CRC Spatial Information (Project 2.07)

Uncertainty in Remote Sensing of Leaf Area Index and Foliage Cover in Australian forests

William Woodgate

william.woodgate@rmit.edu.au

Melbourne, 26th August 2014

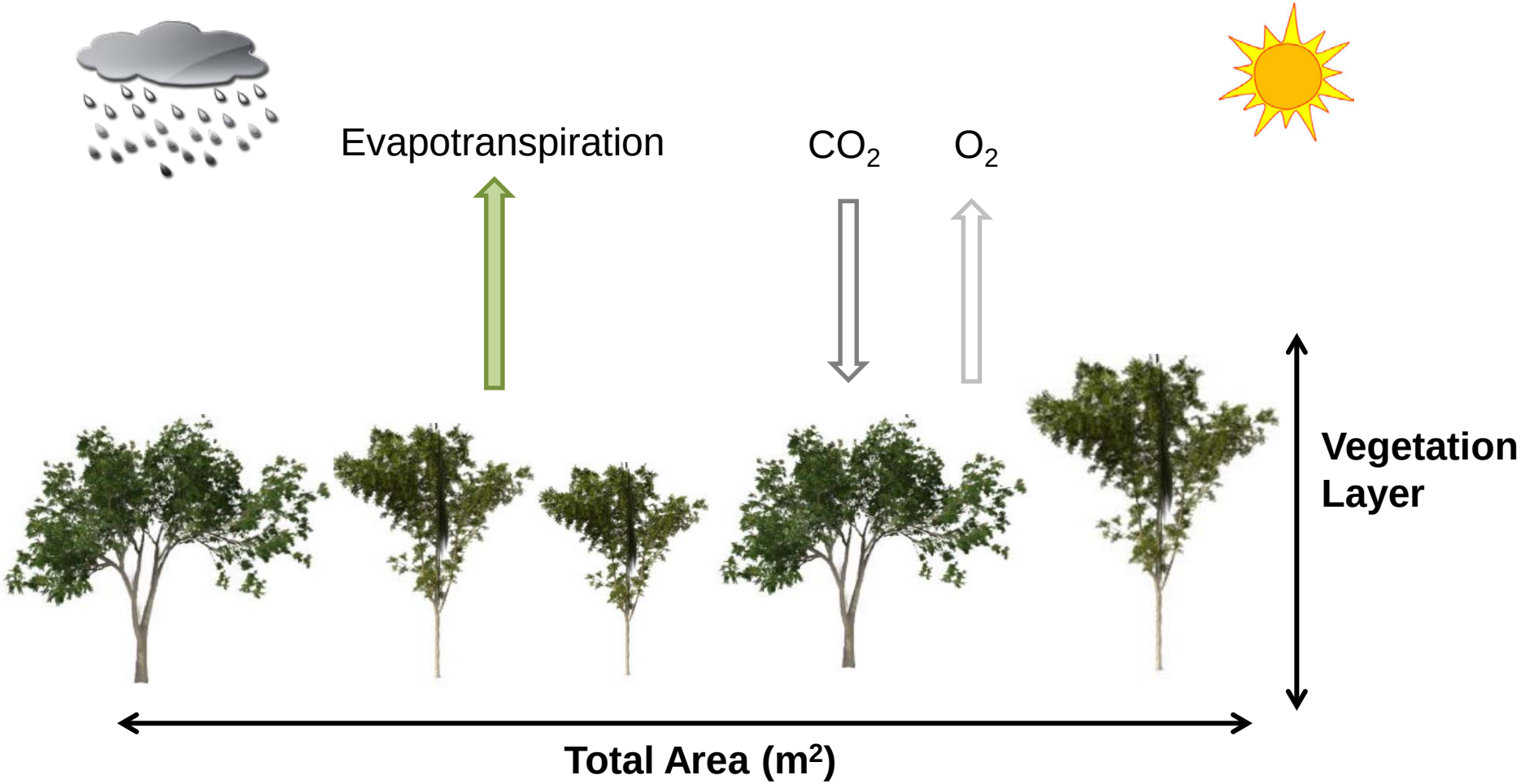
RMIT University

crc•si

Victoria
The Place To Be

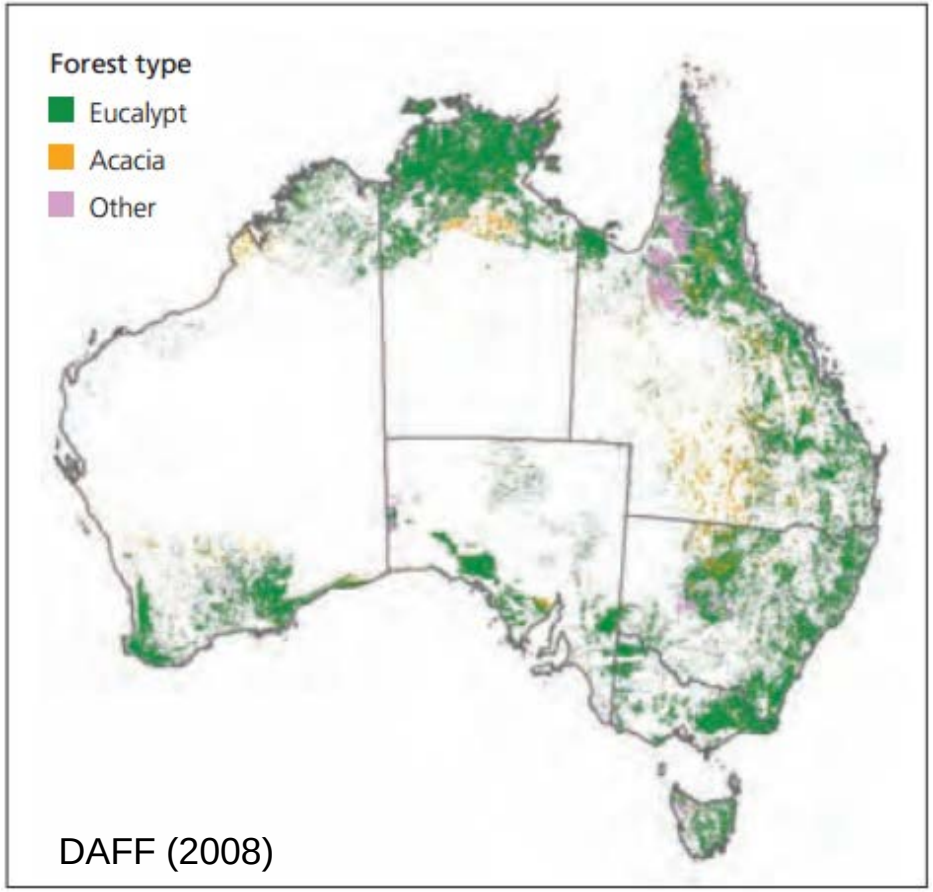
Contents

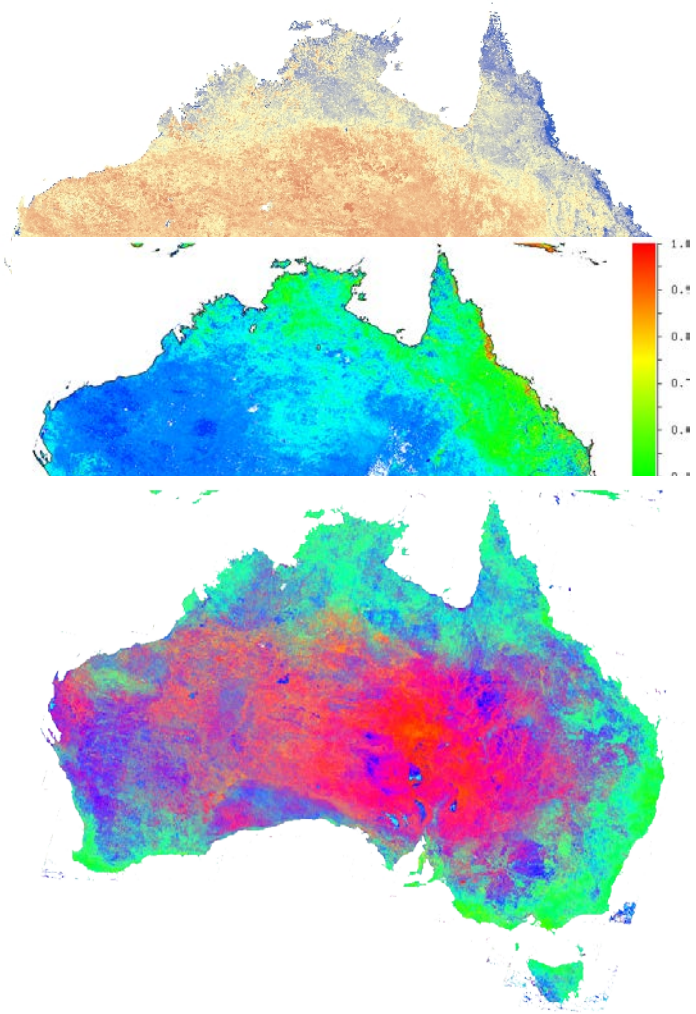
Vegetation as the boundary layer



Leaf Area Index = Total one-sided leaf area (m^2) / Total Area (m^2)

Australian Forests





Distribution of Australia's forests

Remote Sensing Products

Australian forest traits and challenges

Some of the main factors when remotely sensing vegetation:

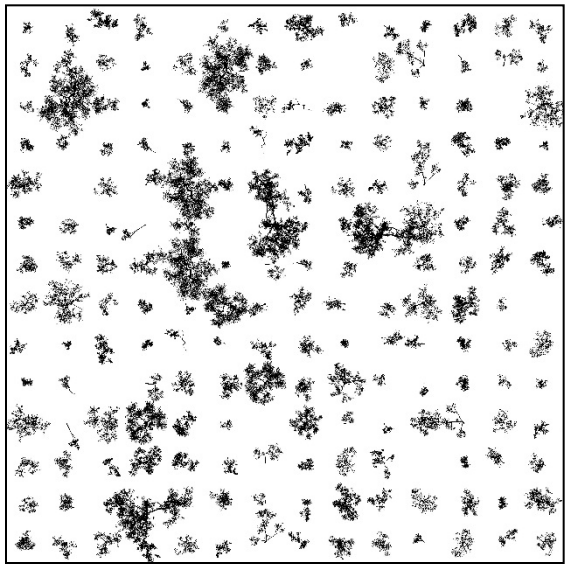
1. *Clumping (at all scales)*
2. *Leaf Angle (distribution)*
3. *Impact of woody components*

Australian forest traits and challenges

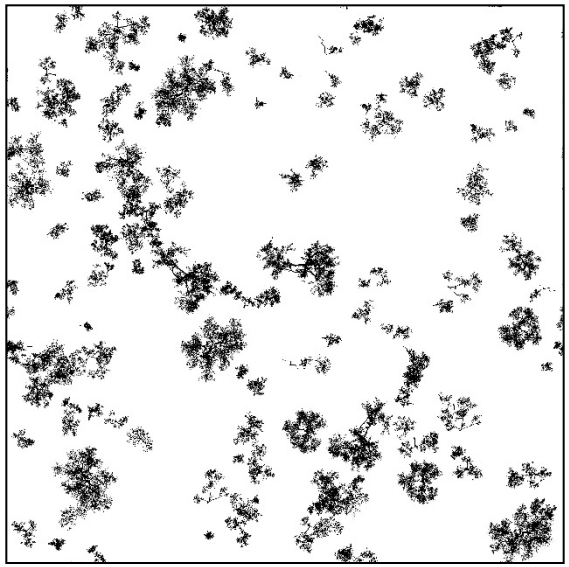
1. *Clumping (at all scales)*

Crown architecture
(within-crown clumping)

Regular Tree Distribution



Clumped Tree Distribution



Tree distribution
(between-crown clumping)

Australian forest traits and challenges

2. *Leaf Angle (distribution)*

Vertical leaf angle
(Eucalypt)

Horizontal leaf angle

Australian forest traits and challenges

3. *Impact of woody components* *(i.e. leaf:woody ratio)*

Upward-looking view of a canopy

Remote Sensing of LAI

LAI = f(canopy gaps, clumping,
leaf & wood angle, leaf:wood ratio)

Part 1: Product Accuracy Requirements

- Need for accurate ground-based measurements in support of calibration/validation activities

Target Accuracies (*products to match within ground-based estimates*)

± 0.5 LAI or 20% maximum (CEOS, GCOS)

5% (WMO 2013)

Main Research Questions/Themes

Part 1

Are there any significant differences between the ground-based instruments for estimating LAI?

Part 2

How accurately can you estimate LAI using these ground-based instruments?

Part 1: Field-based Investigation

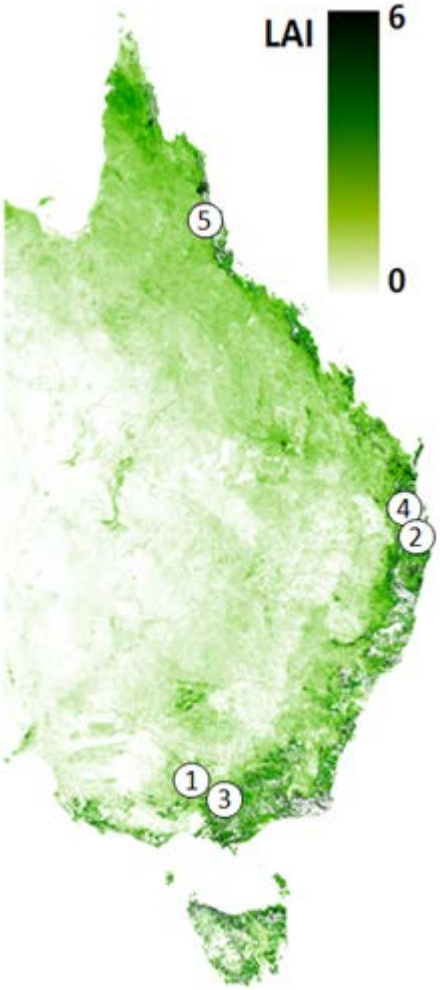
Are there any significant differences between the ground-based instruments for estimating LAI?

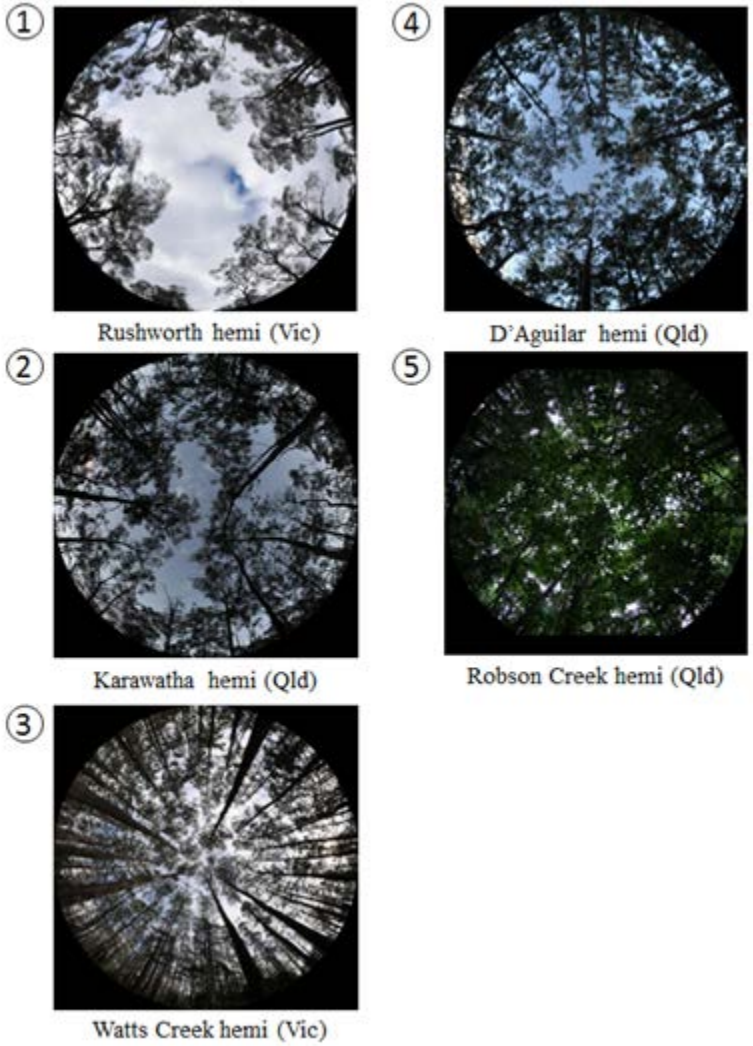
Following…

- Best practise guidelines (where they exist)
- Standard approach

Can only estimate uncertainty. <u>Not</u> accuracy!

Part 1 – Study sites & Instruments





Instruments

Terrestrial Laser Scanner

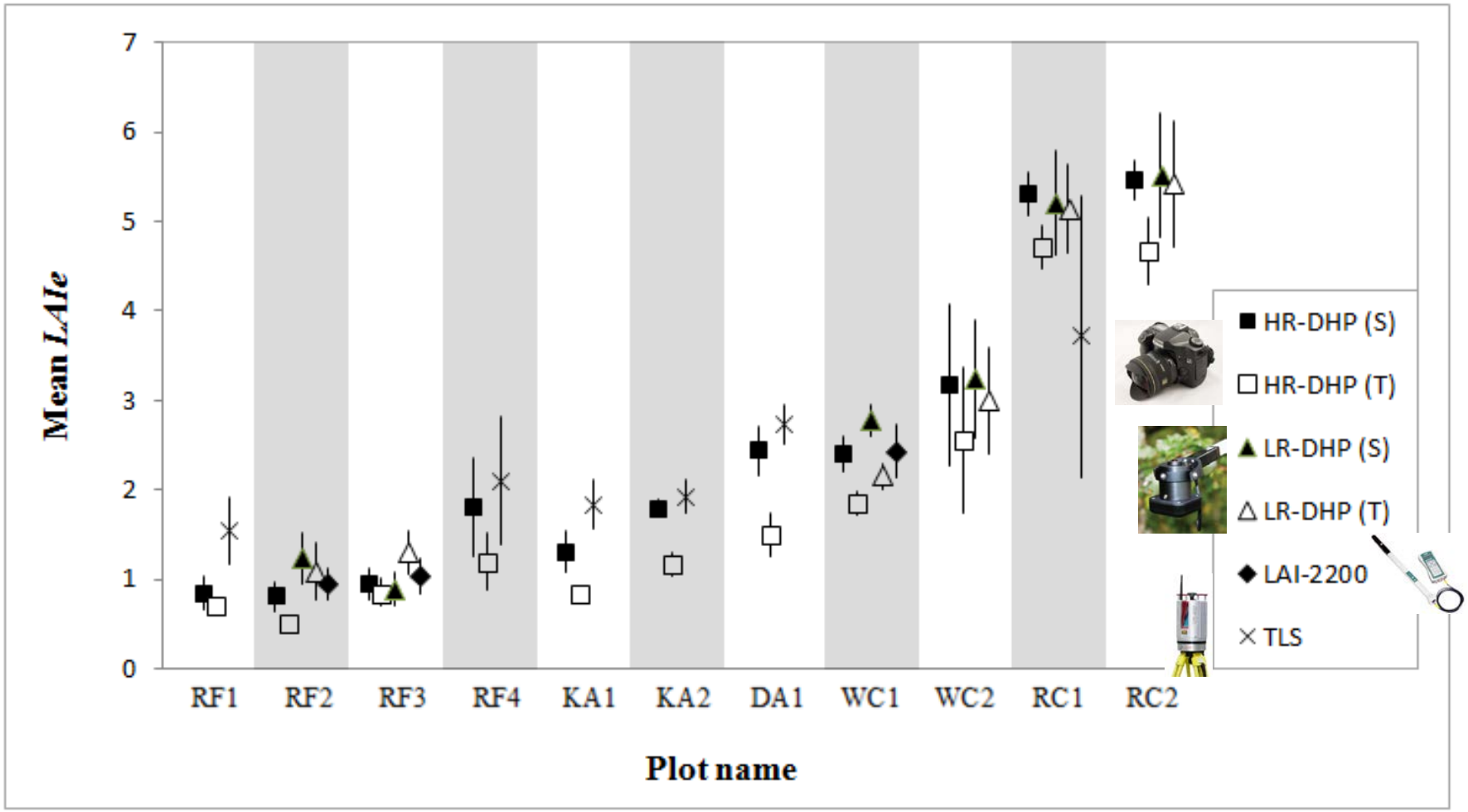
LAI-2200

High and Low Resolution Hemispherical Cameras

Part 1 – Instruments

Instrument	Model (Manufacturer)	Angular resolution (degrees)	FOV (degrees) H, V	Wavelength (nm)
LAI-2200	LAI-2200 (Li Cor Inc.)	NA	300, 75	<490
High res DHP	D90 (Nikon)	0.08	360, 90	400-700
Low res DHP	CI-110 (CID Inc.)	0.26	360, 90	400-700
TLS	VZ400 (Riegl)	0.06	360, 100	1550

Part 1 – Results



Woodgate et al., (2014) in review

Part 1 – Results

- A total of 67 method-to-method pairwise comparisons were conducted across 11 plots.
- Out of 67 comparisons, 29 had an RMSE ≥ 0.5 *LAIe*.

	HR-DHP (S)	HR-DHP (AT)	LR-DHP (S)	LR-DHP (AT)	LAI-2200	TLS
HR-DHP (S)	-	11	6	6	3	6
HR-DHP (AT)	0.58	-	6	6	3	6
LR-DHP (S)	0.24	0.68	-	6	3	1
LR-DHP (AT)	0.23	0.51	0.33	-	3	1
LAI-2200	0.10	0.44	0.27	0.24	-	0
TLS	0.76	0.97	1.49	1.43	NA	-

Bottom diagonal is the average of plot RMSE's between instruments.

Top diagonal is the number of plots where these instruments were compared.

Woodgate et al., (2014) in review

Part 1 – Results & Lessons learned

- Large uncertainties exist for these methods for LAI estimates following standard operational protocols for data collection

What are the main causes of the differences?

- DHP = **exposure** (radiometric sensitivity), lighting and sky background and conditions
- TLS = combination of beam size, range/power, detection threshold, ranging method (phase vs ToF) & wavelength
- LAI-2200 = assumption that all elements are ‘black’ when estimating transmittance

Part 2: Model-based Investigation

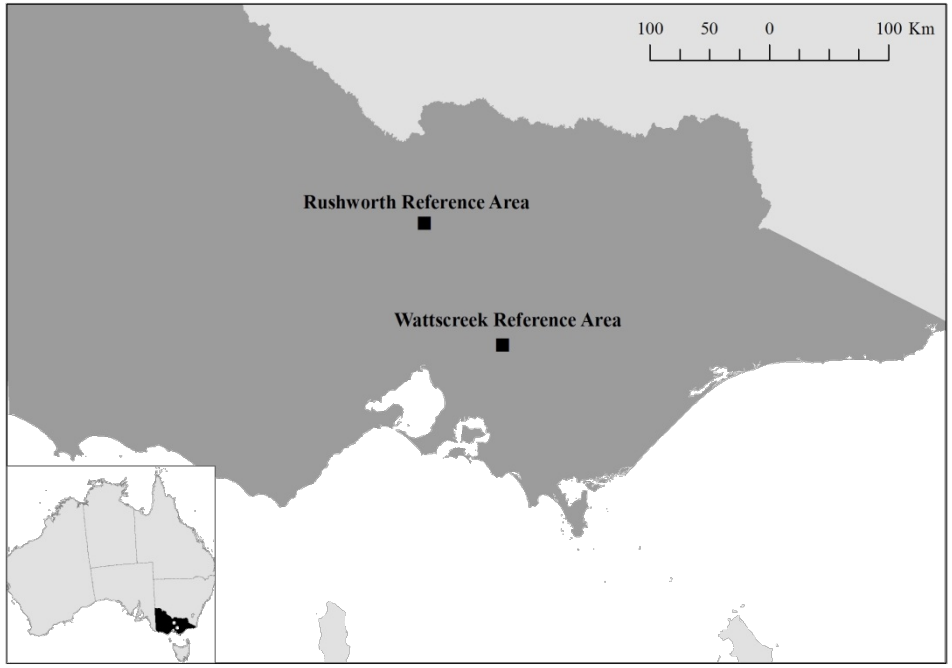
How accurately can you estimate LAI using these ground-based instruments?

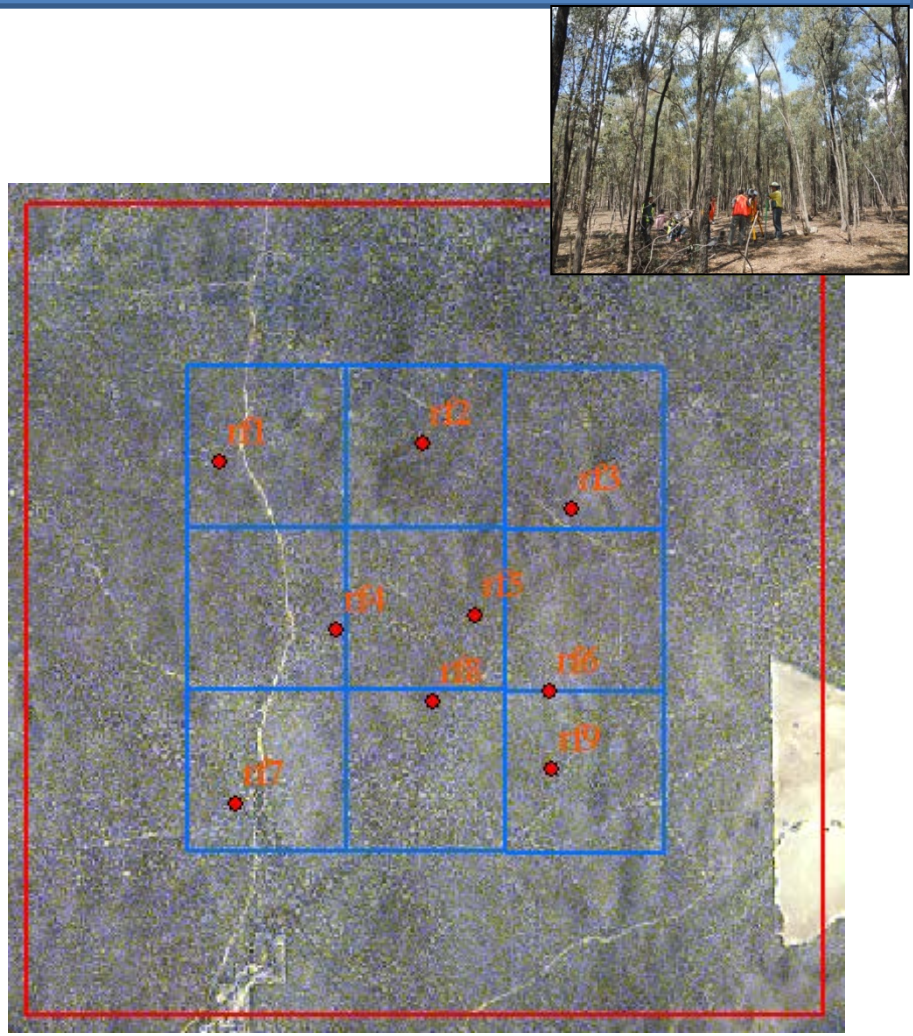
Aim

Evaluate accuracy using a 3D reconstructed forest stand to simulate the instruments

Model parameterisation: creating the forest

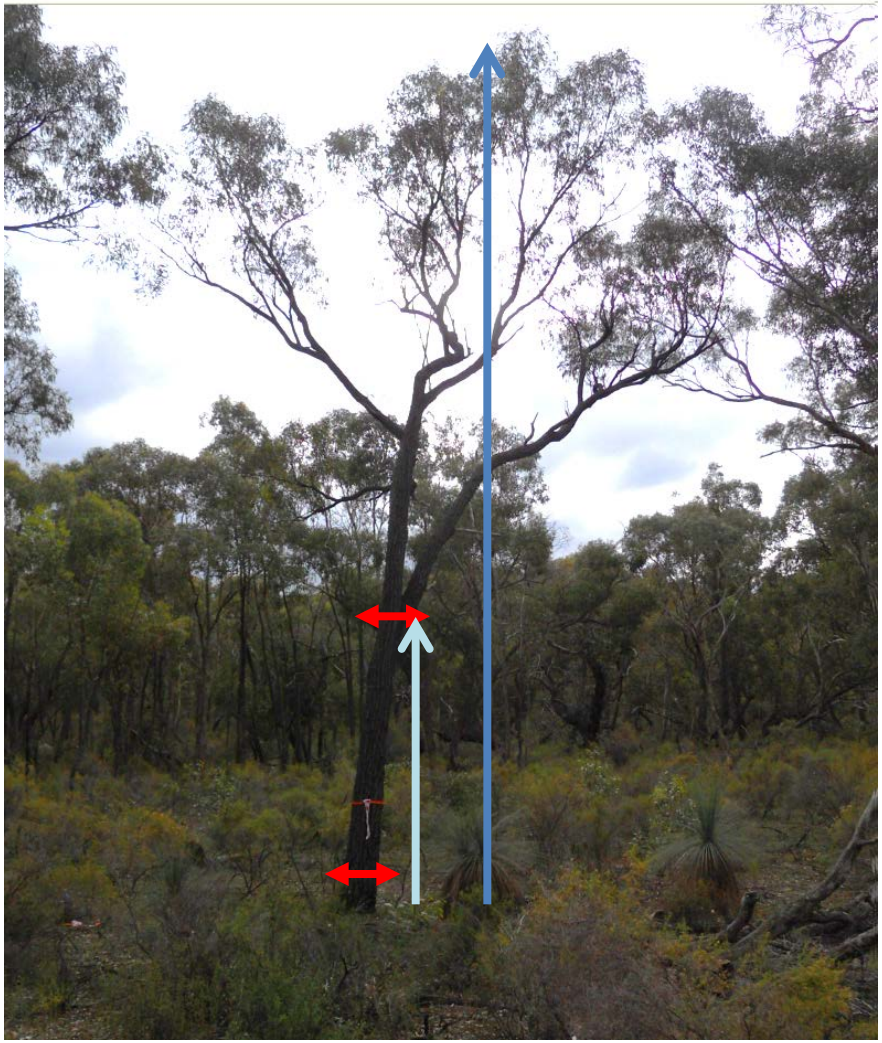
- Rushworth Forest

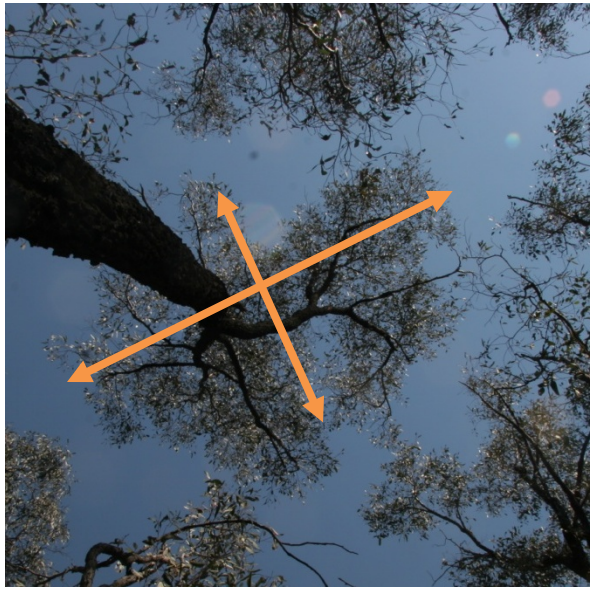


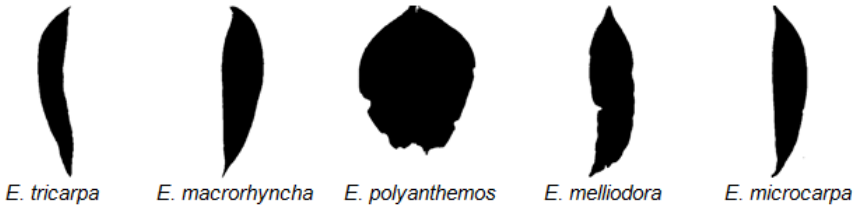


5km

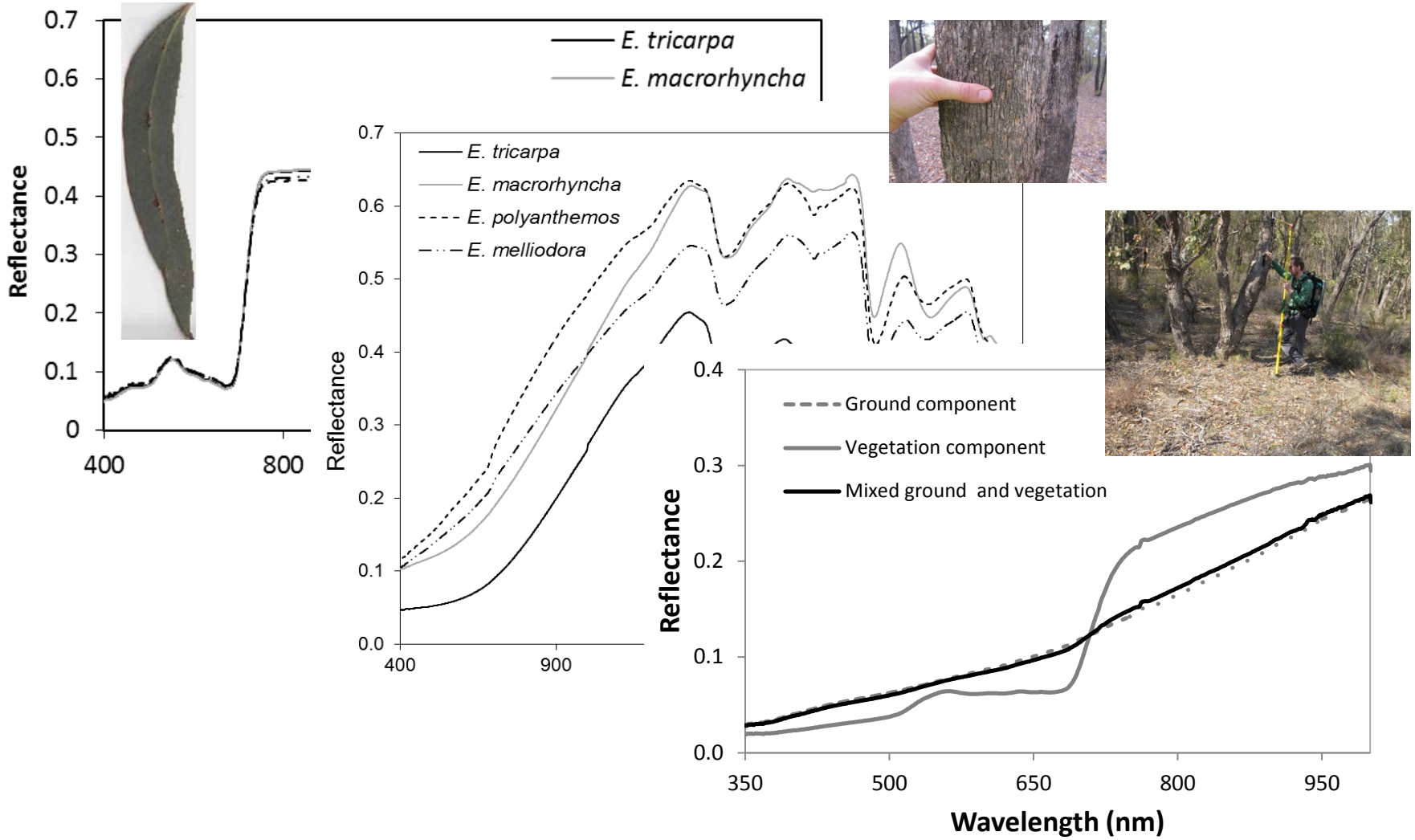
Model parameterisation: creating the trees







Model parameterisation: creating the forest



Model parameterisation: creating the trees

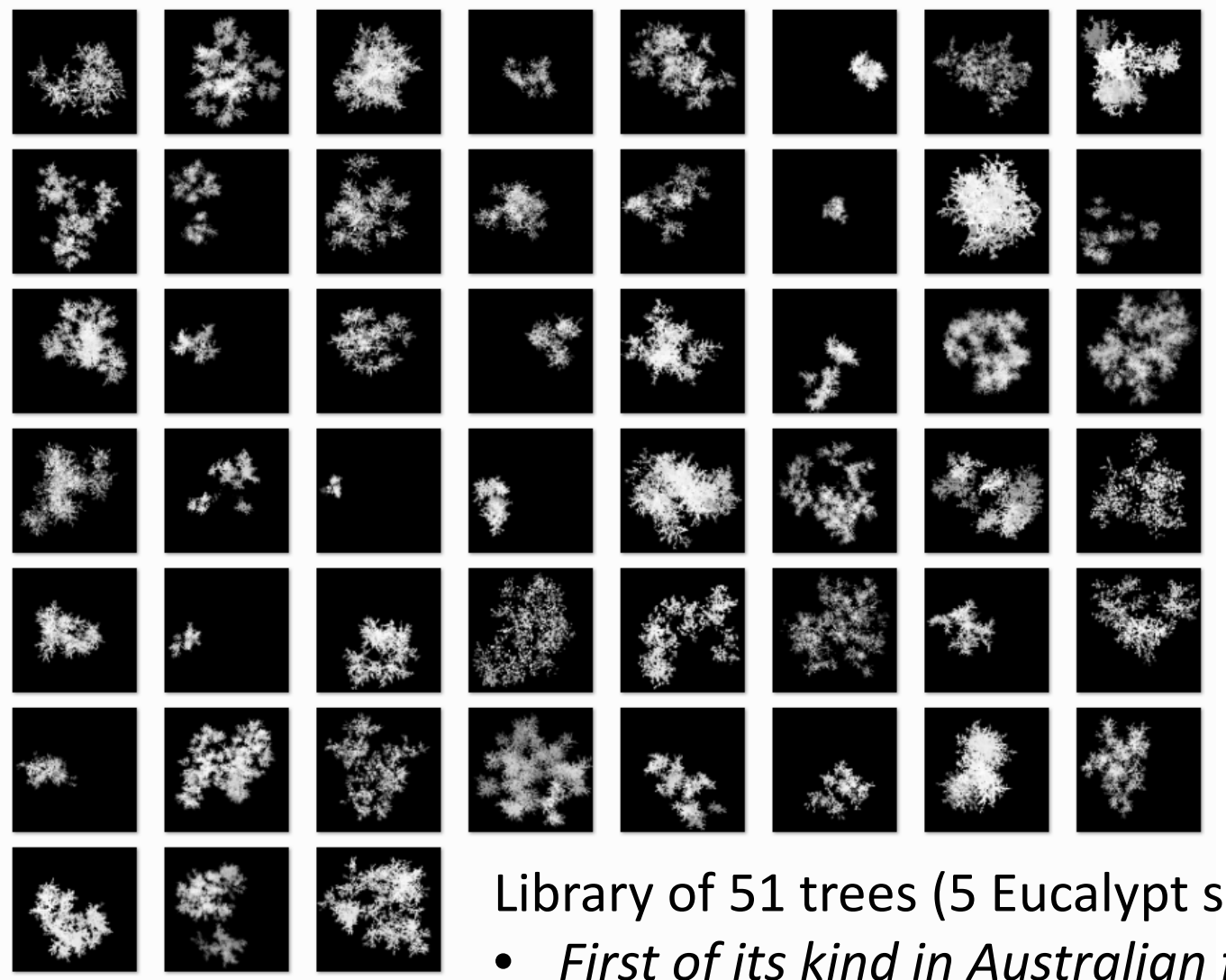
Modelled structure of the trees in OnyxTree (no spectra or leaf template added)

(a) *E. tricarpa*
Height = 18.6 m, DBH = 28.3 cm

(b) *E. macrorhyncha*
Height = 9.6m, DBH = 12.8 cm

(c) *E. microcarpa*
Height=21.8 m, DBH=27.2cm

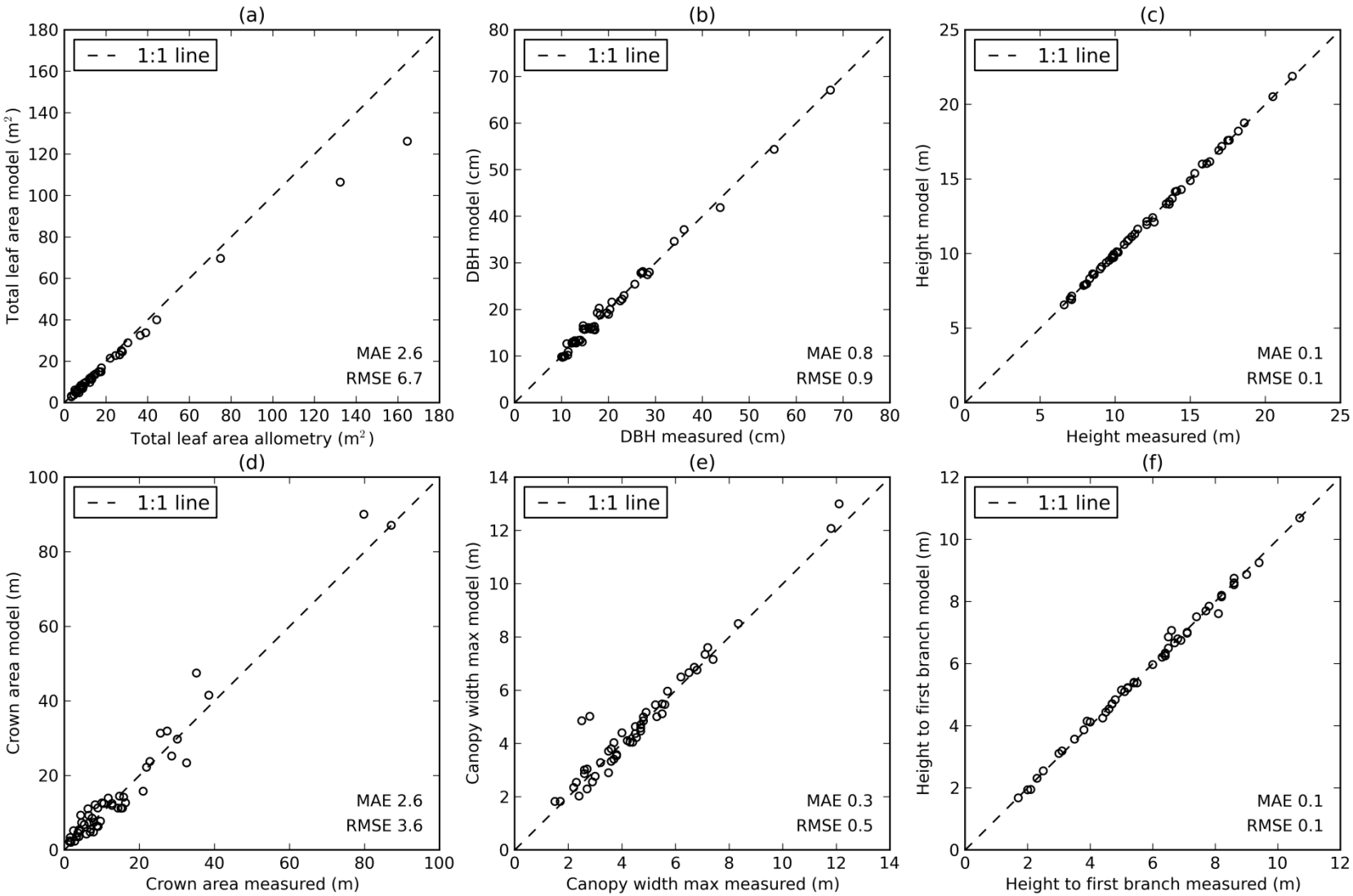
Model parameterisation: creating the trees



Library of 51 trees (5 Eucalypt species)

- *First of its kind in Australian forests*

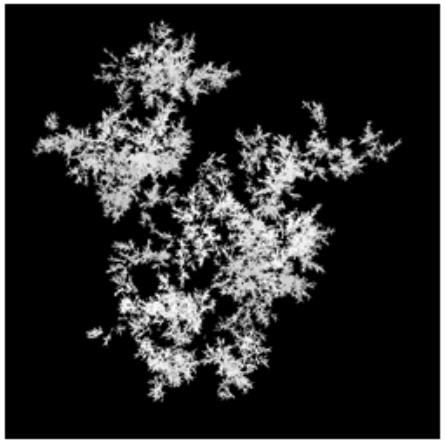
Validation of the 51 tree models



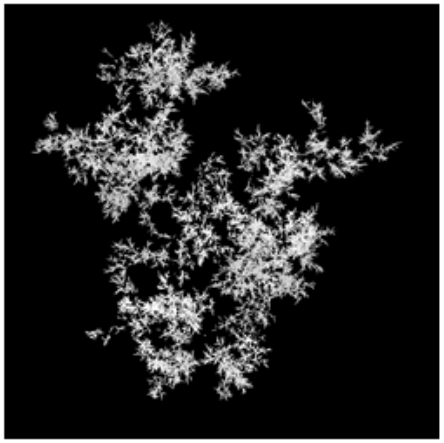
Part 2 results: Within-crown clumping and Leaf Angle

Crown cover simulations

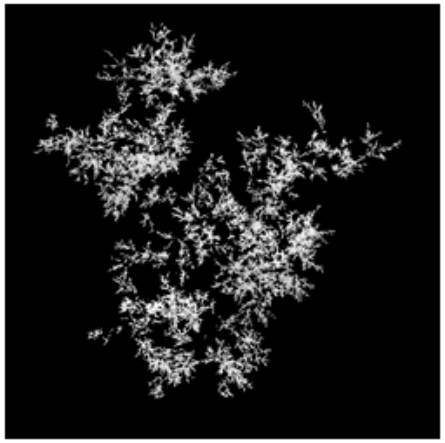
0 degree view angle



Planophile (vza = 0)
Crown cover = 11.63 m^2

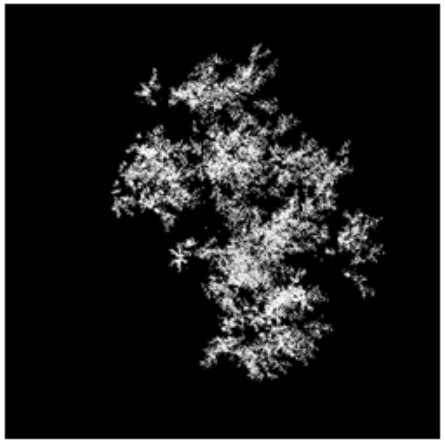


Extremophile (vza = 0)
Crown cover = 10.01 m^2

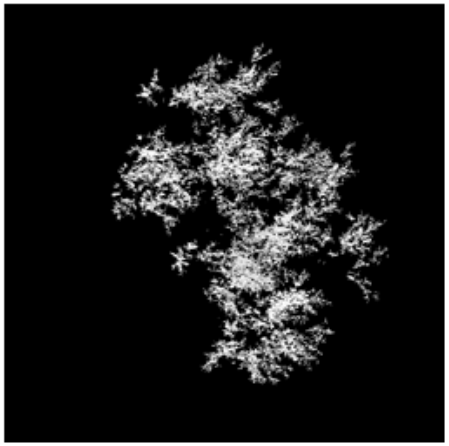


Erectophile (vza = 0)
Crown cover = 8.24 m^2

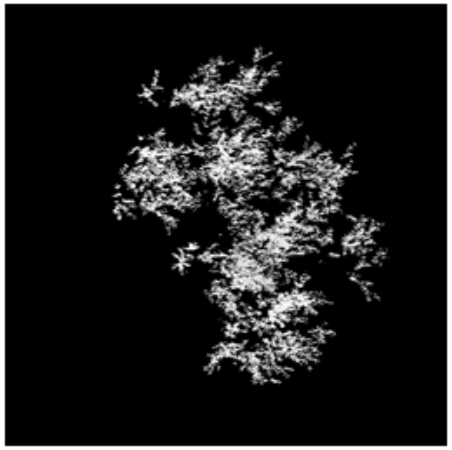
57 degree view angle



Planophile (vza = 1rad)
Crown cover = 8.32 m^2

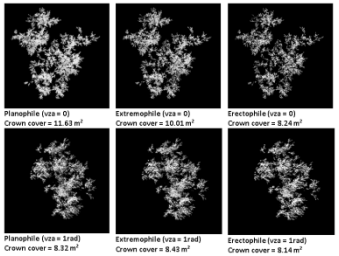


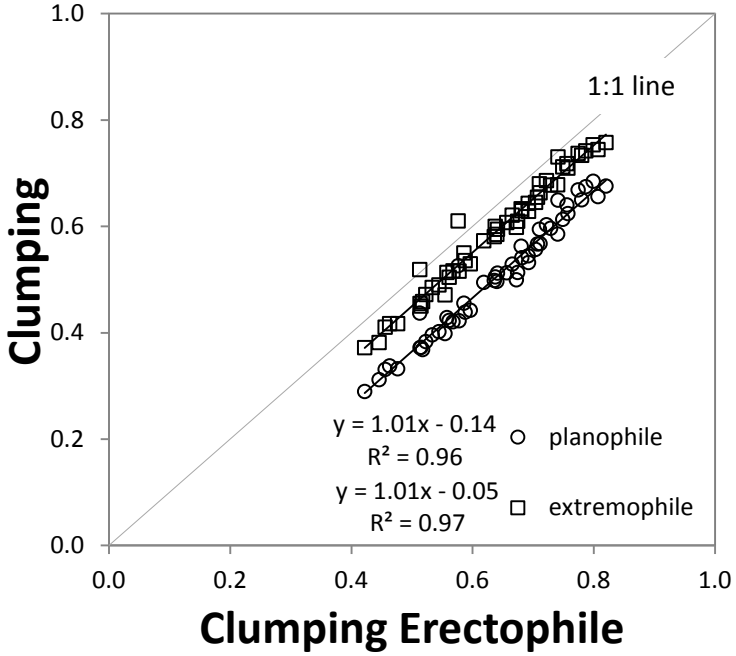
Extremophile (vza = 1rad)
Crown cover = 8.43 m^2



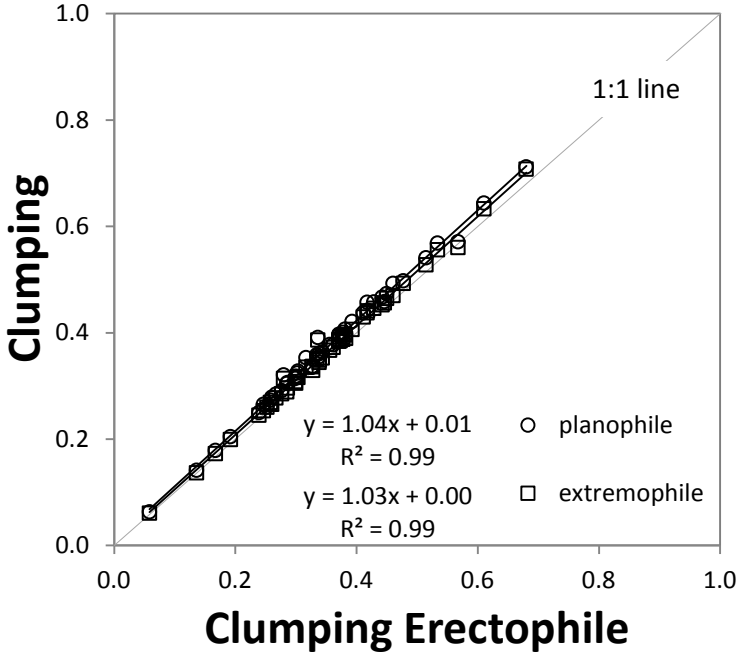
Erectophile (vza = 1rad)
Crown cover = 8.14 m^2

Part 2 results: Within-crown clumping and Leaf Angle





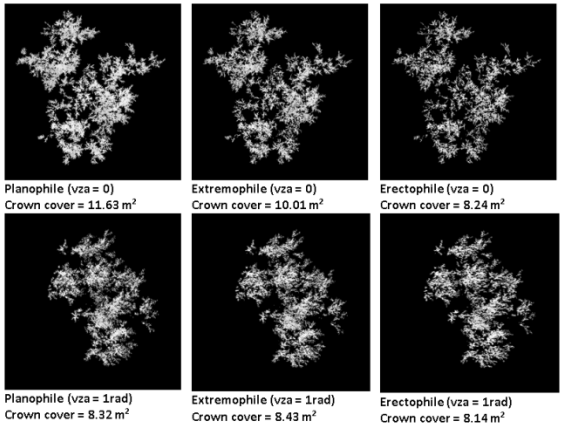
0 degree view angle

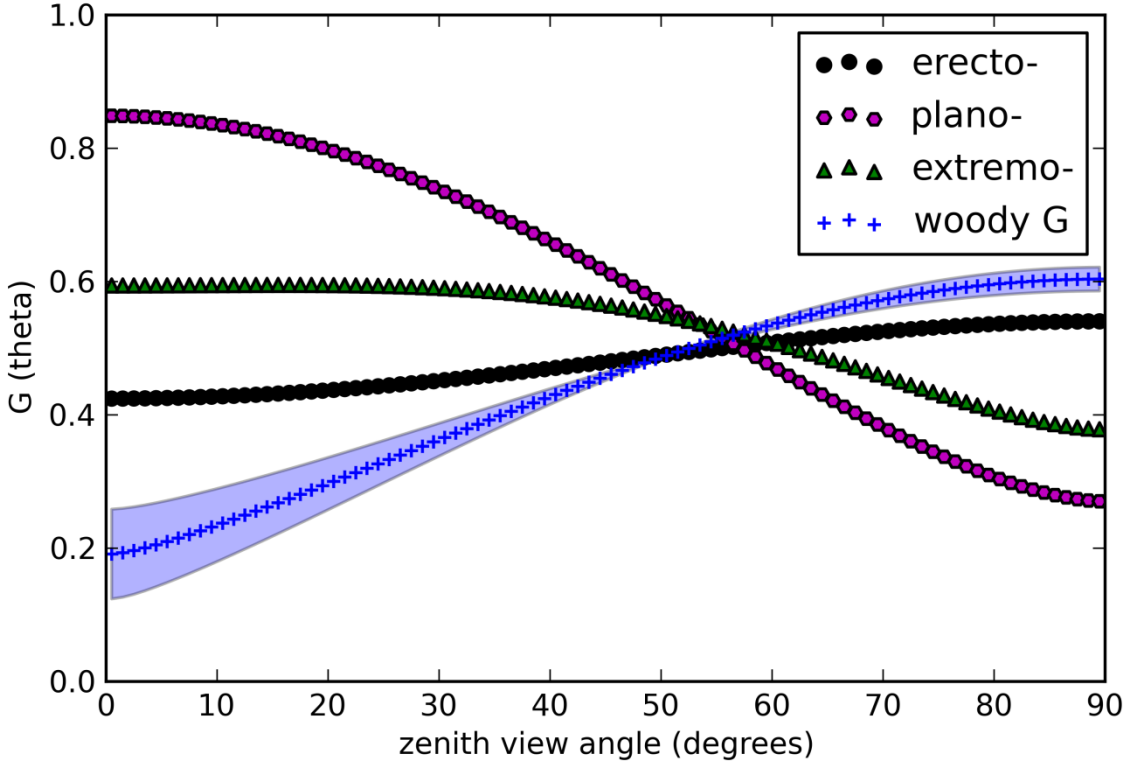


57 degree view angle

Part 2 results: Within-crown clumping and Leaf Angle

Accounting for the woody components





Projection coefficient of leaves and wood

Part 2: Up-scaling from tree to plot to stand

Ongoing work…

Tree

→

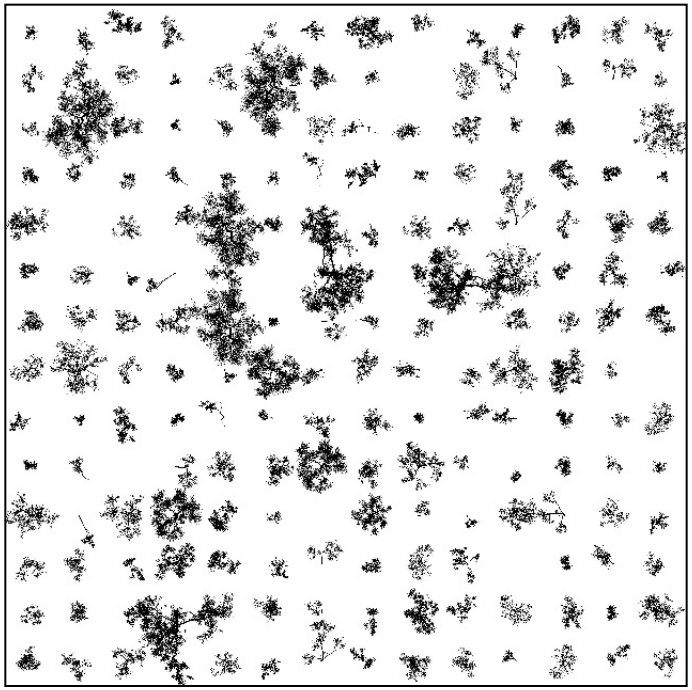
Plot

→

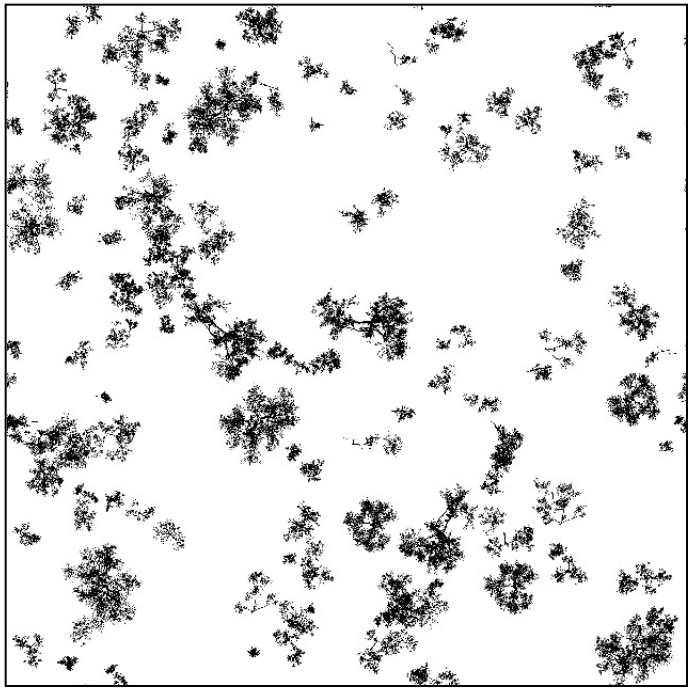
Stand

Clumping Simulations

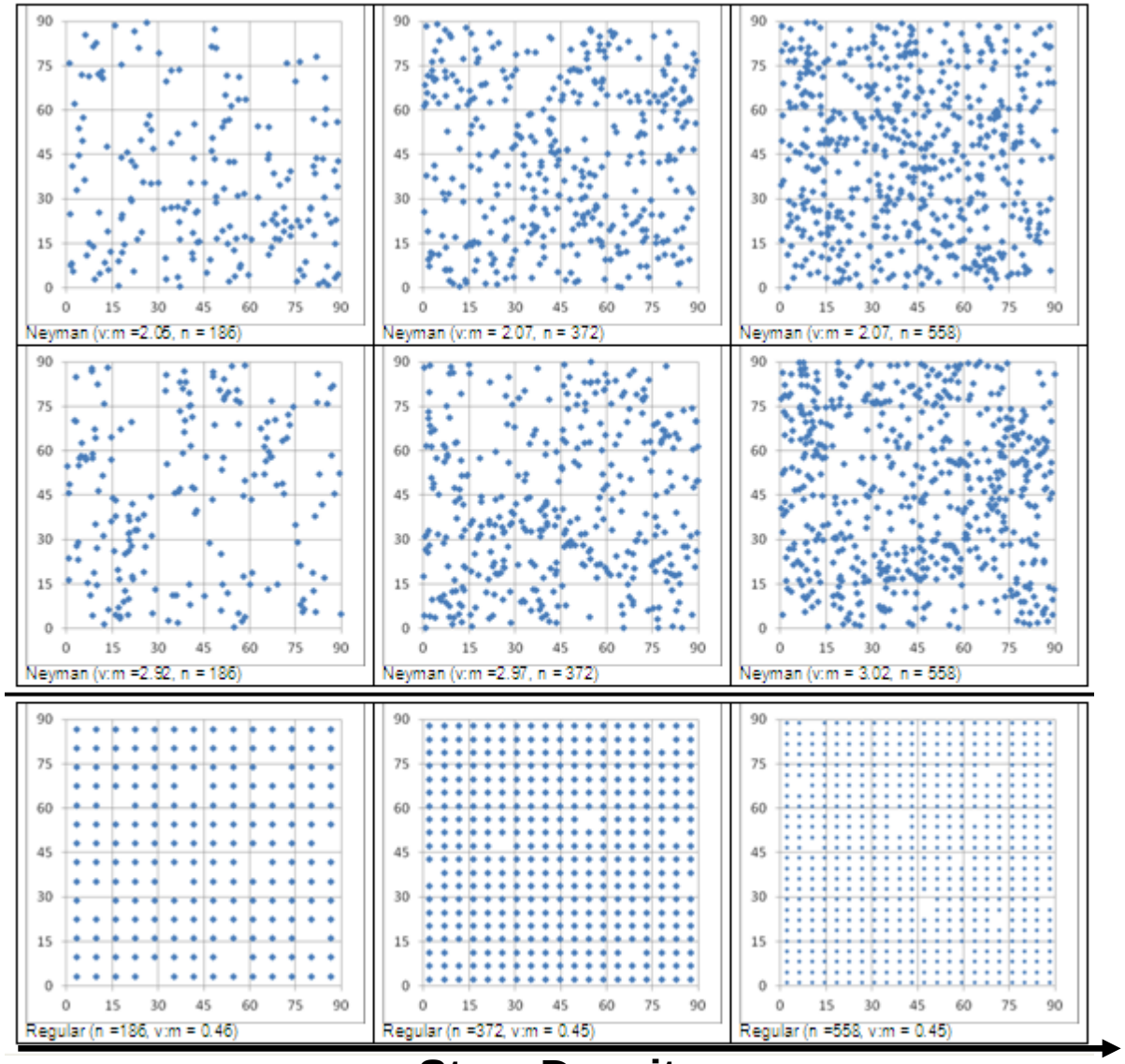
Regular Tree Distribution



Clumped Tree Distribution



Exemplar stem distributions

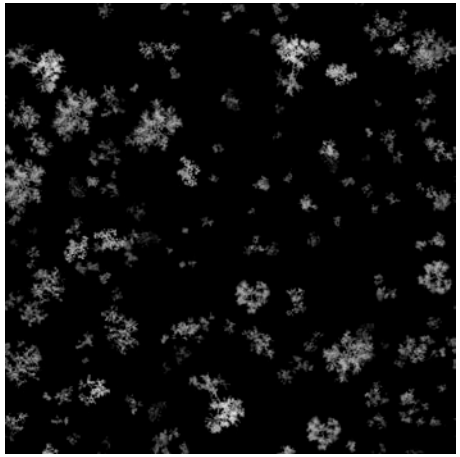


Part 2: Site scale simulations

Stem density = 230 stems ha^{-1}

LAI = 0.4, Cover = 10%

Random tree distribution

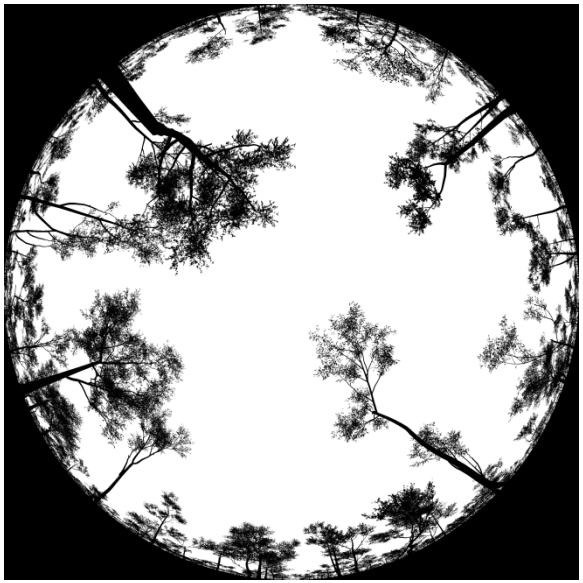


Top-down view (90 x 90 m)

Part 2: Site scale preliminary results

Simulated hemi photo

Part 2: Example site simulations



Openness = 79%

Reference LAI = 0.4

Openness = 65%

Reference LAI = 0.8

Openness = 51%

Reference LAI = 1.2

Questions?

Maybe to include…

Thanks to…

- Supervisory panel (Simon Jones, Lola Suarez, Michael Hill)
- Work colleagues (esp. CRC-SI 2.07 team – Simon Jones, Andrew Haywood, Lola Suarez, Phil Wilkes, Andrew Mellor, Mariela Soto-Berelov. Lab colleagues – Vaibhav Gupta, Laurie Buxton, Bill Langford, Barbara Rasaiah, James Leversha, Tapasya Arya. Staff – Mark Shortis, Chris Bellman, Lucas Holden)
- Mentors (Wu Bingfang, Graeme Kernich)
- Research collaborators (John Armston, Mat Disney, Michael Schaefer)
- Friends and Family
- ++

Selection of Research Outputs

Ground based method intercomparison (journal article)

W. Woodgate, S. Jones, L. Suarez, M. J. Hill, J. D. Armston, P. Wilkes, M. Soto-Berelov, A.Haywood, A. Mellor (2014). Variability of ground-based instruments for estimating Leaf Area Index in diverse forest systems, *Agricultural and Forest Meteorology* (*submitted*)

Crown-scale modeling (journal article)

W. Woodgate, S. Jones, L. Suarez, J. D. Armston, M. Disney, M. J. Hill, P. Wilkes, M. Soto-Berelov, A. Haywood, A. Mellor (2014). Within-crown clumping varying with leaf angle distribution, *IEEE TGARS* (*In prep.*)

TLS international collaboration effort (journal article)

M. T. Schaefer, **W. Woodgate**, J. Armston, A. Strahler, M. Danson, C. Schaaf, G. Newnham (2014). TLSIIG – Leaf area index from foliage profiles derived from five terrestrial laser scanners: a comparison, *Agricultural and Forest Meteorology*, (*In prep.*)

TERN Greenbook (book chapter)

Schaefer, M.T., Farmer, E., Soto-Berelov, M., **Woodgate, W.**, & Jones, S. (2013). Validation of LAI and FPAR products. In M. Soto-Berelov, A. Held, S. Phinn & S. Jones (Eds.), *AusCover Good Practice Guidelines: A technical handbook supporting calibration and validation activities of remotely sensed data products*. http://data.auscover.org.au/xwiki/bin/view/Good+Practice+Handbook/WebHome

Sampling Design (peer reviewed conference paper)

W. Woodgate, Soto-Berelov, M., Suarez, L., Jones, S., Hill, M., Wilkes, P., Axelsson, C., Haywood, A., Mellor, A. Searching for an optimal sampling design for measuring LAI in an upland rainforest. Proceedings of the Geospatial Science Research Symposium GSR2, December 2012, Melbourne. ISBN 978-0-9872527-1-5

Ground based methods and modelling introduction (peer reviewed conference paper)

W. Woodgate, M. Disney, J. Armston, S. Jones, L. Suarez, M. Hill, P. Wilkes, M. Soto-Berelov, A. Haywood, A. Mellor, 2013. The impact of sensor characteristics for obtaining accurate ground-based measurements of LAI, IGARSS Melbourne, July 2013