

# Three-dimensional forest reconstruction and structural parameter retrievals using a terrestrial full-waveform lidar instrument (Echidna®)

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## **Objectives:**

- This study was designed to explore the utility of using a full-waveform terrestrial lidar for three-dimensional reconstructions of forest stands.
- Reconstructions were assembled from multiple scans of full waveform terrestrial lidar using the Echidna® Validation Instrument (EVI).
- The study area included four forest stands in Sierra National Forest, CA and two in Harvard Forest, ME, each 50 m by 50 m in size, with varying canopy structure and species composition, and using data acquired in 2008 and 2009.
- Each lidar pulse return was processed to identify one or multiple “hits” and their associated peak return power, converted peak power to apparent reflectance, located hits in Cartesian coordinate space, and stored them as points in a point cloud with associated attributes.
- In addition, five (Sierra) or nine (Harvard) overlapping scans were registered and merged into a single point cloud, then the ground plane was identified and ground hits classified; a local digital elevation model was produced; non-groundhits were identified as trunk/branch or foliage hits; and commercial software was used to display, manipulate and interact with the point cloud to make direct measurements of trees in the virtual space of the reconstruction.
- The typical size of an EVI scan is 1 hectare and the time required to perform a single scan was about 20 minutes.

## **New Science:**

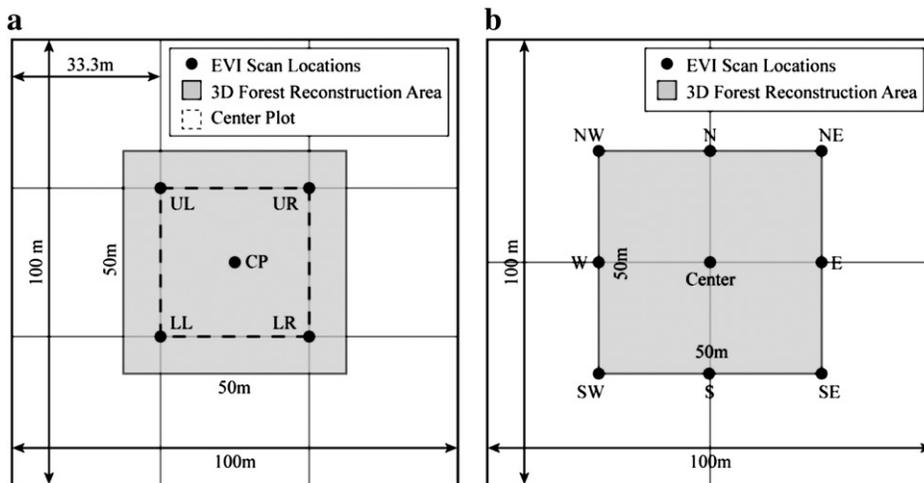
- The study demonstrates that virtual measurements of diameter at breast height (DBH), tree height, and stem count density using Echidna® Validation Instrument and point cloud methodology matched field measurements very well.
- Crown shape parameters are more subjective and possibly somewhat biased, but are still retrieved reasonably well.
- Displaying and manipulating spatial data as a three-dimensional point cloud, a methodology commonly used in other fields, is a relatively new and promising methodology for use in estimating canopy structure parameters and even carbon stocks.
- The full-waveform recording features of EVI allows for the identification of multiple scattering events, provides for modeling, and excludes the effects of local terrain; occlusion is largely eliminated by co registering multiple scans such that these 3-D reconstructed datasets present a more realistic characterization of the actual forest than single scans.

## **Significance:**

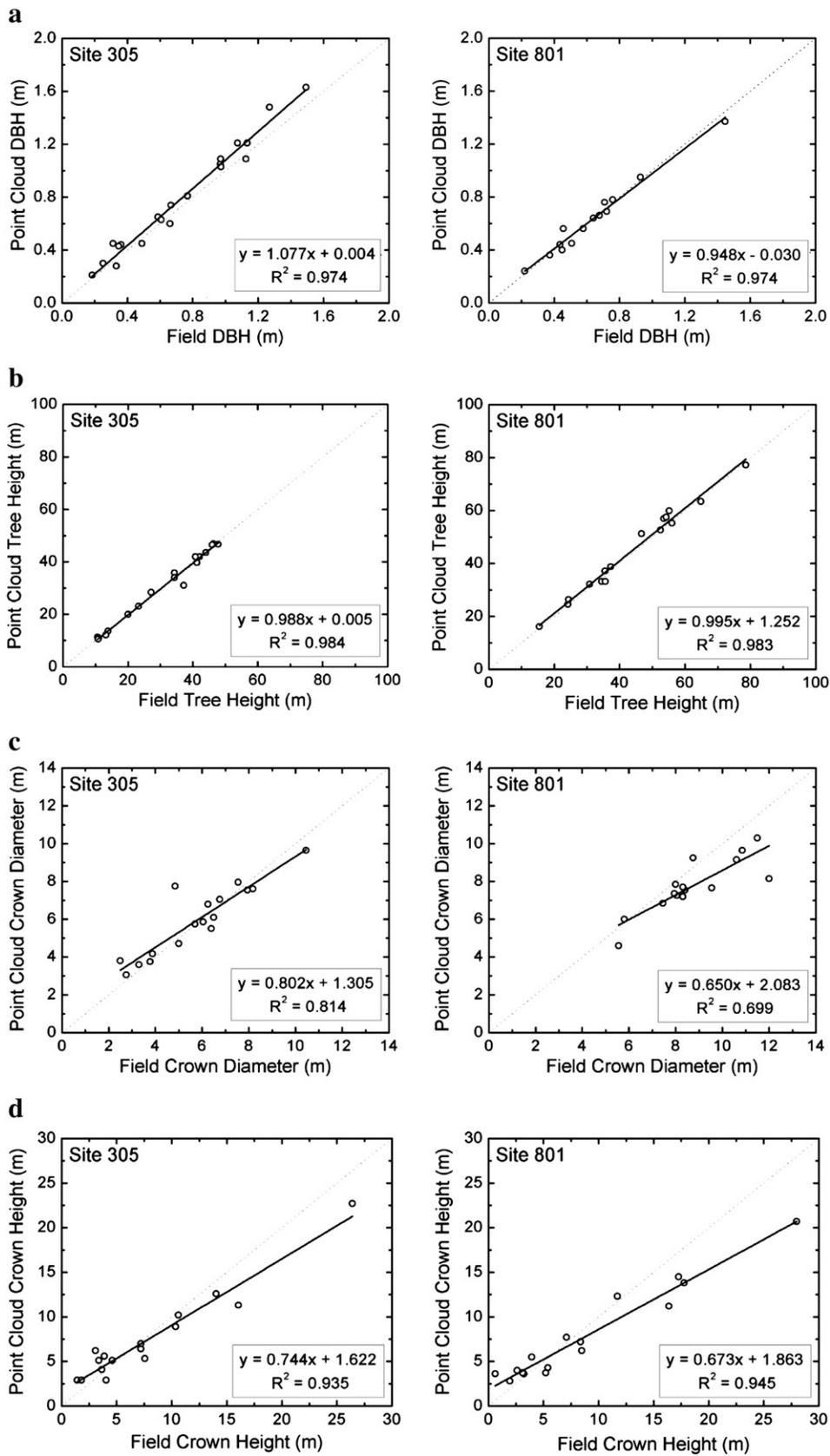
- Reconstruction data from the Echidna® Validation Instrument (EVI) provides a new pathway to estimate forest structure such as tree diameter at breast height (DBH), tree height, crown diameter and stem count density (trees per hectare).
- Because DBH, tree height, and stem count density measurements are the most important for biomass estimation, this study demonstrates the potential of virtual measurements to provide accurate above-ground biomass without the time and effort required to make direct measurements.
- A second-generation instrument, the Dual-Length Echidna® Lidar (DWEL), currently under development, will scan using two wavelengths simultaneously, shortening collection times and potentially increasing accuracy of some measurements, such as distinguishing leaf hits from trunk/branch hits.



**Figure 3:** Mean apparent reflectance images for the center point scan at site 801: a) hemispherical projection; b) Plat carrée (equal angle) projection. The very large trunks are giant sequoias: a giant sequoia fallen trunk lies at the center of the image.



**Figure 6:** Layout of the EVI scans: a) 2008 (Sierra National Forest) b) 2009 (Harvard Forest).



**Figure 13:** Virtual measurements of canopy structural parameters at the individual tree level for site 305 and site 801 in Sierra Nevada National Forest: a) DBH; b) tree height; c) crown diameter; d) crown height