Dual-Wavelength Echidna Lidar: First deployments at TERN sites around Australia

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Highlights: A dual-wavelength echidna lidar (DWEL) has been deployed at three terrestrial ecosystem research network (TERN) supersites across Australia, enabling researchers to successfully distinguish trunks/branches from leaves. For each of the scan locations, the 3D point clouds have been used to generate foliage profiles as well as LAI and PAVD information.

Key words: *DWEL, TLS, foliage profiles, LAI.*

Introduction

A new terrestrial forest scanning lidar has recently been deployed in Australia to three separate terrestrial ecosystem research network (TERN) calibration validation sites to evaluate forest structure. The dual-wavelength echidna lidar (DWEL) is one of two specialised instruments in the world that has been developed specifically to characterise forest structure at fine spatial scales while distinguishing between leafy and woody vegetation which is not as easily achieved using a single wavelength laser scanner. This is achieved by the coaxial alignment of two laser beams of separate wavelengths that display different reflectance properties when interrogating leafy and woody vegetation. DWEL is also capable of capturing partial hits from soft targets (leaves) in the forest canopy due to the retention of the laser pulse shape from these hits and analysis of the fully detected and digitised waveform.

This paper evaluates the first deployments of DWEL around Australia at selected TERN field sites and discusses some of the initial results from these three deployments.

Materials and methods

Instrumentation

The DWEL is a stationary terrestrial laser scanner that uses a rotating mirror to scan in a vertical circle as the whole instrument head rotates in the azimuth direction on its tripod base. This provides full angular coverage of the upper hemisphere as well as much of the lower hemisphere around the instrument. Concurrent, coaxial laser pulses produced by the two onboard lasers (1064 nm and 1556 nm) are long (approximately 5.0 ± 0.1 ns at the full-width half-maximum position of the pulse) and sharply peaked which allows full sampling of the return pulse waveform shape as well as easy interpolation for accurate distance retrievals to scanned objects. Additionally, the lasers have been individually calibrated to provide apparent reflectance measurements. The beam divergence of the lasers and scanning resolution are adjustable, with options of 1.25, 2.5 and 5 mrad available for the lasers and 1, 2, and 4 mrad for the scanning resolution. The resulting data set can be used to examine structural forest parameters, such as the mean tree diameter at breast height (DBH), stem density, basal area, canopy height, leaf area index, foliage profiles and above-ground biomass using approaches originally developed and used with the Echidna validation instrument [1]–[4].

Data Collection

The DWEL instrument has been deployed at three TERN AusCover supersites around Australia (with each site consisting of a 5 km by 5 km area). Within each of these sites are usually a series of long term monitoring plots that are of interest to a variety of different research groups.

Processing steps

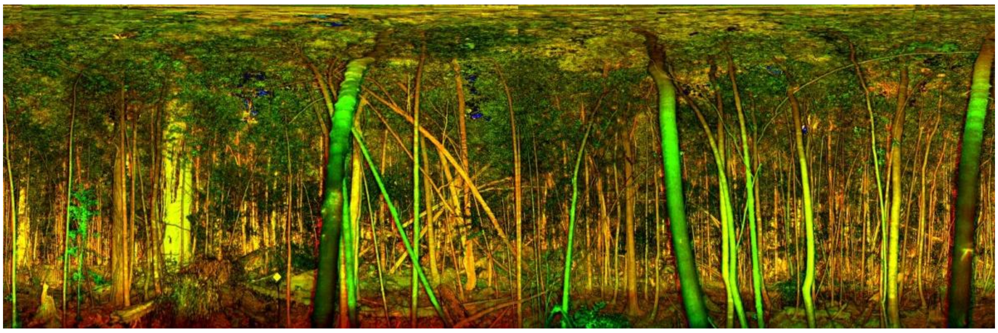
The full waveform data produced by DWEL must go through an initial suite of processing steps before it is usable for scientific analysis. The steps are as follows: 1) convert the raw DWEL binary waveform data to hdf5 format; 2) derive laser direction data from the DWEL rotary encoders and assign to waveform data; 3) the data is then filtered and corrected for any saturation using IDL; 4) 3D point clouds are produced of the individual scattering events with x, y, z coordinates and associated apparent reflectance attributes; 5) point clouds are converted into SPD format; and 7) foliage profiles and LAI estimates are produced using the SPDtools python bindings [4],[5].

Results

Figure 1 displays colour composite images of the mean return values returned in a 4 mrad angular grid at the two wavelengths in selected scans from the 3 locations. Trunks and branches have a similar return power at both wavelengths, while leaves appear much darker at 1556 nm due to absorption by water in the leaves. Thus, trunks appear to be much brighter than the leaves except for the cases where the bark on the trees are either wet or appear to contain moisture. Gaps in the vegetation canopy are characterised by blue colouring.

(a)

(b)



(c)

Figure 1: Colour composite images of the mean return values in the dual-wavelength scans. Red, 1556 nm; green, 1064 nm: blue, canopy gaps. The horizontal dimension is azimuth angle and the vertical dimension is the zenith angle. (a) Site SS at Tumbarumba in Bago State Forest, New South Wales, (b) site Gold0101 in D'Aguilar National Park near Brisbane, Queensland, (c) Log decay site in the Warra Long-Term Ecological Research site, Tasmania.

Concurrent TLS scans were made with a Riegl VZ-400 laser scanner at the QLD and TAS sites allowing comparison of the 3D point clouds themselves as well as the foliage profile and LAI measurements from each scanner, a sample set of these profiles are displayed in Figure 2.

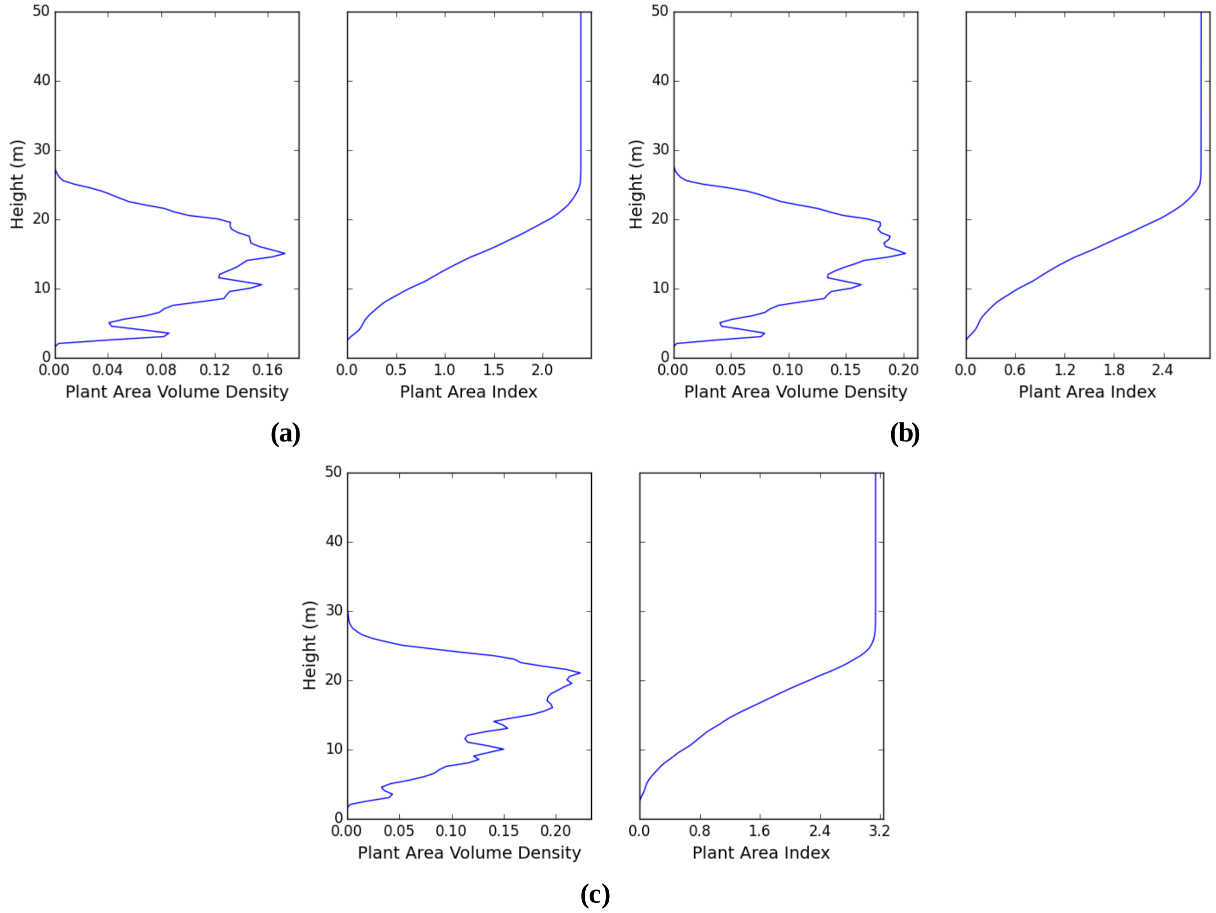


Figure 2: An example of foliage profiles from (a) DWEL 1064nm, (b) DWEL 1556 nm and (c) Riegl VZ-400 (1556 nm) at the QLD Gold0101 field site created using the python binding of the SPDtools software suite.

Foliage profiles of the DWEL and Riegl VZ-400 TLS instruments appear to be of a similar shape, particularly in the 1556 nm waveband. The extended range of the Riegl sensor results in an improved delineation of the canopy elements at range. The 1064 nm waveband of the DWEL instrument depicts a slightly different shape than that of the Riegl and DWEL 1556 nm band. The reason being that the 1064 nm is sensitive to both leaves and woody vegetation while the 1556 nm waveband is most sensitive the woody vegetation.

Conclusions

The dual-wavelength terrestrial lidar scans that are displayed in this research show very good contrast between leafy and woody vegetation when scanned using the DWEL instrument. Consequently, this allows foliage profiles and the plant area index to be calculated that are sensitive to changes in the amount of green or woody vegetation in a scan.

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