Quantifying forest dynamics in a free-air CO_2 enrichment experiment using terrestrial laser scanning

Kim Calders[1], Glenn Newnham[2], Matthias Boer[3], Mathias Disney[4,5], David Ellsworth[3], Martin Herold[6], Belinda Medlyn[3], Stuart Phinn[7], Pasi Raumonen[8], Peter Scarth[7], Dan Wu[7], John Hickson[9], Hans Verbeeck[1]

[1]CAVElab - Computational & Applied Vegetation Ecology, Faculty of Bioscience Engineering, Ghent University, Belgium; [2]CSIRO, Private Bag 10, Clayton South, VIC 3169, Australia; [3]Hawkesbury Institute for the Environment, Western Sydney University, Locked Bag 1797, Penrith, NSW, 2751 Australia; [4]UCL Department of Geography, Gower Street, London WC1E 6BT, UK; [5]NERC National Centre for Earth Observation (NCEO), UK; [6]Laboratory of Geo-Information Science and Remote Sensing, Wageningen University & Research, Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands; [7]Remote Sensing Research Centre, School of Earth and Environmental Sciences, University of Queensland, Brisbane 4072, Australia; [8]Computing Sciences, Tampere University, Korkeakoulunkatu 7, 33720 Tampere, Finland; [9]School of Geography. University of Nottingham. Nottingham. UK.

1. Introduction

Deforestation and forest degradation account for about 12% of global anthropogenic carbon emissions, which is second only to fossil fuel combustion (Le Quéré et al., 2009). This estimate is highly uncertain due to inadequate estimates of forest carbon stocks and is expected to range from 6 to 17% (van der Werf et al., 2009). Carbon emissions are partly compensated for by carbon uptake from the regrowth of secondary forests and the rebuilding of soil carbon pools following afforestation. However, the global distribution of terrestrial carbon sinks and sources is highly uncertain. Constraining the inaccuracy of these carbon estimates is essential to quantify benefits of avoided deforestation, return on investment in forest management and to support effective future climate mitigation actions (Pan et al., 2011). The debate concerning a possible Amazon forest die-back, i.e catastrophic losses of forest cover and biomass, illustrates the growing concern that terrestrial ecosystems (and tropical forests in particular) might not be able to maintain uptake of anthropogenic emissions at the current rate (Huntingford et al., 2013). A better understanding of forest growth dynamics will improve our understanding of the carbon cycle and mechanisms responsible for terrestrial sources and sinks of carbon, reducing their uncertainties of magnitude and distribution (Pan et al., 2011).

Our current knowledge about forest growth is limited, mainly due to challenges in accurately measuring tree structure, e.g. tree height and aboveground biomass (AGB), repeatedly and objectively. Diameter at breast height (DBH) is often used to indirectly estimate height or AGB through empirical relationships (i.e. allometric models), or to quantify forest growth (Ellsworth et al., 2017) as it is relatively easy to measure. However, due to the difficulty and high cost of destructively sampling trees, the measurements that underpin those allometric models are based on a limited sample size, which is also heavily biased towards smaller trees.

Figure 1: Illustrations of the free-air CO_2 enrichment experiment EucFACE.

Published in: Markus Hollaus, Norbert Pfeifer (Eds.): Proceedings of the SilviLaser Conference 2021, Vienna, Austria, 28–30 September 2021. Technische Universität Wien, 2021. DOI: 10.34726/wim.1861
This paper was peer-reviewed. DOI of this paper: 10.34726/wim.1901

Novel techniques using 3D terrestrial LiDAR (also referred to as terrestrial laser scanning, TLS) can provide us with a more accurate way to estimate the structure of trees (Calders et al., 2015a). TLS can objectively measure the canopy structure in 3D with high detail and accuracy, and recent work on characterising forest structure using TLS showed (a) a much better agreement with destructively harvested reference measurements compared to traditional techniques (Calders et al., 2015a); and (b) superiority and stability of TLS measurements in the context of repeatable measurements (Calders et al., 2015b).

2. Measuring forest growth in a free-air CO_2 enrichment experiment

EucFACE is a free-air CO_2 enrichment experiment that consists of six circular 25 m rings in a mature broadleaved evergreen forest (Figure 1). The main species is *Eucalyptus tereticornis*, which has a distribution through sub-tropical and temperate zones in Australia. Three rings have been exposed to a CO_2 increment of +150 parts per million (i.e. the projected global atmospheric CO_2 concentration for 2050) compared to ambient concentrations since 2012, with the other three rings serving as control plots. TLS data has been collected at EucFACE rings in 2012, 2015, 2018 and 2020 using a RIEGL VZ-400. Figure 2 shows a cross section through the TLS data of one of the rings in 2012. The objective of this work is to test the hypothesis that "*elevated CO_2 concentration levels have an effect on forest growth?*". Here, we will show results from estimating tree growth explicitly through 3D TLS data over an eight-year period, taking into account the full structure of the tree, and link this to elevated CO_2 concentration levels. We will show results from both (a) gap fraction analysis and (b) the extraction of tree point clouds from within each EucFACE ring. We will then show the time progression of stand structural dynamics of plant area index, as well as individual tree parameter dynamics including DBH, tree height and crown area.

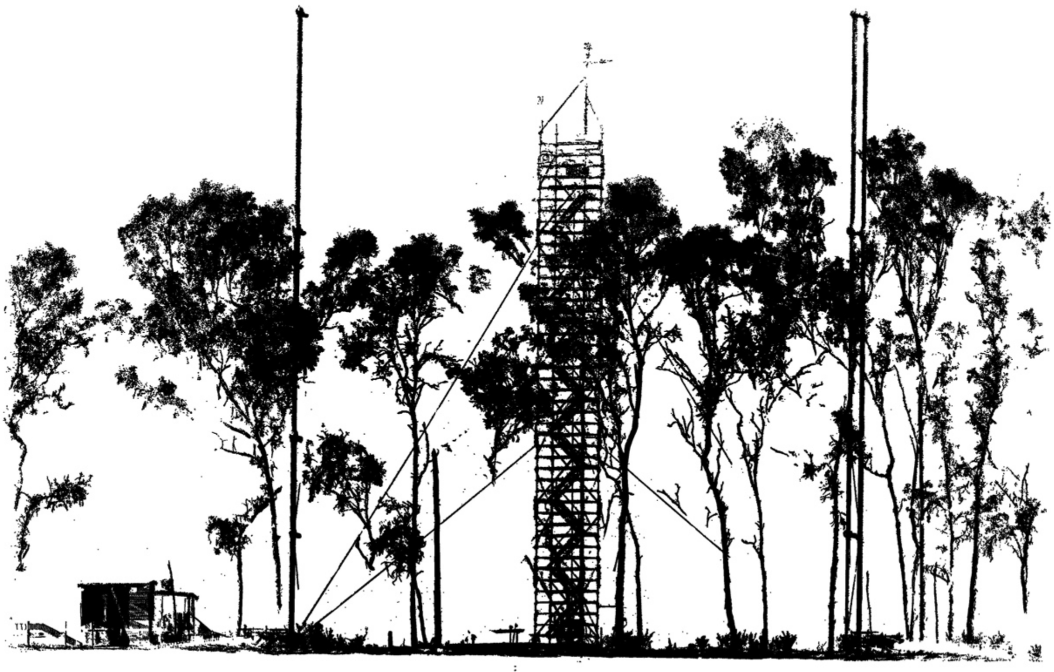

Figure 2: Terrestrial laser scanning 2012 data cross section of ring 1 of the EucFACE experiment.

Acknowledgements

KC was funded by the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 835398.

References

Calders, K. et al. (2015a) Nondestructive estimates of above-ground biomass using terrestrial laser scanning. *Methods Ecol. Evol.* 6, 198-208.

Calders, K. et al. (2015b) Monitoring spring phenology with high temporal resolution terrestrial LiDAR measurements. *Agric. For. Meteorol.* 203, 158-168.

Ellsworth, D. et al. (2017) Elevated CO2 does not increase eucalypt forest productivity on a low-phosphorus soil. *Nat. Clim. Change* 7, 279–282.

Huntingford, C. et al. (2013) Simulated resilience of tropical rainforests to CO2-induced climate change. *Nat. Geosci.* 6, 268-273.

Le Quéré, C. et al. (2009) Trends in the sources and sinks of carbon dioxide. *Nat. Geosci.* 2, 831-836.

Pan, Y. et al. (2011) A Large and Persistent Carbon Sink in the World's Forests. *Science* 333, 988-993

van der Werf, G. R. et al. (2009) CO2 emissions from forest loss. *Nat. Geosci.* 2, 737–738