# Cheap and Colourful: landscape-scale aerial photogrammetry as a substitute for terrestrial LIDAR

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**Abstract:**
I explore the potential for 3D reconstructions from low-cost aerial photography to replace terrestrial LIDAR in landscape-scale vegetation monitoring. I find that these techniques can be highly effective in replacing LIDAR scans for general-purpose monitoring, at low enough cost to out-compete manual measurement.

Historically, forest managers have faced a choice between gathering information on selected organisms in detail, or on a landscape in aggregate. Manual monitoring is slow, expensive, and produces high-quality but low-volume results, while the resolution of satellite data is too low to provide detailed per-tree data. Specialist remote-sensing platforms are relatively costly and require substantial training. Cheap, reliable, high resolution data – capable of resolving features and attributes of individual plants – would be a significant breakthrough. The National Arboretum in Canberra serves as a site for the development and testing of next-generation environmental monitoring systems. Within the arboretum, the ANU Research Forest is under intensive long-term monitoring, and provides an excellent case study as a wide variety of measurements and data are available.

Terrestrial LIDAR is almost unchallenged for production of centimetre-resolution pointcloud data at landscape scale. The hardware is available in a number of forms – stationary or mobile, mono- or multi-spectral – with prices starting in the tens of thousands of dollars for a complete system. The comparison dataset I use was produced by CSIRO researchers walking between each row of trees with a handheld Zebedee scanner; it provides excellent spatial detail but no colour.

The input data for my analysis was collections of 40-250 top-down digital photos taken from about 30 meters above ground level, with a hobbyist UAS (DJI Phantom 1). I experimented with open-source (Visual SFM, CMP-MVS) and proprietary (Pix4D) software for 3D reconstruction, discarding 'cloud' processing options. CMP-MVS produced good outputs, but was sensitive to input quality and requires powerful computer hardware. Pix4D can be tuned to get fair results from poor data, but may be unjustifiably expensive for some users. Figure 1 shows a section of one such pointcloud.

*Figure 1. A captured pointcloud, showing detailed spatial and spectral information for every tree in the forest.*

I am unaware of any other system which can capture a centimetre-resolution full-colour pointcloud on this scale – at a cost affordable by interested individuals, and with data collected in just a few minutes.

While exploring the forest digitally has certain advantages, the true potential is for automated analysis. Unsatisfied with the available software, I wrote a collection of Forest Analysis Tools (Hatfield-Dodds, 2015). These tools identify and measure trees within a pointcloud (before canopy closure), creating a table with the location, height, canopy area, and mean RGB colour of each tree. This data can be used to investigate correlations between the full range of attributes, check individual trees or whole stands in detail, or – with consistent flights over the area – track the growth and change of each tree through time.

Aerial photogrammetry has strong advantages in up-front and operating cost over LIDAR scanning, and delivers data which can replace LIDAR or manual field measurement for routine monitoring.

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