Characterizing within crown traits to better understand tree strategies

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Background:

- Trees invest in aboveground architecture primarily to support the display of foliage for photosynthesis. However, light capture strategies are necessarily tempered by biophysical and environmental constraints. For example, species prioritizing foliage display in high sunlight environments must balance light capture with thermoregulation.
- Multiple within crown traits likely coordinate across scales (leaf, branch, whole crown) and along vertical canopy gradients to help trees optimize photosynthesis and adapt to their local environments. However, we still lack a complete understanding of how this occurs, in part, because of the difficulty of sampling in tall, complex forest canopies.
- Here we present our efforts to better understand these strategies in five temperate tree species by trait sampling from a canopy lift with high-density LiDAR remote sensing.

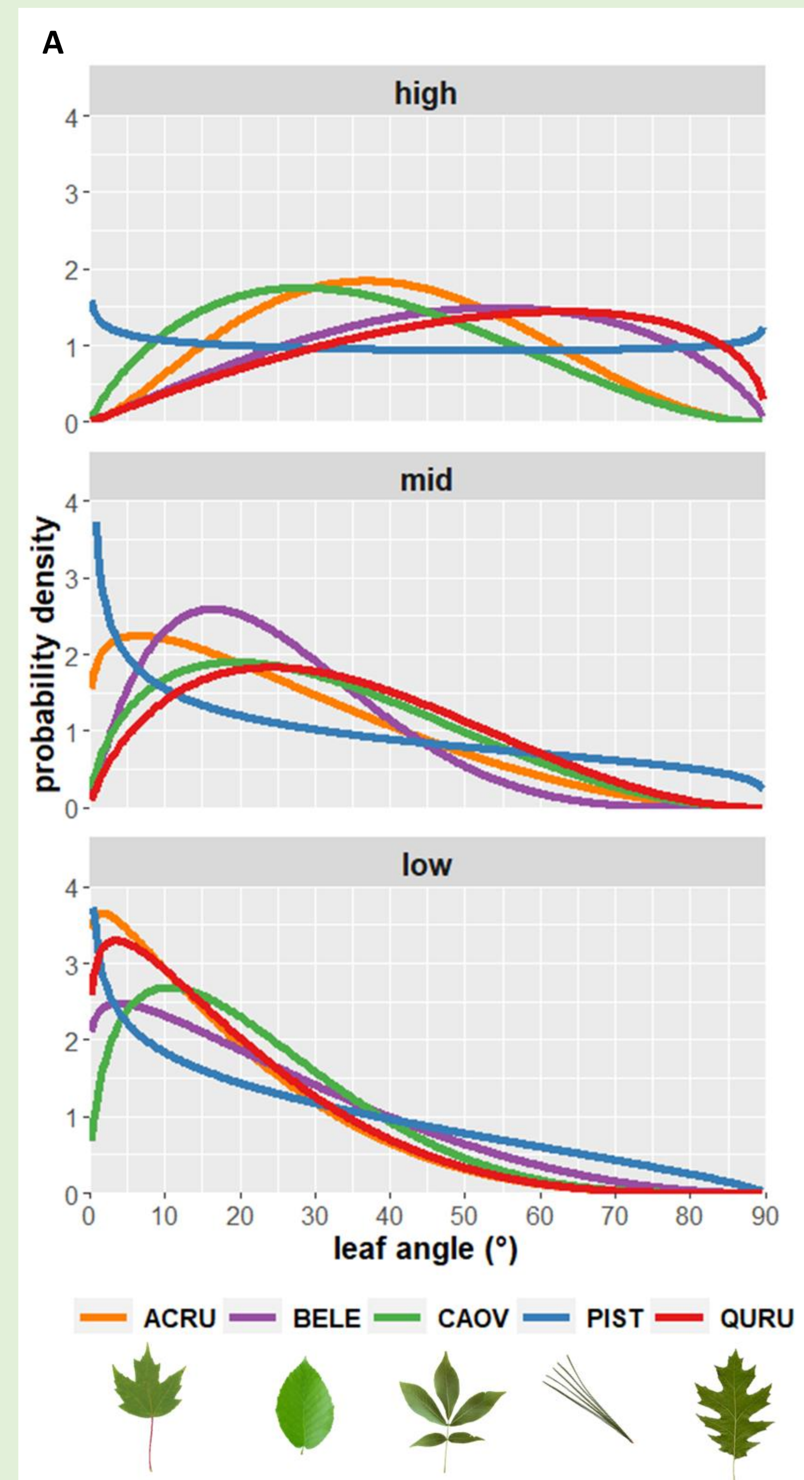
Fieldwork:

- During the 2022 growing season, we used a 92 ft. mobile canopy lift (**Figure 1**) to make measurements along vertically gradients in the crowns of five of the dominant species of a mixed hardwood – pine forest in Durham, New Hampshire, USA.
- We characterized how numerous leaf and branch traits changed along light gradients from sunlit upper canopy to shaded lower canopy. This work presents just a few key structural traits we measured, including leaf angle distribution, foliage clumping, and plant area density.
- Our study species include:
  - shagbark hickory, *Carya Ovata* (CAOV)
  - red maple, *Acer rubrum* (ACRU)
  - northern red oak, *Quercus rubra* (QURU)
  - black birch, *Betula lenta* (BELE)
  - eastern white pine, *Pinus strobus* (PIST)

Figure 1: (A) We used a 92 ft. mobile canopy lift to sample leaf and branch traits along vertical canopy gradients in five common trees species. **(B, C)** View from top of the canopy.

Leaf angle distribution and foliage clumping:

- Leaf angle distribution (LAD) and foliage clumping are two important structural parameters for understanding how tree canopies interact with sunlight.
- We characterized LAD (**Figure 2A**) through the canopies of our target trees by measuring more than 2000 leaves in situ using a digital angle tool (**Figure 2B**).
- Clumping occurs at multiple scales (e.g., branches, crowns, stands) in forest, and can be described in numerous ways. Here we chose to characterize clumping (**Figure 3A**) at the branch-level using a ratio of branch silhouette area (**Figure 3B**) to total branch dry foliar mass, which we are calling specific branch area (SBA, cm^{-2} g^{-1})



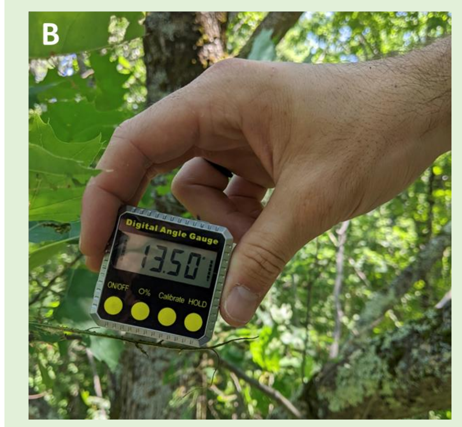


Figure 2: (A, left) Leaf angle distributions of high, middle, and low canopy foliage.
(B, above) We made more than 2000 leaf angle measurements across the five species using a digital angle tool.

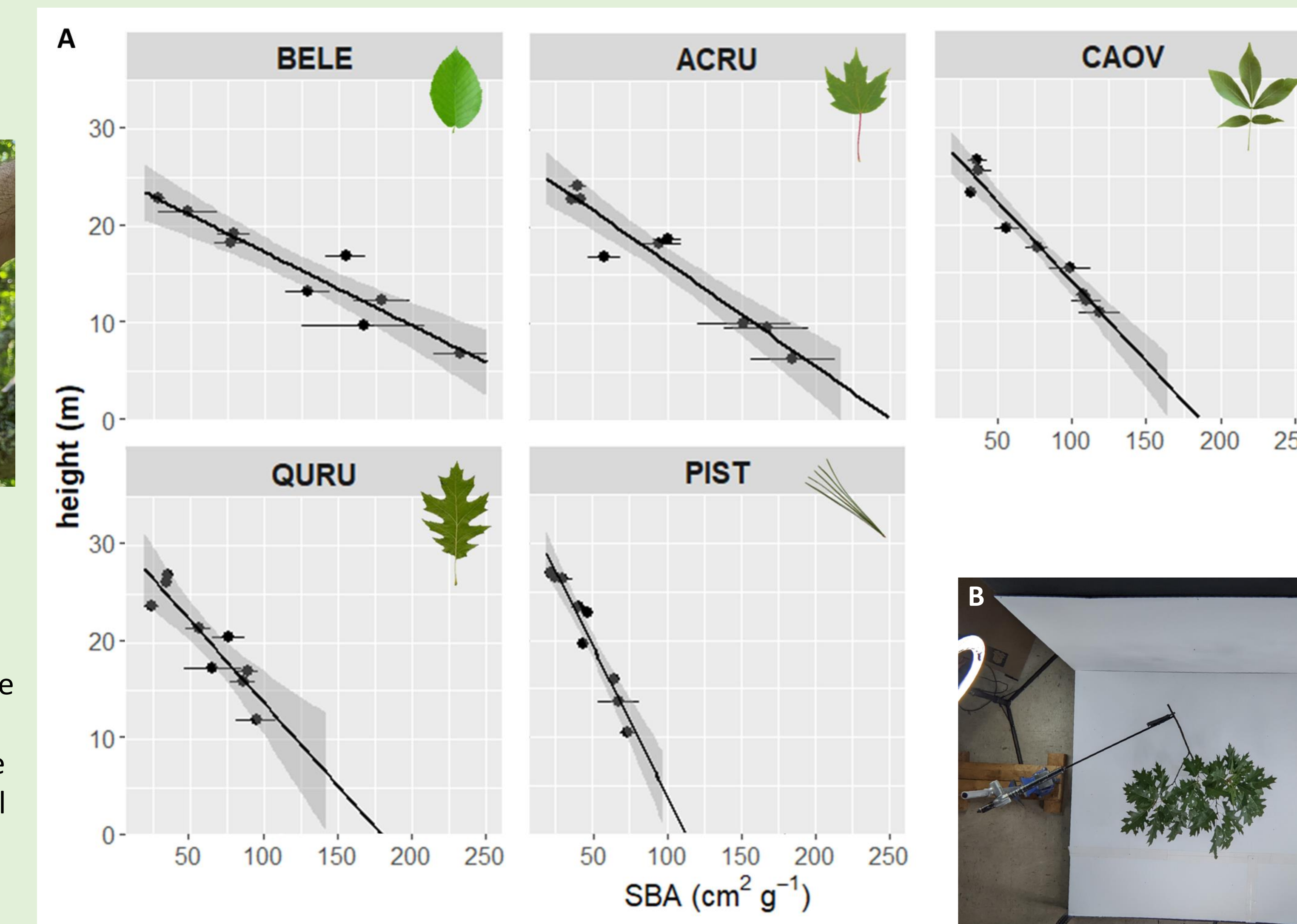


Figure 3: (A, left): Patterns of foliage clumping along canopy vertical gradients. Foliage clumping here is characterized using SBA, a ratio of branch silhouette area to total dry foliar mass. **(B, below)** Branch silhouette area was measured by taking photographs from above of collected branches set up in native orientation.

Plant area density:

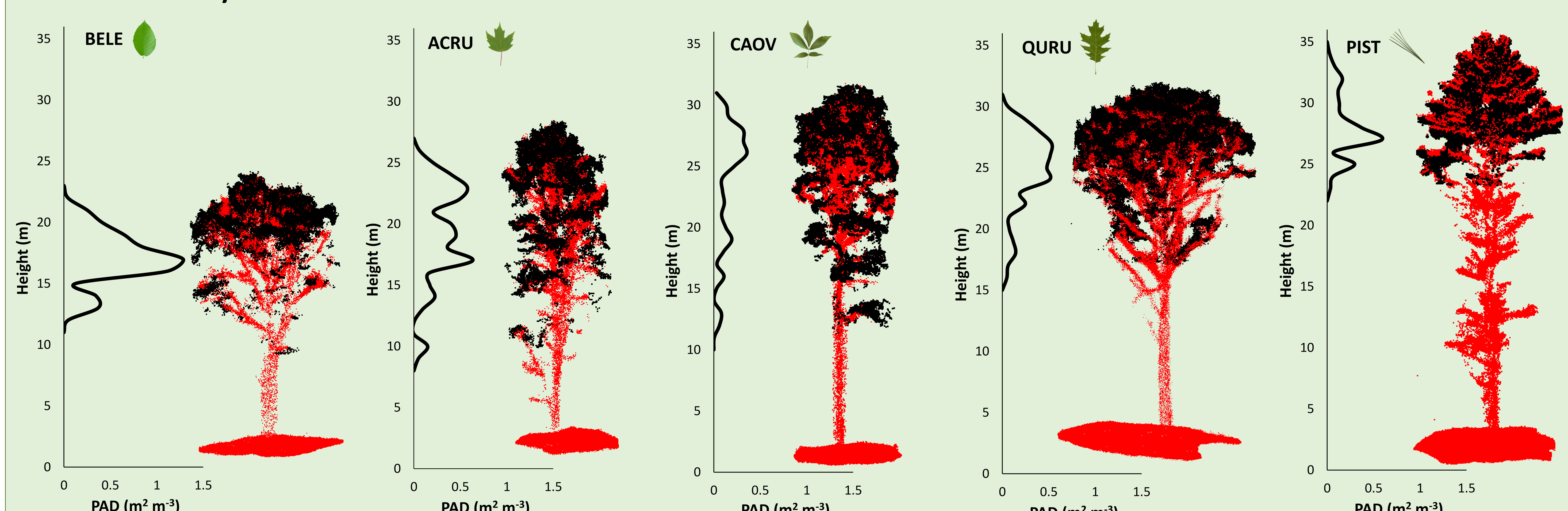


Figure 5: Characterizing leaf and branch traits is informative, but a key measurement for contextualizing these traits is understanding how different species distribute foliage through their crowns. To understand species-specific foliage distribution, we collected high-density UAS LiDAR over our study. This figure shows plant area density (PAD; m^2 m^{-3}) profiles for a single individual of each species. The LiDAR visualization includes leaf-on returns (black) and leaf-off returns (red) to enhance visualization. Only leaf-on returns were used to calculate PAD profiles. Plant area index includes returns that may include both foliage and woody material, though the signal is likely largely driven by foliage distribution.

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Questions, comments?
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