The Accuracy of Drones in Forest Structure Analysis: Determining Height and DBH of Canopy Trees

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A video production of this project is available at: vimeo.com/410777825

Introduction

As drone technology is increasingly prevalent in research applications, we sought to demonstrate the capability of drone-collected imagery to supplant the need for manual forestry data collection.
Drone technology offers a safer, cost-effective, efficient alternative to traditional data collection methods in environmental fields.

Objectives

- Evaluate the accuracy of drone technology to measure tree height and diameter at breast height (DBH).
- Produce an orthomosaic map and 3D model of study site.
- Enhance UNC's technological expertise and contribute to the use of technology in data collection for community partners.

Study Site

Mason Farm Biological Reserve is a 367-acre reserve in Chapel Hill, NC. Forests are mixed stands of hardwoods and softwoods. Drone flights and analyses were done on an open meadow with distinct mixed species canopy trees (red polygon, Fig. 1). The drone was originally flown over plots within adjacent stand but spatial homogeneity prevented orthomosaic and 3D model generation for analysis (Fig. 1). These plots were still used for height and DBH relationship (Fig. 2).

Fig. 1

Methods

Field surveys determine study-specific height and DBH values used for analyses

- Randomly sampled eight 0.1-ac. circular plots.
- Measured tree height & DBH and fit field data to common DBH-height relationships; performed AIC analysis to determine the best model (Fig 2.; $R^2 = 0.79$).

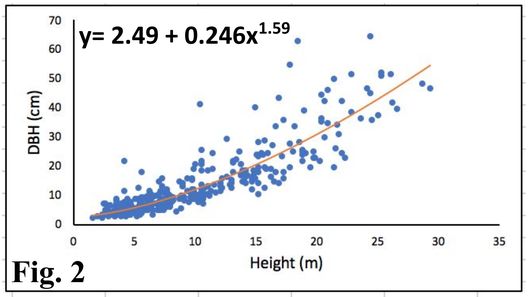

Fig. 2

Drone flights provide aerial imagery for ground-truthing analysis

- 16 trees in and along meadow adjacent to field survey plots measured for DBH and height. These served as our known values that drone derived metrics were compared to.
- DJI Phantom quadcopter flown at 100m above site in a double serpentine flight path (Fig. 4).
- Over 400 drone captured images were stitched together using SfM photogrammetric software to produce orthomosaic map and 3D model.
- Line measurement tool applied to tree pixels in Pix4D produced 3D model to obtain drone derived height measurements (Fig. 3).
- Drone derived heights were fit to Fig. 2 regression model to estimate DBH.

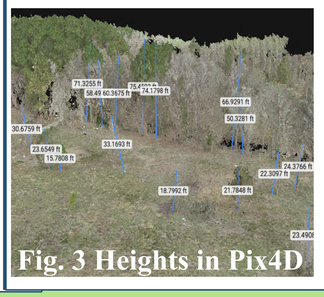

Fig. 3 Heights in Pix4D

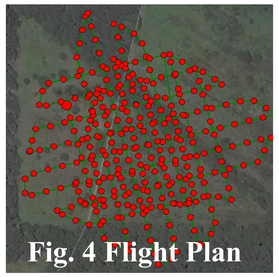

Fig. 4 Flight Plan

Results

Orthomosaic Map and 3D Model

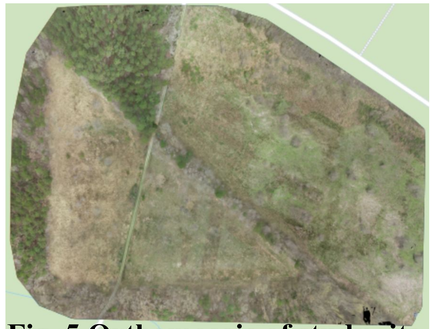

Fig. 5 Orthomosaic of study site

Fig. 6 3D model used to estimate tree heights

Height and DBH Regressions

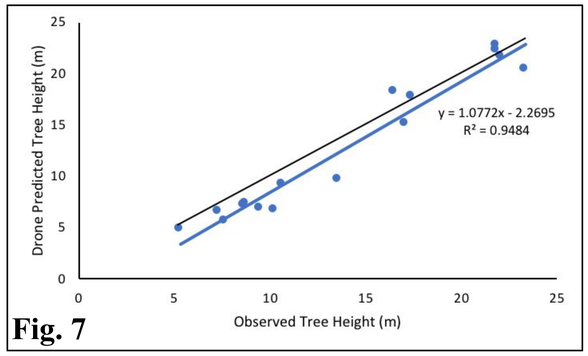

Fig. 7

- There was a statistically significant relationship between known and estimated height with a very high correlation ($R^2 = 0.95$).
- Though most estimated heights are below the 1:1 line suggesting a slight underestimation bias, the bias is minimal as 75% of estimates are within 2.0 m of observed height measurements and 100% are within 4.0 m.
- Predicted height differs from observed height by an average of 1.65 m.

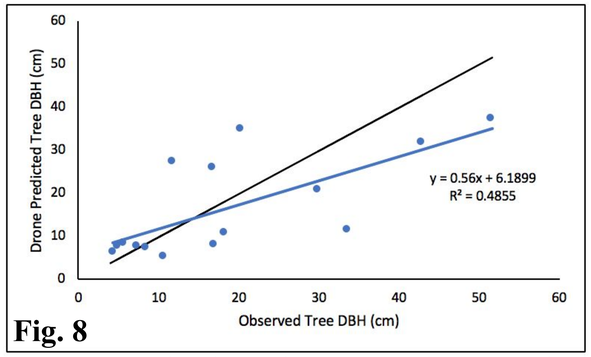

Fig. 8

- Known and estimated DBH were less strongly correlated ($R^2 = 0.49$).
- Only 33.33% of estimations lie within 4.0 cm of observed measurements.
- Predicted DBH differs from observed DBH by an average of 8.42 cm.
- The maximum difference observed was 22.03 cm and the minimum difference was 0.22 cm. Differences vary over a wide range which is likely due to wide scatter and poor fit in Fig. 2.

Next Steps

- Create species-specific DBH-height regression models for more accurate drone DBH estimates
- Survey larger areas to better characterize forest structure and ensure spatial variability even in denser stands
- Develop methods to automate Pix4D height measurement

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