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The impact of sensor characteristics for obtaining accurate ground-based estimates of LAI

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Queensland Government

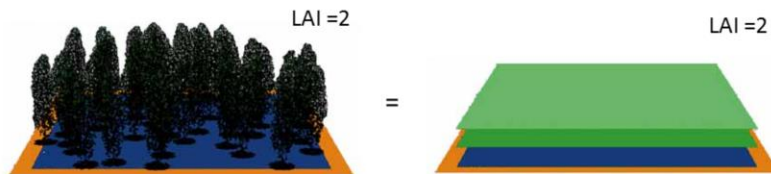


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What is Leaf Area Index (LAI)?

*...defined as the total one-sided surface area of foliage
per unit of ground area*

$$LAI = \frac{\sum \text{Leaf Area}}{\text{Area}}$$



...an Essential Climate Variable (ECV)



Background

- + Importance (ECV, input into climate and productivity modeling to name a few)
- + Has also been used at many scales from local to global – where a few LAI products from satellites exist (most prominent MODIS LAI)
- + Focus on LAI of forested areas

Ground-based technique examples

		Large Area Characterisation	Permanent record	Instrument Cost	Processing requirement
Indirect	A black hemispherical camera mounted on a tripod.	Good	Yes	Low	Medium
	A yellow and black terrestrial LiDAR scanner mounted on a tripod.	Medium	Yes	High	Medium
	A handheld plant canopy analyser device.	Good	No	Medium	Low
	A person using a tool to measure a tree trunk.	Good	No	Low	Low
Direct	A yellow excavator harvesting a tree.	Poor	No	High	High

Background

- indirect estimates suited for rapid large area (plot level up to 1ha) characterization of LAI
- indirect instruments will be the focus of my research

Satellite products target accuracy

LAI products accuracy target:

± 0.5 LAI or 20% maximum



- Ground-based estimates are the reference values for LAI products

Future accuracy target:

$\pm 3-5\%$ maximum

- What room for error does this leave ground-based estimates of LAI?

Background

Needs to be very accurate especially if used as a reference estimate for cal/val

Problem of no absolute truth!

Also don't have any recommendations for % of measurements that should be within the specified accuracy tolerance

Indirect instruments - sources of error

<u>Instrument/ sensor</u>	<u>Sensor operation</u>	<u>Sampling strategy</u>	<u>Processing</u>	<u>Scene/ Landscape</u>
-FOV -resolution -wavelength -active/passive ...	-lighting conditions -sky background -Level/tilt -xyz offset ...	-configuration -number of m's ...	-classification & filtering -algorithm type ...	-tree types -tree density -vegetation layers -understorey -terrain ...

- *Desired outcome is to make informed decisions as to which sensor + sampling strategy + processing to use for a desired accuracy tolerance*
- *An experimental design to investigate with fieldwork is exceptionally costly*

Modelling component

Few studies have simulated the sensors to investigate sensor and sampling impacts for LAI estimation

Pros

- Level of detail
- Flexibility of model (LAD, tree clumping)
- Ability to isolate sources of bias
- Truth known

Cons

- Initial amount of fieldwork is large (for a *representative* model of a forest)
- Level of detail – creation of tree library is time intensive
- Establish validity – requires other sources of data (ALS, imagery)

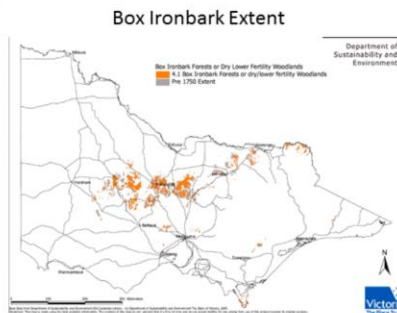
-3D MCRT model is librat

-tree geometries modelled down to the leaf level

Rushworth study site



Box Ironbark Forest



Located central Vic, Aus

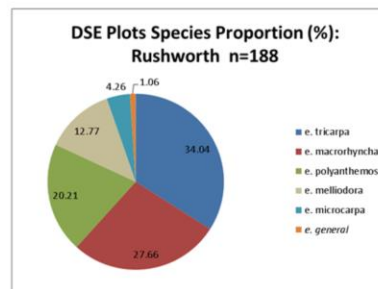
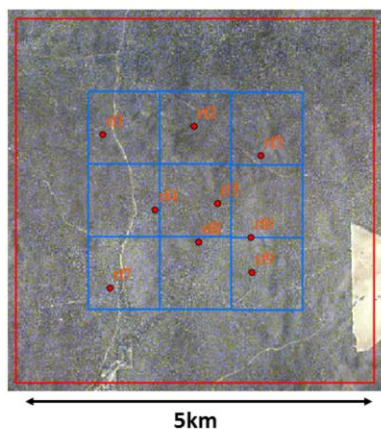
Selected forest stand representative of the Box Ironbark forest community (estimated area coverage = 250 000ha)

All large trees are Eucalypt species

Single strata - Not much understorey

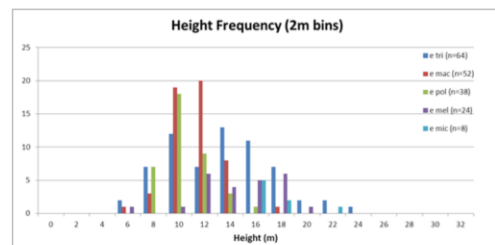
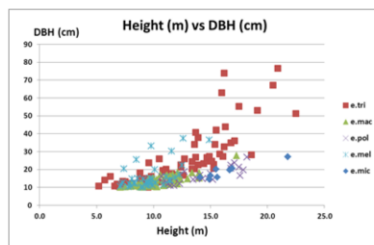
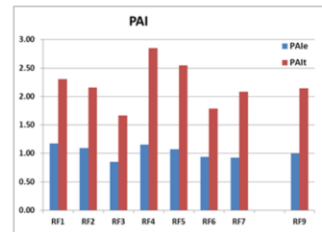
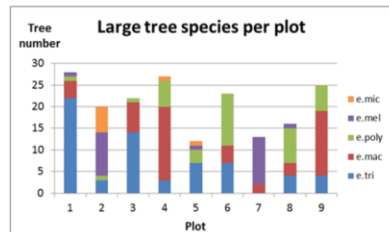
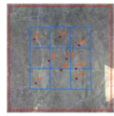
Capturing the variability

- Representative tree library



- 9 standard forest inventory plots in a stratified random sampling design over the 3x3km area
- In addition to standard forest inventory plots we measured LAI with low & high res DHP, TLS (Riegl Vz 400), and some with LAI-2200
- TERN Auscover site with ALS and Hyperspectral flown (AISA Eagle Hawk) – 5x5km coverage
- + leaf spectra and chemistry
- + destructive harvest just outside site extent of 24 trees

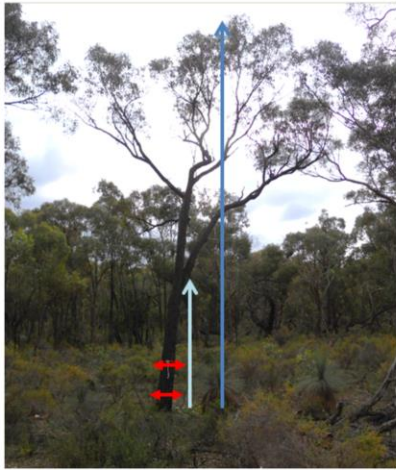
Capturing the variability



Some plot statistics

PAI calculated with Caneye using high-res DHP

Measurements into the 3D model



Measurements used to create the individual tree models

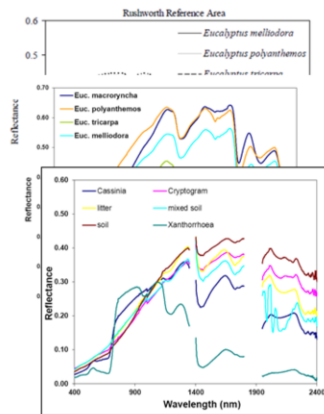
- DBH, height to first branch, top height, crown dimensions, average lead width & length

- Used Onyx tree to create geometric model of trees

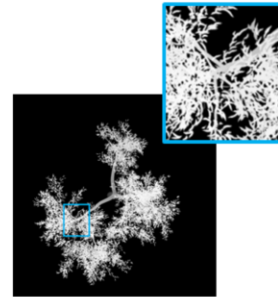
Ray tracing simulation



Onyx tree



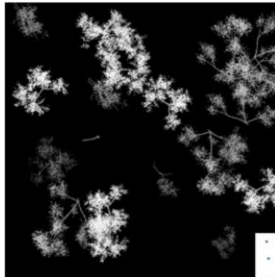
Profile view simulation



Top-down simulation

Added leaf spectra and leaf plates to model
 -can parameterise LAD functions e.g. Wang or De Wit

Ray tracing simulation



20x20m plot characteristics

- Foliage projective cover = 35%
- Leaf area index = 1.1
- Total plant area index = 1.7
- Ave tree height = 12.9

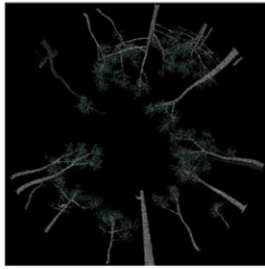


left: ray tracing simulation of 20x20m height map (top down) of a random distribution of trees representing a forest inventory plot at Rushworth.

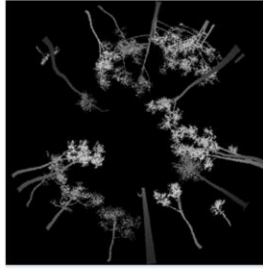
right: simulation of the plot, sun at nadir, camera view angle 40 degrees zenith

- can parameterise scene with a specific tree distribution e.g. Poisson or Neyman
- we have xy coordinates of some large plots ($r = 40\text{m}$). Still need to derive Neyman parameters

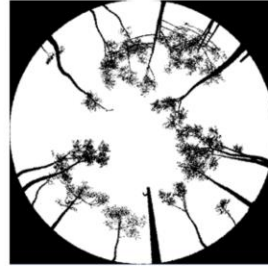
Hemispherical simulation



RGB colour composite



Distance image

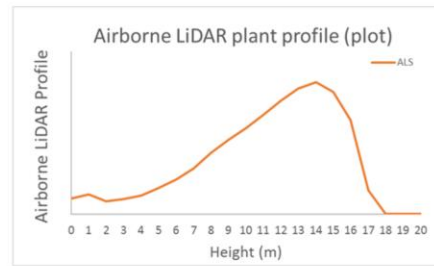
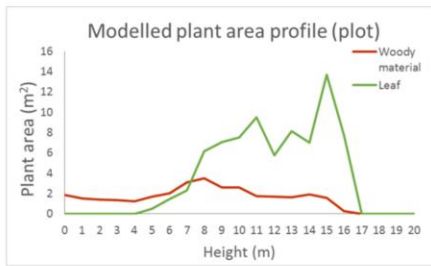


Gap image (binary)

Example of hemi simulations of 20x20m plot

Validation example

Comparison of ALS above-ground return histogram and Plant & leaf area profiles from the real models (not inferred from any sensor)



Other validation

- compare overstorey cover estimates with airborne LiDAR and ground-transects
- compare with LAI from destructive harvest

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Example of checking the exact model plant and leaf area profile to the Lidar profile
-more validation to be done

Next steps

- sensitivity of sensor parameters to gap fraction
- effectiveness of formulae to derive LAI and clumping – compare with known true LAI
- investigate sampling strategies to make recommendation of # measurements and distribution etc.

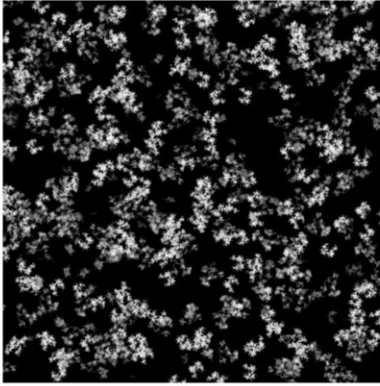
Acknowledgements

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Extras – quick look



Left: 100x100m scene with same tree density as 20x20m plot (tree density = 560/ha)



Right: Google maps quick-look (same scale)