A pan-tropical campaign to link architectural and biophysical traits

Phil Wilkes[1,2], Alexander Shenkin[3], Harm Bartholomeus[4], Benjamin Brede[4], Andrew Burt[1], Kim Calders[5], Toby Jackson[6], Alvaro Lau[4], Eduardo Maeda[7], Matheus Nunes[7], Louise Terryn[5], Matheus Boni Vicari[1], Hans Verbeeck[5], Mathias Disney[1,2], Lisa P. Bentley[8] and Yadvinder Malhi[3]

[1] University College London, Department of Geography, Gower Street, London, WC1E 6BT, UK
Email: {p.wilkes, mathias.disney, a.burt}@ucl.ac.uk

[2] NERC National Centre for Earth Observation (NCEO)

[3]Environmental Change Institute, School of Geography and Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK
Email: {alexander.shenkin, yadvinder.malhi}@ouce.ox.ac.uk

[4] Laboratory of Geo-Information Science and Remote Sensing, Wageningen University, P.O. Box 47, Wageningen 6700 AA, the Netherlands
Email:{alvaro.lausarmiento, harm.bartholomeus, benjamin.brede}@wur.nl

[5]CAVElab - Computational & Applied Vegetation Ecology, Department of Environment, Ghent University, Belgium
Email: {kim.calders, louise.terryn, hans.verbeeck}@ugent.be

[6] Department of Plant Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EA
Email: tj312@cam.ac.uk

[7] Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland
Email:{eduardo.maeda, matheus.nunes}@helsinki.fi

[8] Department of Biology, Sonoma State University, 1801 E. Cotati Ave., Rohnert Park,CA 94928, USA
Email: lisa.bentley@sonoma.edu

1. Introduction

The variation in structure and form of trees is critical in linking leaf and tree physiology to tree function and to coordinate constraints on tree growth and mortality. Measurement of tree architecture is being revolutionized by ground-based 3D terrestrial laser scanning (TLS) in combination with new theoretical frameworks.

Here we present preliminary results from a project that has captured TLS data from forest plots spanning the tropics; from Peruvian cloud forest, to Ghanaian savanna, to Malaysian dipterocarp upland. Following leaf and wood trait campaigns previously conducted across a bottom-up forest carbon cycling network (GEM, Malhi et al. 2021), our goal is to understand the functional role of tree architecture in tree and forest demographics, resilience, and growth and reproduction strategy. This is crucial for predicting forest response to climate change.

We have so far constructed 3D tree models from 19 plots and ~250 species. Linking tree architecture with leaf and wood traits has resulted in an unprecedented database of tree 3D structural, demographic, and functional trait data.

2. Methods

A leaf traits campaign was conducted (see Asner et al. 2016) where a suite of physiological traits were measured for a subsample of trees (Shenkin et al. 2021). Plots cover a range of forest types and conditions spanning the tropics (Table 1 and Figure 1). For the same subsample of trees TLAdata were captured with a RIEGL VZ-400 (UCL, WU and Ghent) or VZ-400i (University of Helsinki) on a regular grid. (Wilkes et al. 2017). Each trait tree was tagged with a qrDAR code (https://github.com/philwilkes/qrdar) to enable post-scan identification.

Trees were automatically extracted in post processing and manually "cleaned" to remove neighbouring trees or add missing canopy sections. TLSeparation (Vicari et al. 2018) was run to remove leaf points; the remaining wood points were then enclosed using TreeQSM v.2.3 which produces a 3D, topologically coherent volume model for each tree. Analysis of tree structure was performed on QSMs using treestruct (https://github.com/ashenkin/treestruct).

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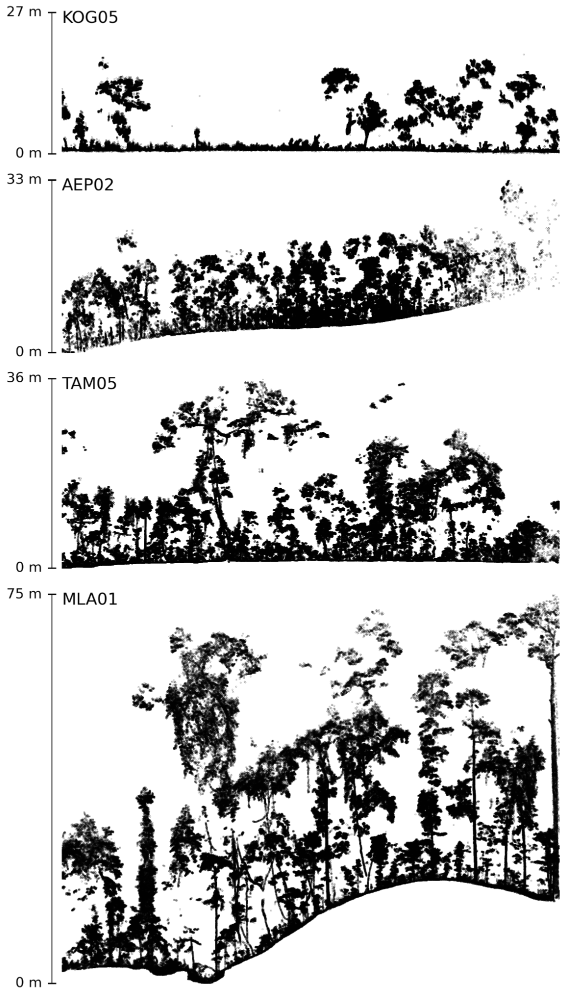

Figure 1. 1 m slices through TLS data for a subset of plots highlighting differences in forest structure and terrain.

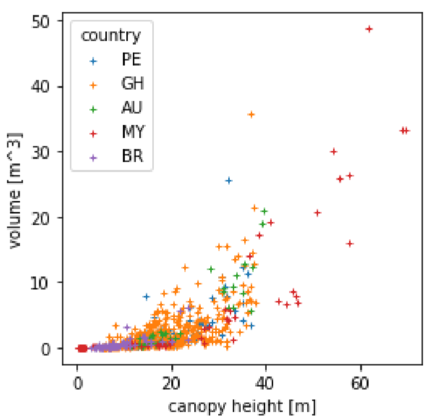

Figure 2. Tree height vs. volume for N=730 trees

3. Results and Discussions

So far, across the 19 plots, over 730 trees from 250 species have been extracted, modelled and linked with the trait database. This represents the largest architecture-trait database currently compiled spanning the tropics. Trees range in height from 2 - 100 m, including the tallest tropical tree yet discovered (Shenkin et al. 2019), and volume from 0.01 - 48.7 m^3 (Figure 2).

Initial analysis indicates that the finer structures in tree crowns play a significant role in tree function, especially where surface area (as opposed to volume) is the critical scalar. We also find that tree and branch architecture lie on orthogonal axes suggesting that the former is determined by life-history and the latter by phylogeny. Finally, we find that wind, rather than gravitational stability, is likely a controlling determinant of tree height.

Branches were also harvested and modelled for a subsample of trees (Wilkes et al. in review). Early results suggest that branch architecture and tree shape comprise orthogonal axes in trait ordination analyse. New tools are required to analyse these smaller branch structures, due to the inherent limitations of TLS data and QSM reconstruction at these scales.

4. Conclusions

This project represents a coordinated collaboration between a number of institutions across the globe spanning nearly a decade of functional trait and TLS campaigns. The results coming from these coordinated efforts underscore the importance of collaboration and continuous funding streams. Furthermore, while these campaigns benefit science, they have also served to strengthen institutional ties across counties. We endeavour to offer these campaigns as models for those seeking to generate large, deep, and connected datasets across disparate ecosystems.

Table 1. List of plots. ISO country codes used. Team codes; WU Wageningen University, UCL University College London and UoH University of Helsinki. *N trees* is trees extracted so far.

Plot	Country	Year	Lat	Lon	Area (ha)	Grid (m)	Angular step	Team	N trees
ESP-01	PE	2014	-13.175	-71.595	1	20	0.06	WU	26
ANK-01	GH	2016	5.268	-2.694	1	10	0.04	UCL/WU	96
KOG-02	GH	2016	7.262	-1.150	1	20	0.04	WU	73
KOG-04	GH	2016	7.303	-1.180	1	20	0.04	WU	74
KOG-05	GH	2016	7.305	-1.165	1	20	0.04	WU	121
TAM-05	PE	2017	-12.831	-69.271	1	10	0.04	UCL	38
TAM-06	PE	2017	-12.839	-69.296	1	10	0.04	UCL	24
AEP-02	AU	2018	-17.147	145.587	0.5	10	0.04	UCL	27
AEP-09	AU	2018	17.121	145.634	1	10	0.04	Ghent	57
AEP-33	AU	2018	-17.285	145.571	0.5	10	0.04	UCL	27
AEP-41	AU	2018	-16.136	145.441	0.5	10	0.04	Ghent	32
MLA-01	MY	2018	4.747	116.970	1	10	0.04	UCL	48
SAF-03	MY	2018	4.691	117.588	0.5	10	0.04	UCL	35
SAF-05	MY	2018	4.716	117.610	0.5	10	0.04	UCL	10
CBN-01	MY	2019	4.951	117.792	1	10	0.04	UoH	43
CRP-01	BR	2019	-14.712	-52.352	0.25	10	0.04	UoH	5
CRP-02	BR	2019	-14.712	-52.352	0.25	10	0.04	UoH	7
NXV-01	BR	2019	-14.423	-52.210	1	10	0.04	UCL	60
VCR-02	BR	2019	-14.832	-52.168	1	10	0.04	UCL	14

5. Acknowledgements

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