Factsheet # 4
LiDAR Derived Canopy Fuel Metrics for Wildfire Modeling

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Understanding multiscale dynamics of landscape change through the application of remote sensing & GIS

Introduction: Wildfire behavior modeling programs like FARSITE and FlamMap utilize spatial data like fuels, topography and weather to predict wildfire growth and crown fire initiation and propagation. They require inputs of canopy height (CH), canopy bulk density (CBD) and canopy base height (CBH) to create spatial layers for modeling fire growth within crown fuels (Finney, 1998; Finney, 2006). Previously, most of these inputs were derived from layers of coarse resolution which led each pixel to be spatially homogeneous below the scale of resolution (Finney & Andrews, 1994). In reality, forest fuels are heterogeneous and by allowing inputs down to 10 m resolution, canopy fuels can be mapped more accurately and modeled accordingly (Kato *et al.*, 2007).
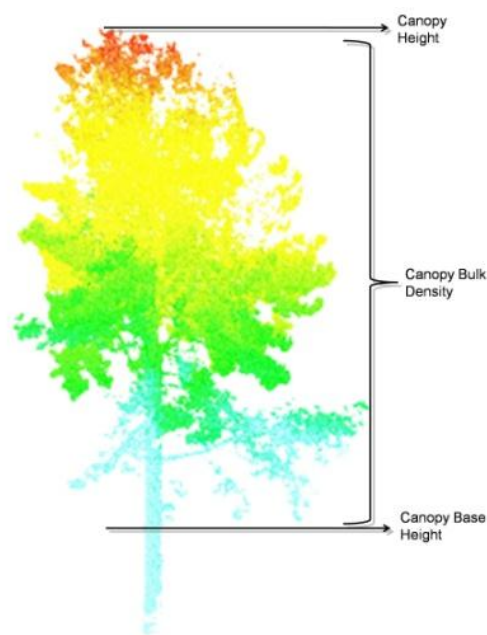

Above: Examples of canopy fuel metrics
Below: Sample of a LiDAR point cloud representing a field plot
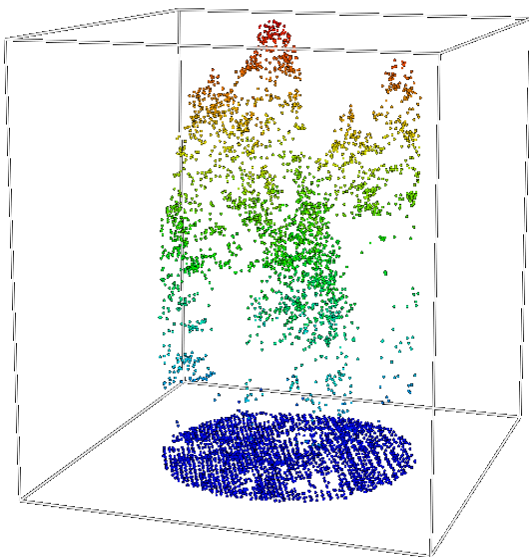
Canopy Fuel Metrics: Canopy height (CH) is defined as the highest height at which the canopy fuel density within a stand is less than 0.012 kg/m³. Canopy base height (CBH) is defined as the lowest height at which the canopy fuel density within a stand is greater than 0.012 kg/m³. In terms of crown fire initiation CBH is the lowest height above the ground where there is enough canopy fuel to support a fire vertically through the canopy. Canopy bulk density (CBD) is defined as the maximum 5 ft running mean of canopy fuel density within a stand. In terms of crown fire initiation it is the mass per unit volume of canopy biomass that would burn in a crown fire (twigs and foliage <3mm diameter) (Reinhardt et al., 2006). Of the three, CBD is the most difficult to quantify due to multiple canopy layers (Perry et al., 2004). One should also note that the term 'canopy' refers to the whole stand whereas 'crown' is a characteristic of an individual tree

Study Area: Regression models were built using field data collected in the Ahtanum State Forest (Washington DNR) on the east slopes of the cascades. This forest is characteristic of Eastern Cascade dry forests, dominated by Ponderosa pine (*Pinus ponderosa*) and associated mixed mesic conifers like Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engalmanii*) and western larch (*Larix occidentalis*).

Methods and Results: LiDAR metrics were extracted out of the dataset using FUSION software (McGaughey, 2007). Fuel metrics were extracted out of the field data using FuelCalc (Reinhardt et al., 2006). Regression models were built using R software (http://CRAN.R-project.org). The results are shown in the graphs on the left. Each graph shows a 1:1 relationship line. By modeling these fuel metrics in this specific forest type, the goal is to further validate these models in similar forests. Additionally, maps of each canopy fuel metric can be produced at desirable resolutions for use in wildfire modeling, wildfire planning and smoke emission estimations.
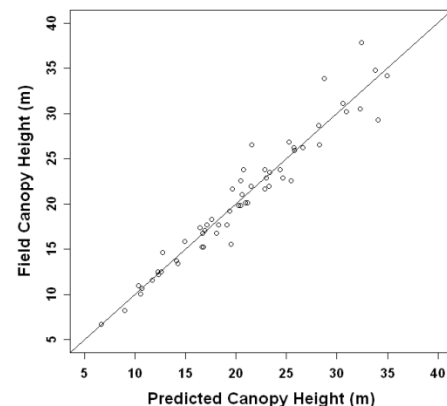
Predicted versus Field-measured canopy height (R²=0.94, P-value <0.0001)
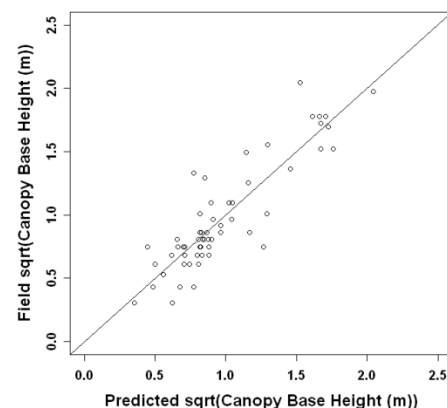
Predicted versus Field-measured (square-root transformed) canopy base height (R²=0.78, P-value <0.0001)
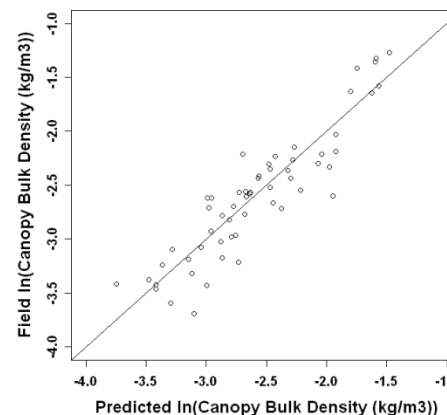
Predicted versus Field-measured (log-transformed) canopy bulk density (R²=0.83, P-value <0.0001)

THE ISSUE: Canopy fuel metrics are needed as inputs to wildfire and smoke models but the raster layers for these metrics are too homogenous at coarse spatial resolutions. LiDAR has been utilized for measuring various forest structure characteristics at high resolution. Regression models using LiDAR metrics were developed for Ponderosa pine stands representative of eastern WA. By improving the ability to estimate canopy fuels at higher resolutions, spatially explicit fuels layers can be created and used in wildfire and smoke models leading to more accurate estimations of crown fire risk and particulate emissions.

THE KEY QUESTIONS:
Can canopy fuel metrics be derived from LiDAR in a fire-prone forest?