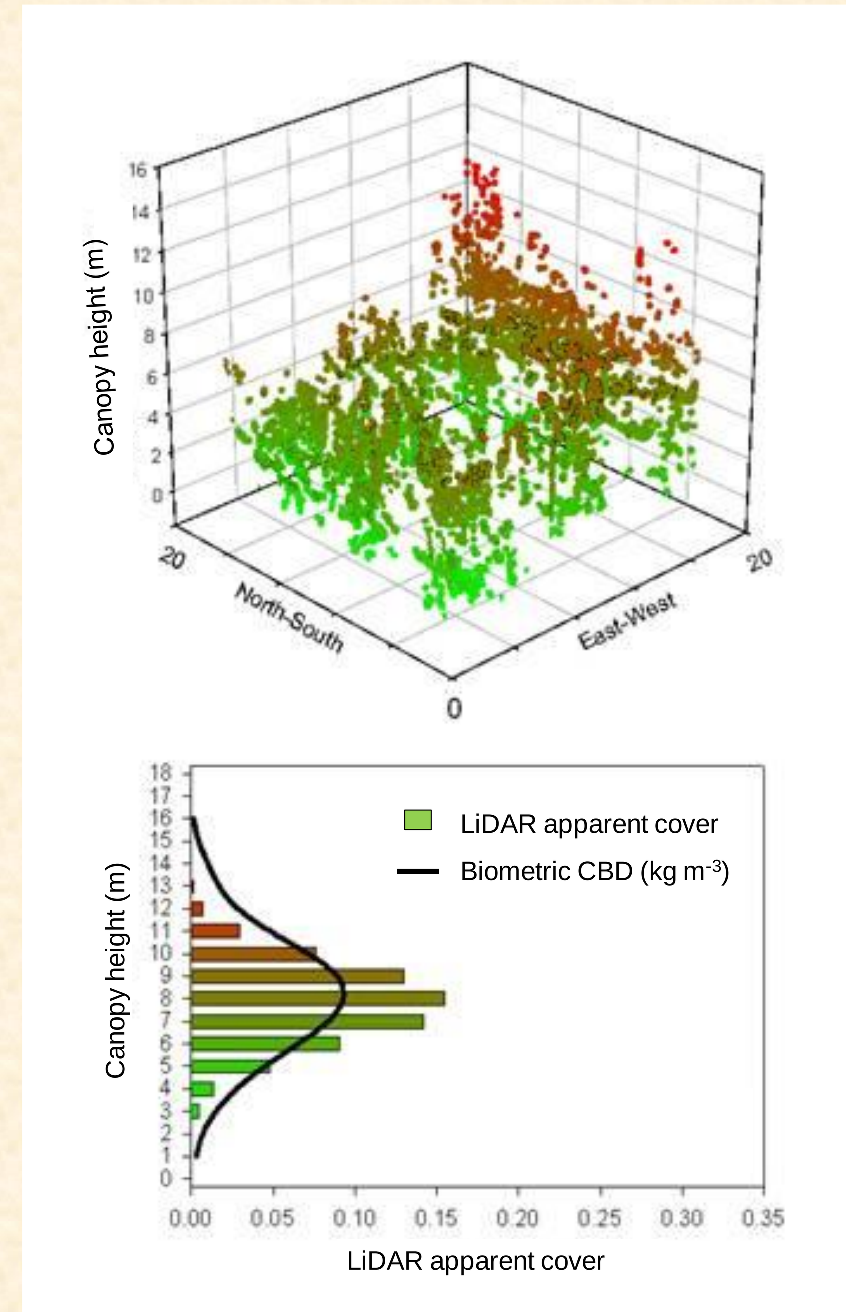

Figure 2a. Upward profiling LiDAR data for one of the 20 m x 20 m plots before harvest. Figure 2b. LiDAR apparent cover and estimated canopy bulk density (kg m^{-3}).

We then calibrated LiDAR returns with available fuels estimated from the sequential harvest data. Regression equations relating crown fuel weight to LiDAR returns were highly significant (Table 2).

Table 2. Relationships between crown fuel weight (CFW) of canopy fuels and profiling LiDAR returns, expressed at % percent of pre-harvest returns above 2 meter height. CFW units are g m^{-2}.
All models are significant at $P < 0.001$.

Variable	Equation	r^2	F
Available fuel	y = 18.8 x + 77.0	0.97	306.2
Needle mass	y = 6.7 x + 35.0	0.97	261.5
1 + 10 hour live	y = 8.7 x + 28.7	0.98	511.9
1 + 10 hour dead	y = 4.1 x - 11.5	0.99	1020.2
1 + 10 hour all	y = 12.8 x + 17.2	0.99	924.3

Regression equations developed from destructive harvests to predict CBD in 1-meter layers from upward-scanning profiling LiDAR data and downward-scanning LiDAR data were also highly significant, with r^2 values ranging from 0.71 to 0.98.

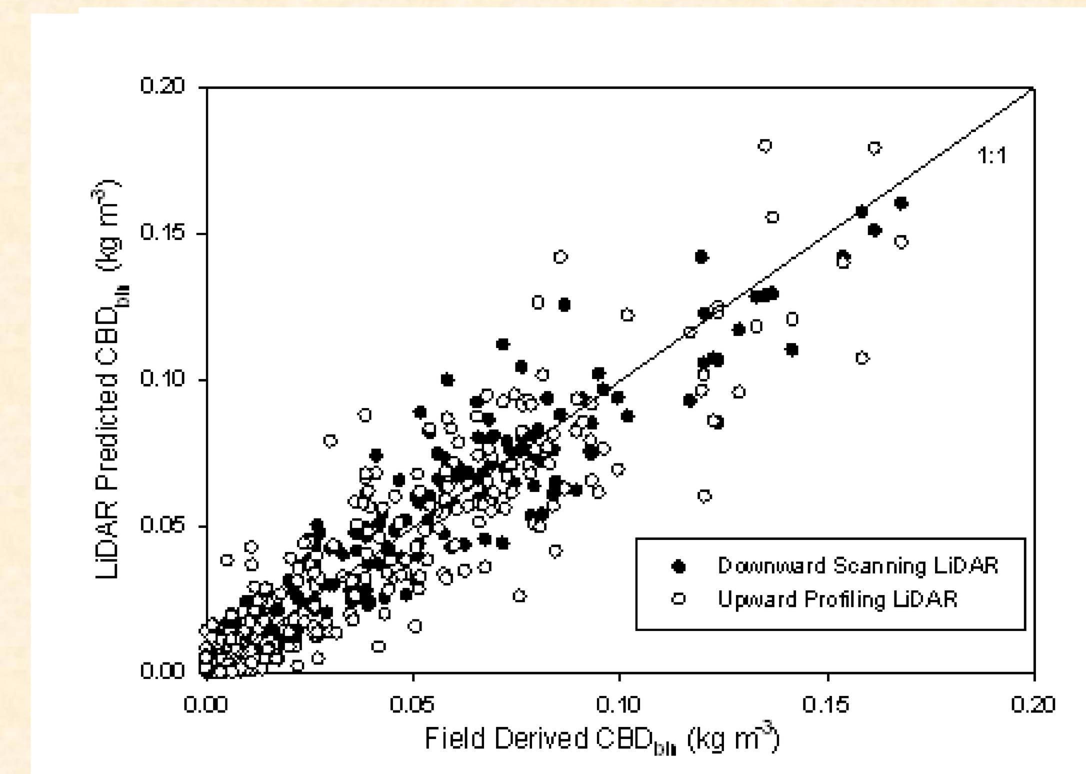

Figure 3. Predicted values of CBD_{bin} from equations for upward profiling LiDAR (open symbols) and downward scanning LiDAR (closed symbols), plotted against biometric estimates of CBD_{bin} in 1-meter layers.

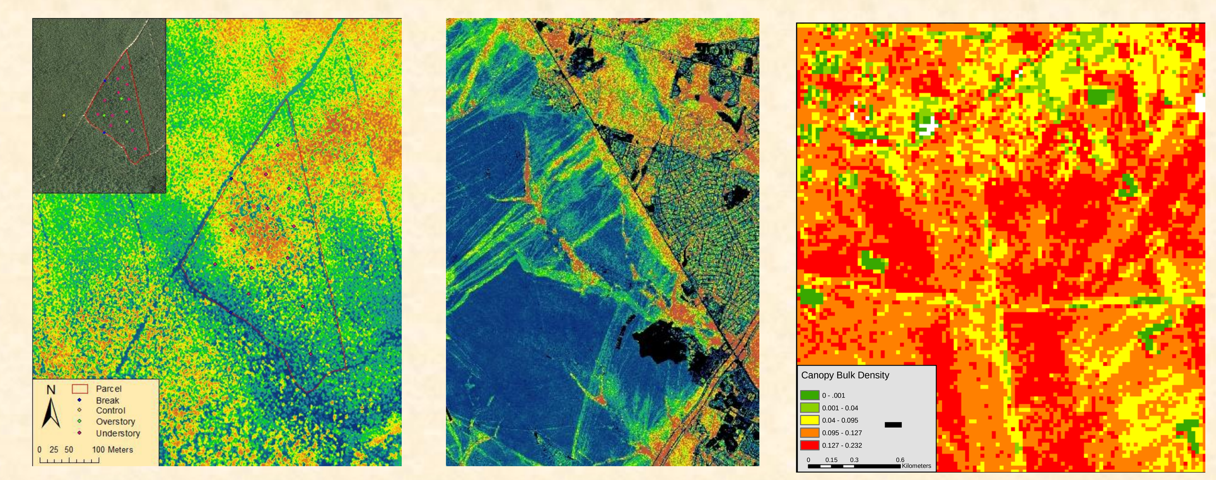

Figure 4a,b. Examples of Scanning LiDAR canopy height profiles that can be used to calculate accurate values of maximum CBD in 1-meter layers, as shown in Figure 4c.

Conclusions

Although the initial calibration of LiDAR using destructive harvests is time-consuming, unambiguous estimates of canopy fuels can then be used to produce highly accurate maps of canopy fuels for hazardous fuels assessments and modeling of fire behavior.