Forest management and climate change impacts on understory microclimates

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Introduction

- Forests create their own microclimates. If you've ever stepped into a cool forest on a hot summer day you've felt the effect of the forest canopy buffering the understory from extreme conditions (**Figure 1**).
- As the climate continues to warm, this buffering effect may become increasingly important for advance regeneration of climate sensitive tree species at their southern range margins[1].
- Management and climate change stressors can alter forest stand structure and composition in ways that may reduce understory buffering and surpass critical climate thresholds for regeneration[2,3].
- Therefore, there is a need to better understand how stand structure and composition relate to understory microclimates in the face of climate change.

Goal & Objectives

GOAL: Better understand how forest stand structure affects understory responses to climate change.

OBJECTIVES

1) Determine the extent to which forest stand structure and composition drive understory microclimate buffering in different times of year
2) Determine the effectiveness of airborne measurements for predicting landscape-level microclimate buffering

Methods

Microclimate buffering: the difference between forested and non-forested climate conditions at any given time

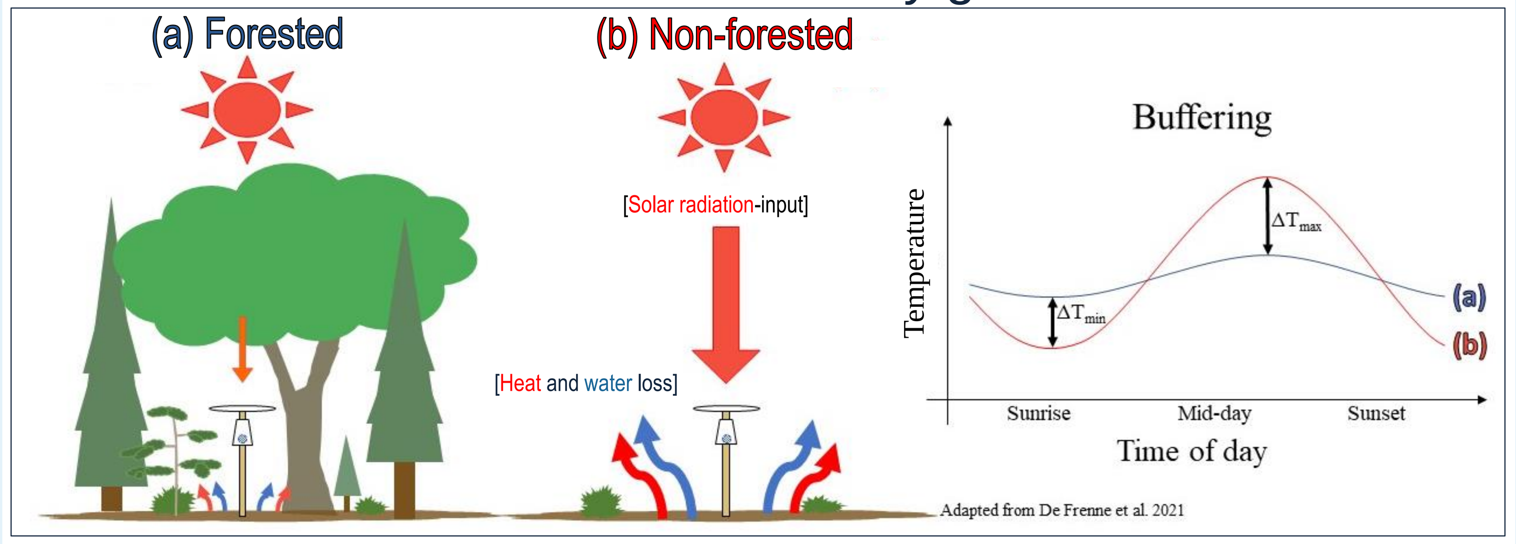


Figure 1. Microclimate buffering between (a) forested and (b) non-forested sites. Non-forested sites receive greater solar input and release more heat and moisture compared to forested sites, which can lead to larger daily fluctuations in temperature and relative humidity.

- We established 60 survey plots across a broad range of canopy structures and compositions in managed stands at the Penobscot Experimental Forest in Maine
- Microclimate (temperature and relative humidity) was sampled every 2 hours at each site with remote data loggers
- We measured basal area, stem density, and canopy closure using traditional forest inventory methods and airborne laser scanning (ALS, airborne lidar; **Figure 2**).

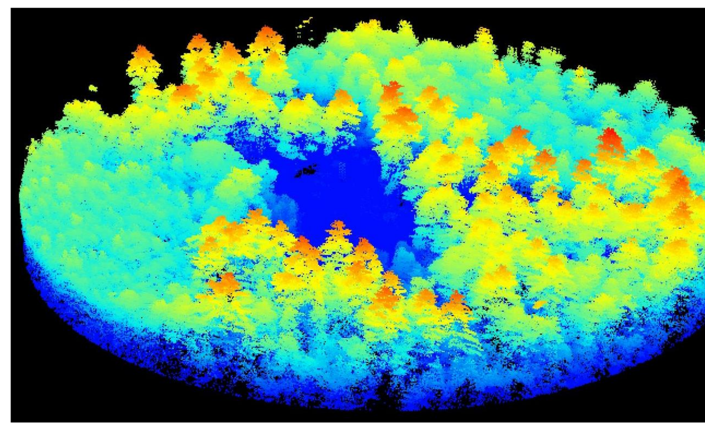
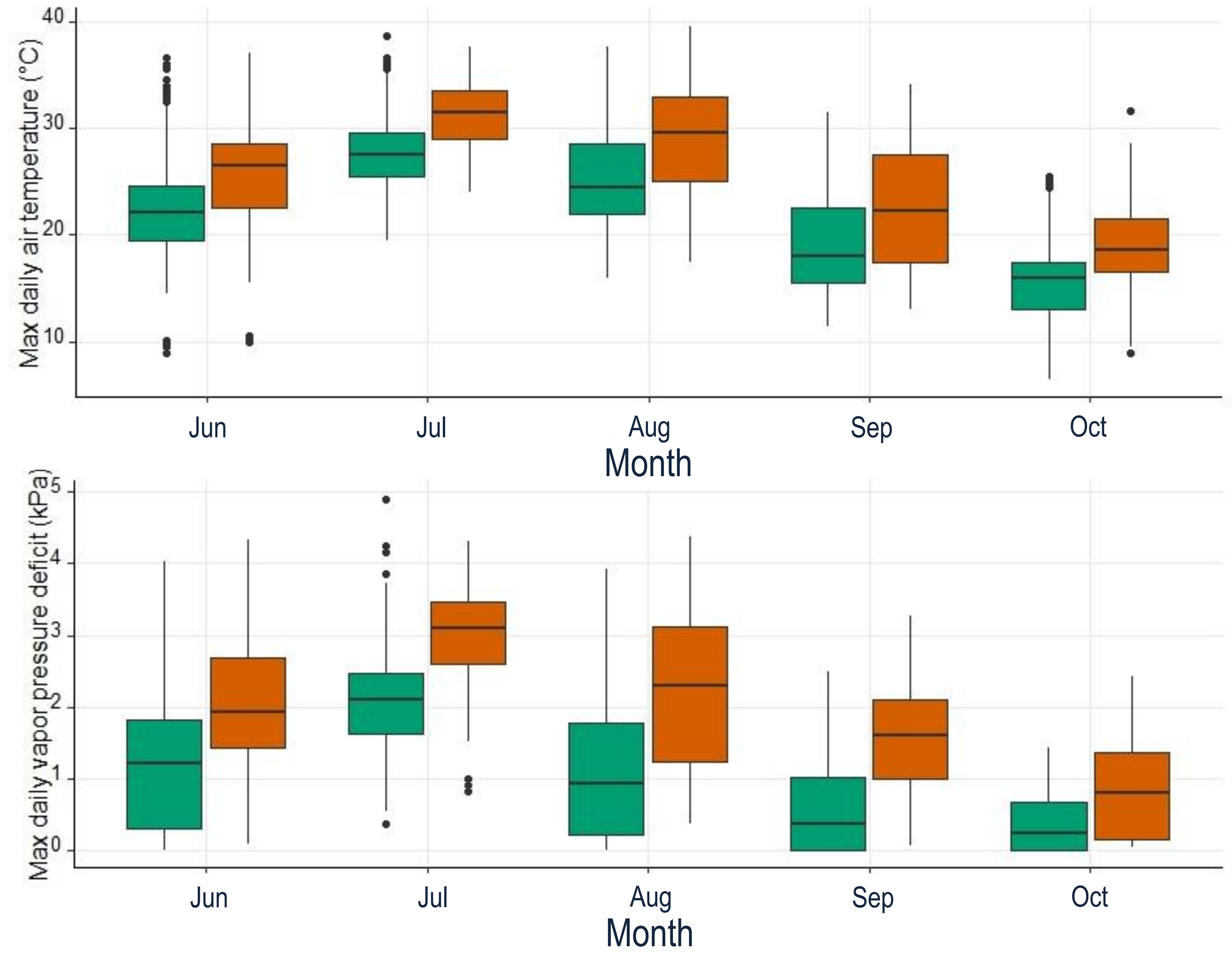


Figure 2. 3D point cloud of a microclimate survey plot at the Penobscot Experimental Forest generated from NASA G-LiGHT (https://gliht.gsfc.nasa.gov/).

Preliminary Results

- Non-forested sites reach higher daily maximum temperatures and vapor pressure deficits than forested sites (**Figure 3**).



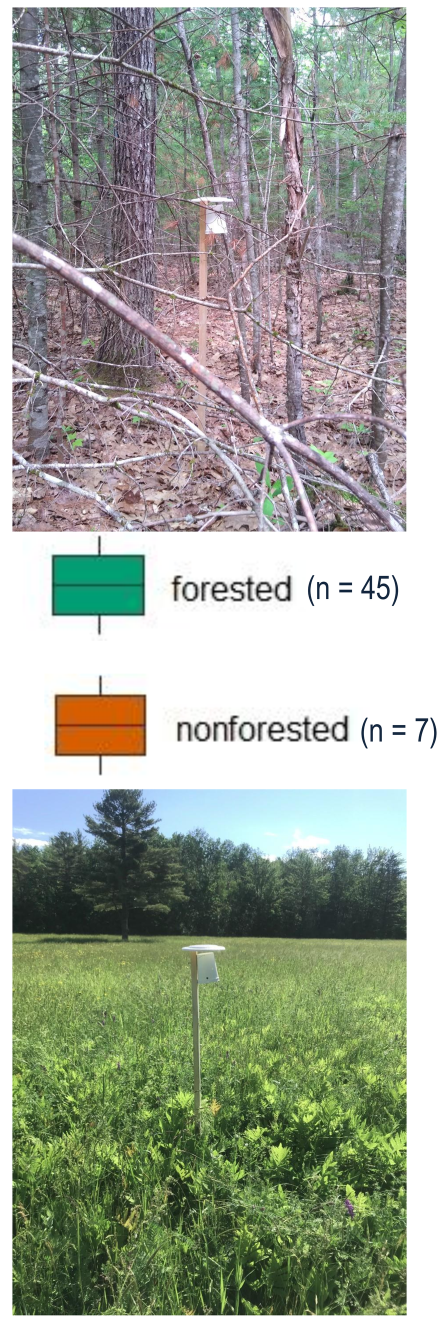


Figure 3. Monthly averages of daily maximum temperature (top) and vapor pressure deficit (bottom) for forested and non-forested sites from June-October 2022. Vapor pressure deficit (VPD) is a standardized measure of air aridity calculated from relative humidity and temperature.

- Microclimate buffering varies widely by day, although effects are fairly consistent across months. On average, forest understories reach daily maximum temperatures that are 3°C cooler with 27-67% lower maximum VPD during the growing season (**Figure 4**).

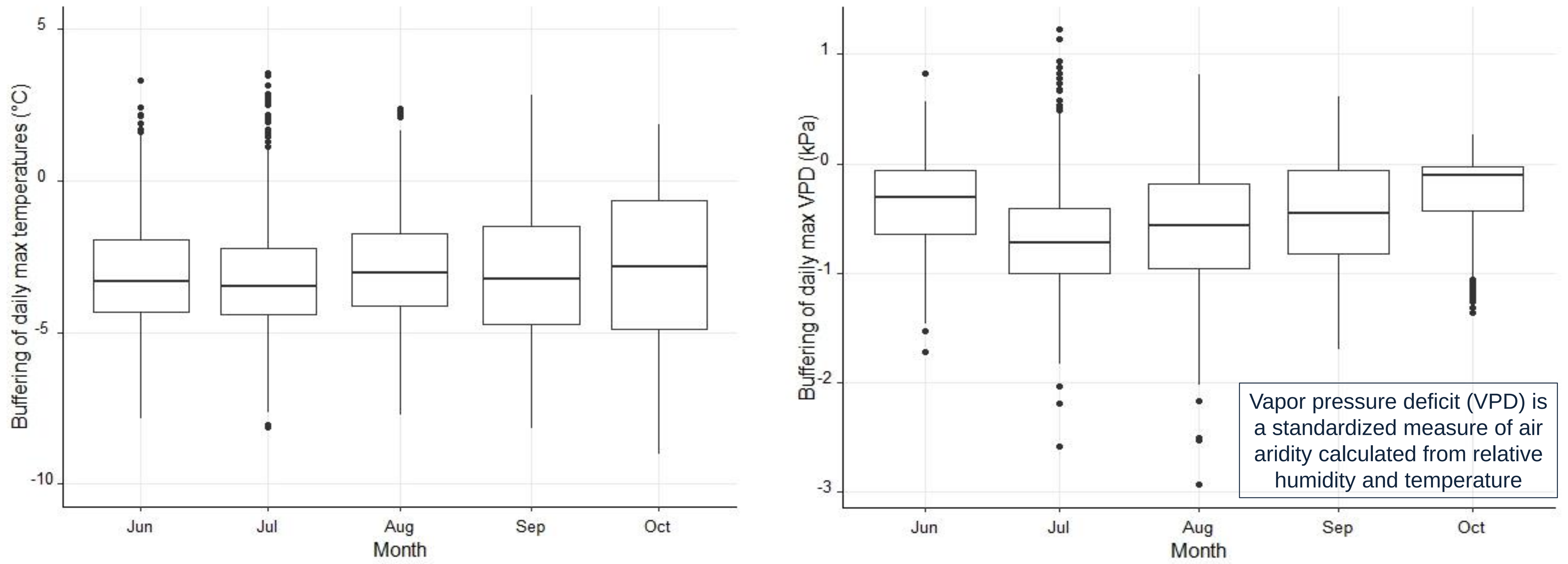
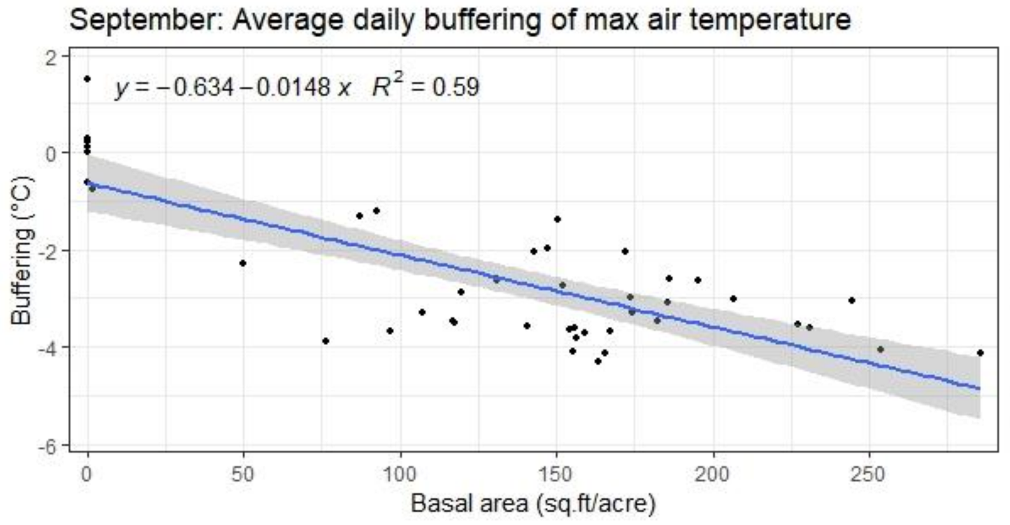


Figure 4. Monthly average buffering of daily maximum temperature (left) and vapor pressure deficit (right) for forested sites from June-October 2022.

- Microclimate buffering increases with basal area and canopy closure (**Figures 5, 6**).



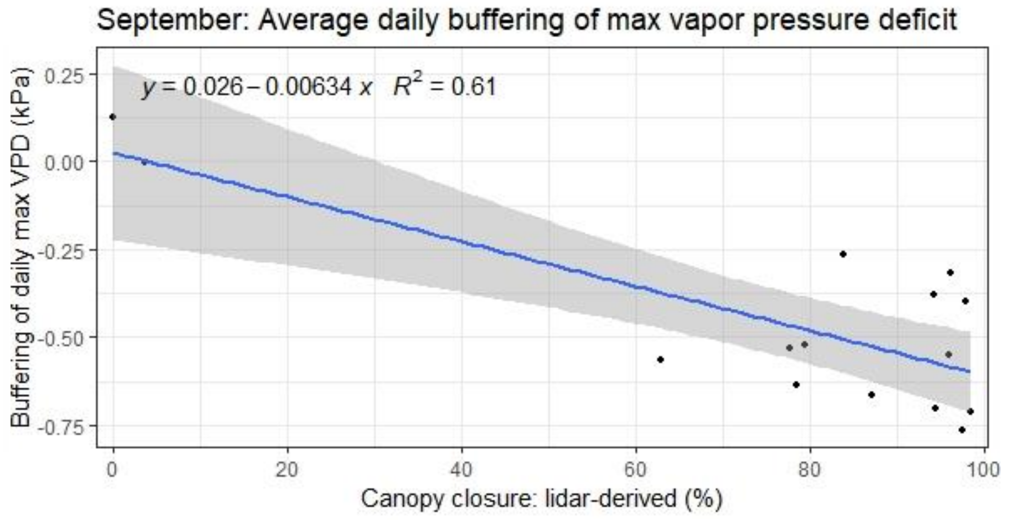


Figure 5 (left). Relationship between basal area (sq.ft/acre) of all trees > 1cm DBH and buffering of daily maximum temperature for all sites in September 2022.

Figure 6 (right). Relationship between lidar-derived canopy closure and buffering of daily max vapor pressure deficit for all sites in September 2022.

Preliminary Results cont'd

- On the hottest days, stands with higher basal area have an even stronger buffering effect than on cooler days (**Figure 7**).

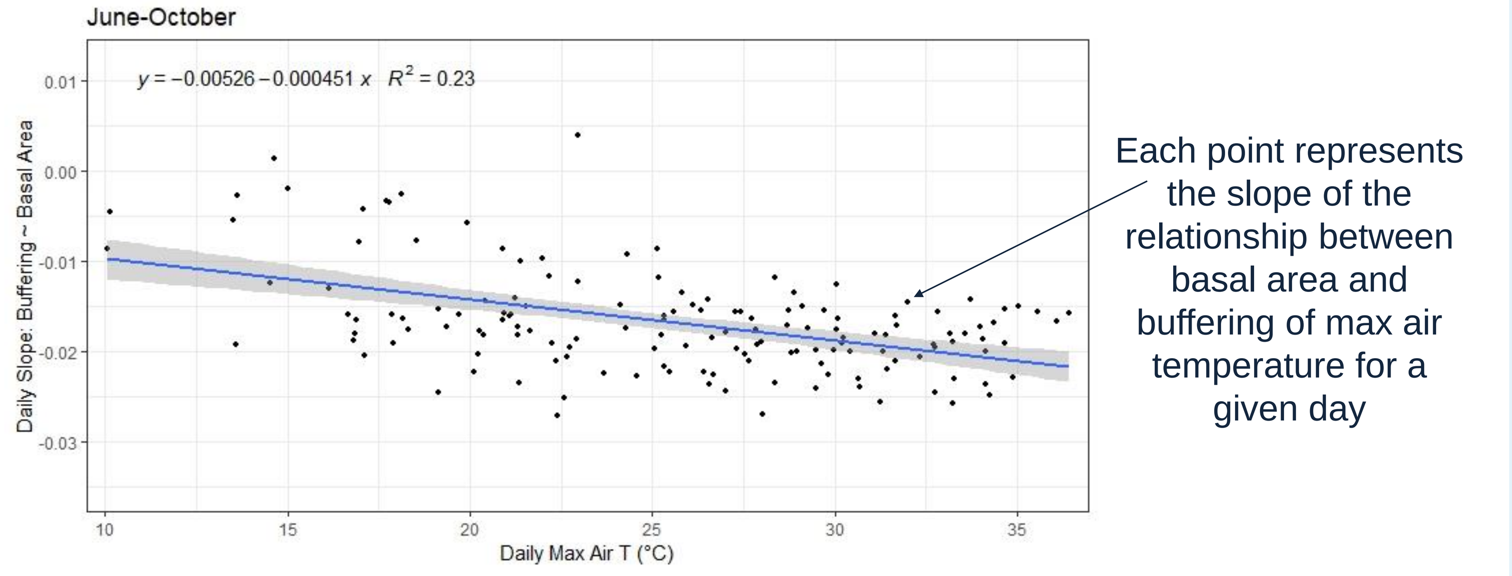


Figure 7. The relationship between basal area and buffering of maximum daily temperatures is stronger when ambient conditions are warmer. Each point represents the slope of the relationship for one day.

- Airborne lidar accurately estimates canopy closure (**Figure 8**).

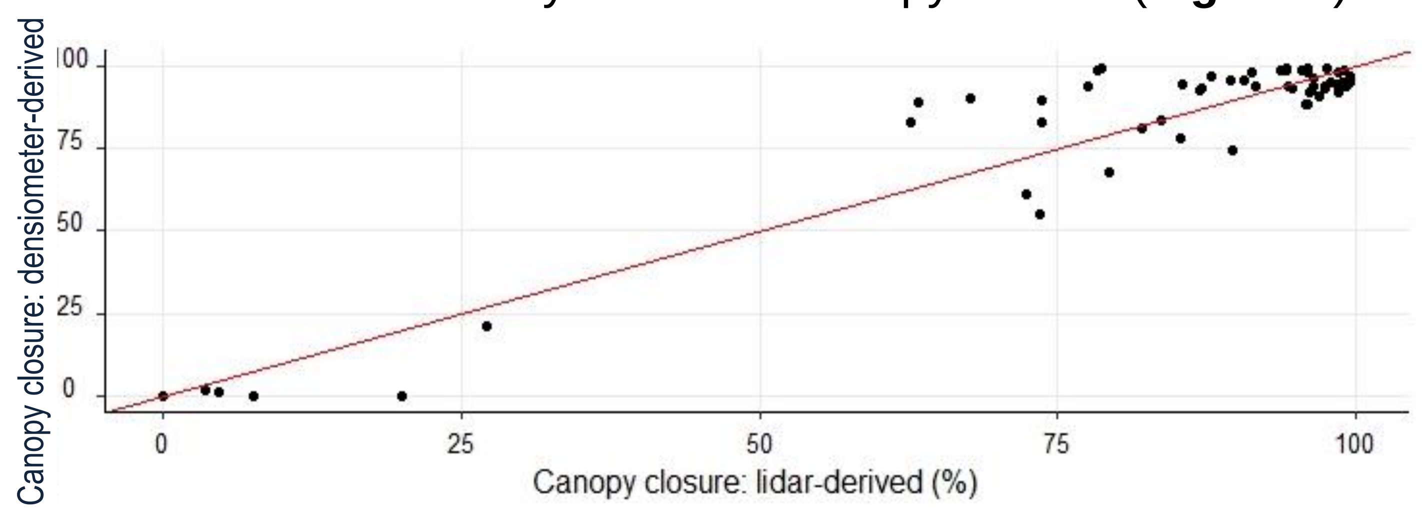


Figure 8. Comparison of canopy closure derived from lidar versus from a spherical densiometer in the field. The 1:1 line of agreement is shown in red. Lidar-derived canopy closure was estimated from first returns only with a 1-meter height cutoff at 1-meter spatial resolution. Raster values were averaged over a 30-meter radius.

Conclusions & Future Research

- Understory temperature and vapor pressure deficit vary greatly between sites with different forest structures and compositions.
- Next, we will build linear mixed effects models to quantify contributions from each predictor variable.
- Models will be combined with wall-to-wall lidar metrics to estimate microclimate buffering across the 4,000-acre forest at different times of day and year (**Figure 9**).

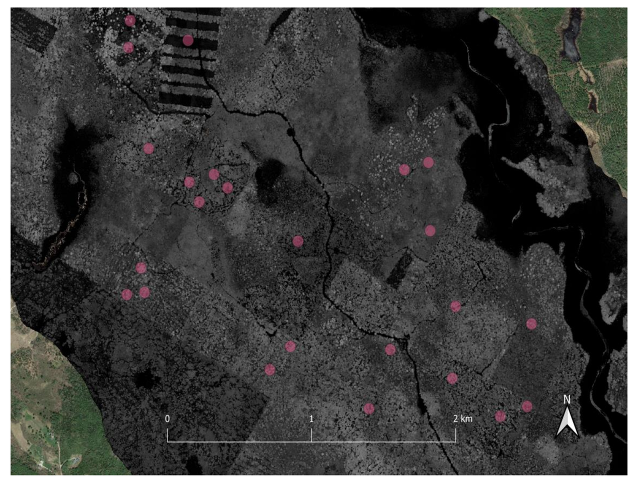


Figure 9. Lidar-derived canopy height model at the Penobscot Experimental Forest, with microclimate survey plots overlaid.

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