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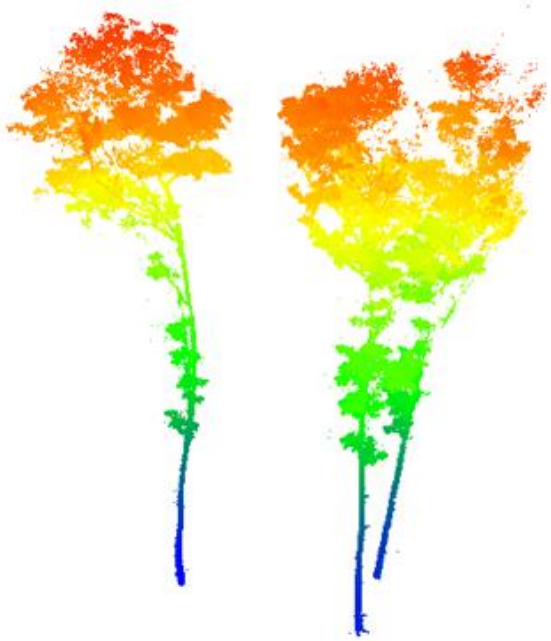

A novel dual wavelength terrestrial laser scanner for assessing forest fuel moisture content

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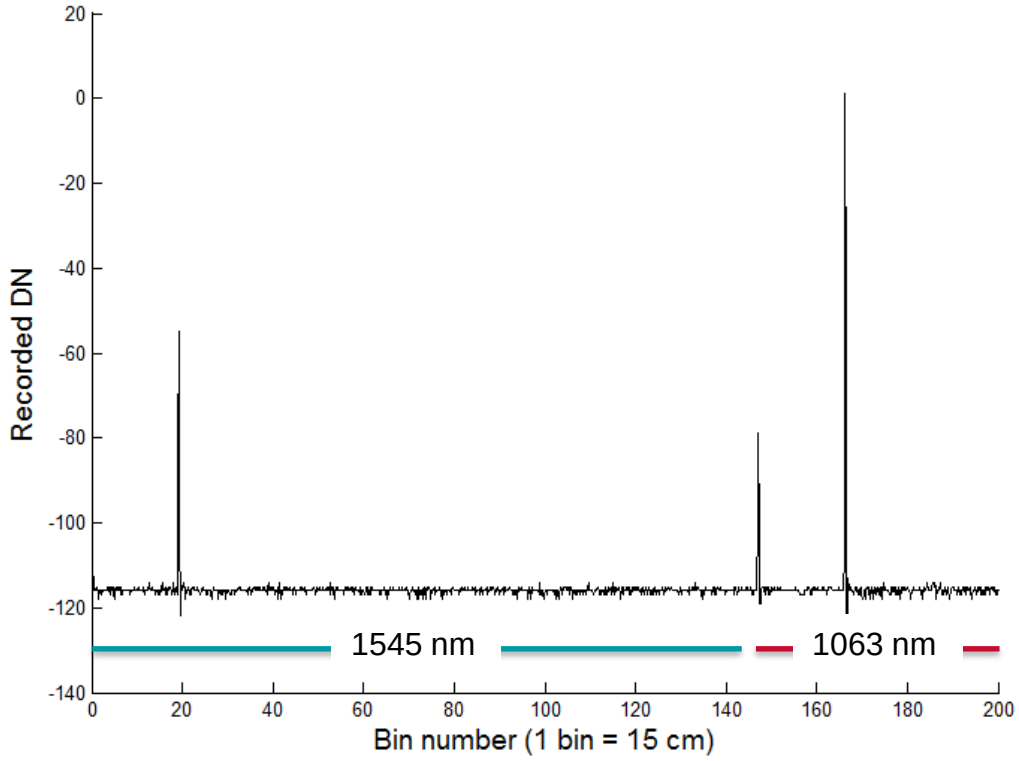
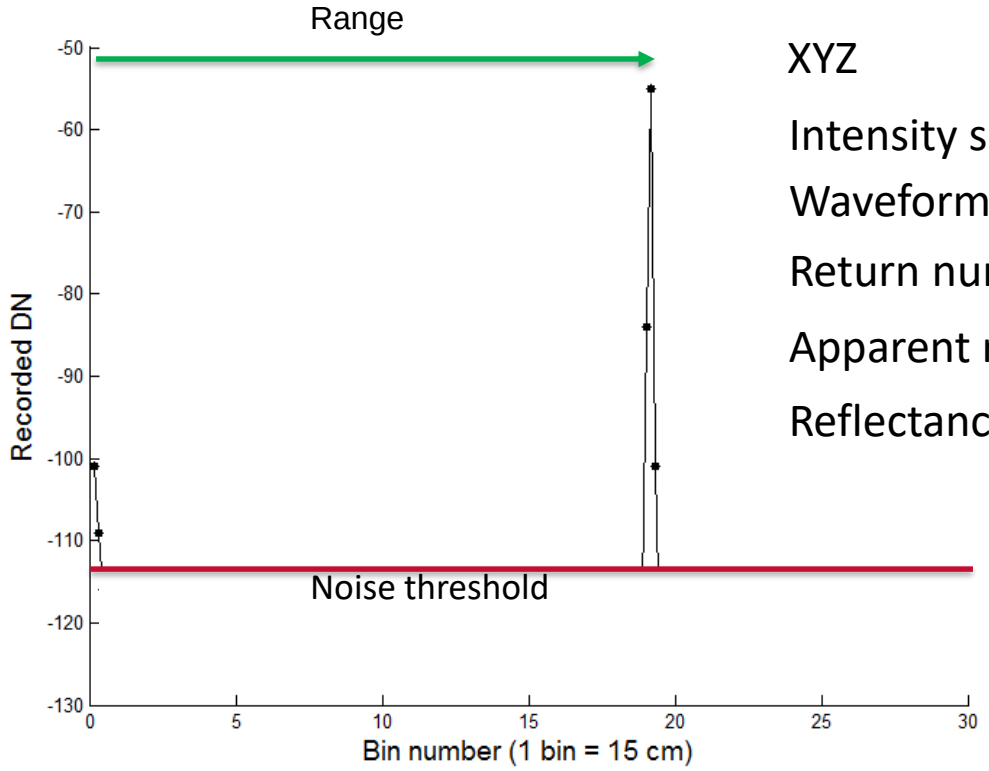
Limitations of existing TLS for forest ecology

Single wavelength	**Two or more laser wavelengths**
Scan geometry not suitable	**Hemispherical or bi-hemispherical scanning**
Single return (first or last or first & last)	**Full waveform data recording**
No control over power output – saturation	**Access to optical pathway – filter to adjust power**
No access to instrument characteristics	**Design and operational characteristics all known**
No access to pre-processing algorithms	**Access to binary data records – start from scratch with data processing and analysis**

Salford Advanced Laser Canopy Analyser (SALCA)	
Centre wavelengths	1545.4 nm and 1063.4 nm
Pulse length	3 ns (1545 nm) and 1 ns (1063 nm)
Pulse rate	5 kHz
Beam width at sensor	3.6 mm (1545 nm) and 2.4 mm (1063 nm)
Beam divergence	0.56 mrad
Laser output energy	5 μJ (1545 nm) and 0.5 μJ (1063 nm)
Detector field of view	2.67 mrad
Sampling rate	1 GHz
Range resolution	15 cm
Maximum range	105 m
Angular sampling step	1.05 mrad
Angular displacement between wavelengths	6 μrad

Data characteristics and data processing





XYZ

Intensity sum

Waveform width

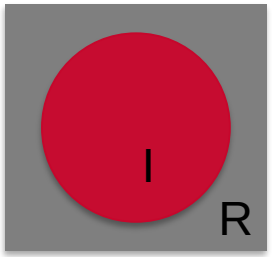
Return number

Apparent reflectance

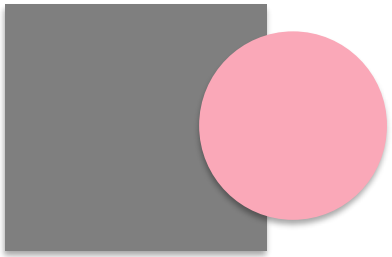
Reflectance ratio

SALCA scan data

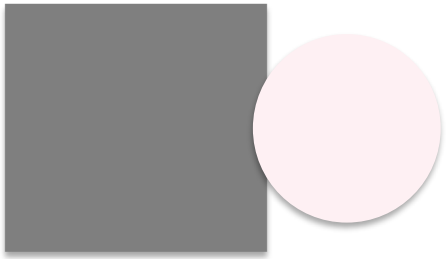
Dual-wavelength principle



Intensity $_{\lambda}$ ∫ Reflectance $_{\lambda}$



Intensity $_{\lambda}$ ∫ Reflectance $_{\lambda}$ x Illuminated Area



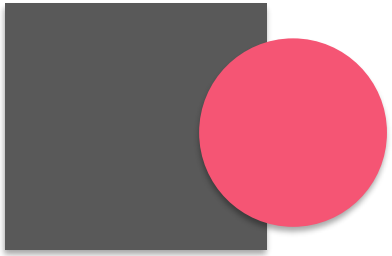
Intensity close to detection threshold

Dual-wavelength principle

1063 nm

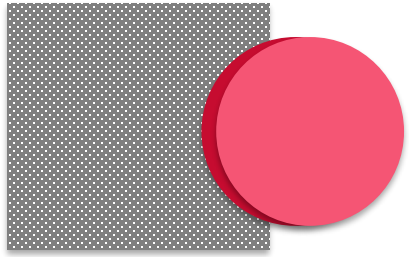
Intensity $_{\lambda 1}$ ∫ Reflectance $_{\lambda 1}$ x Illuminated Area

1545 nm



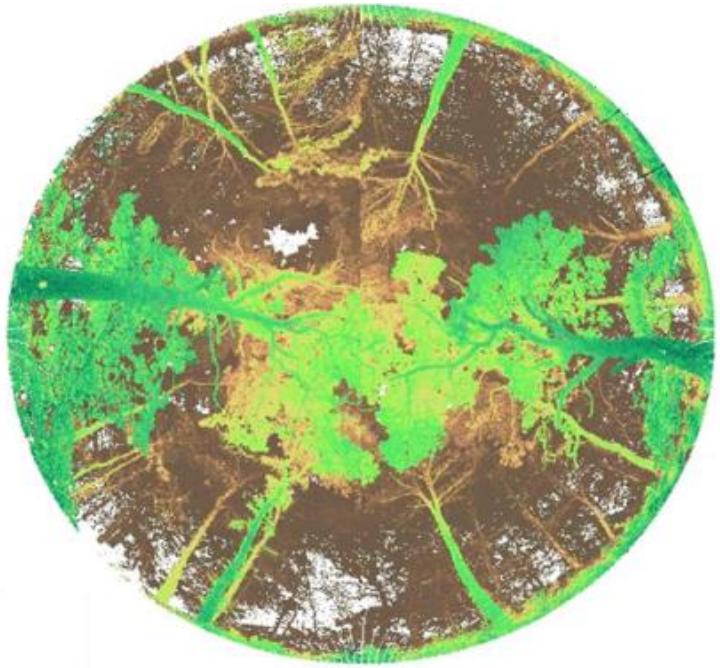
Intensity $_{\lambda 2}$ ∫ Reflectance $_{\lambda 2}$ x Illuminated Area

Ratio

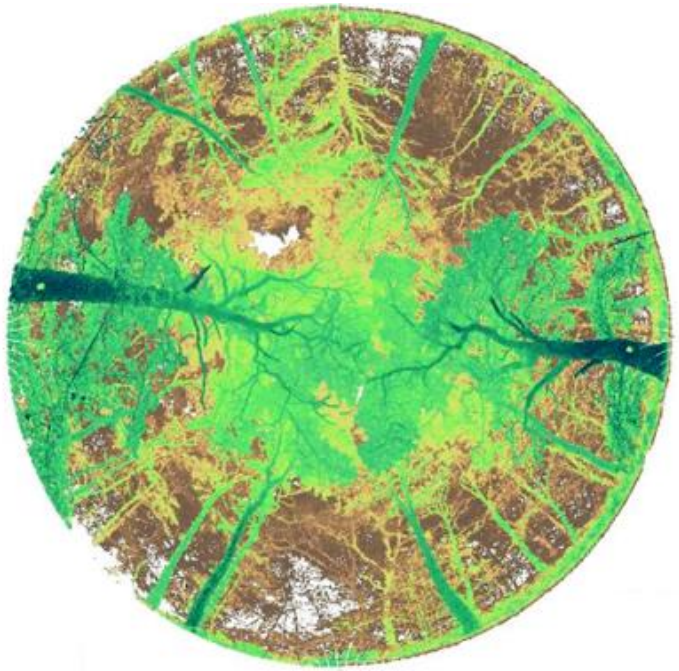


Ratio of Reflectance $_{\lambda 1/\lambda 2}$ NOT a function of Area

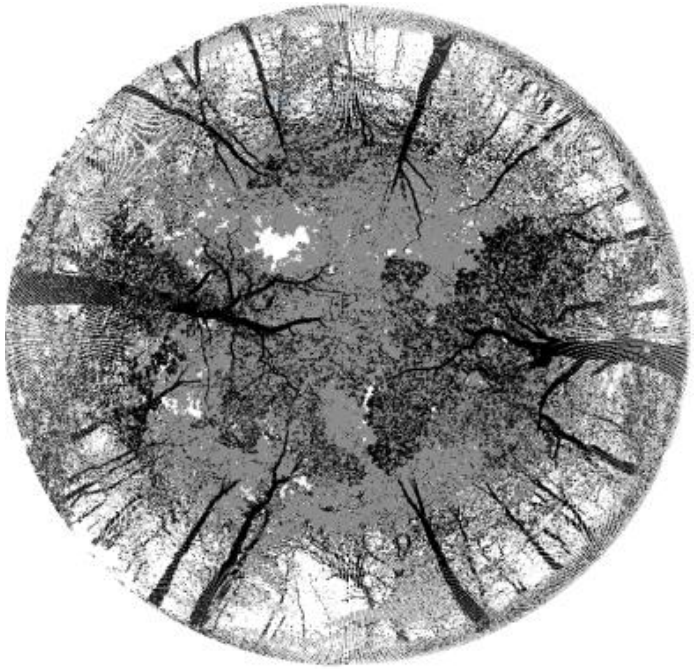
Dual-wavelength NDI



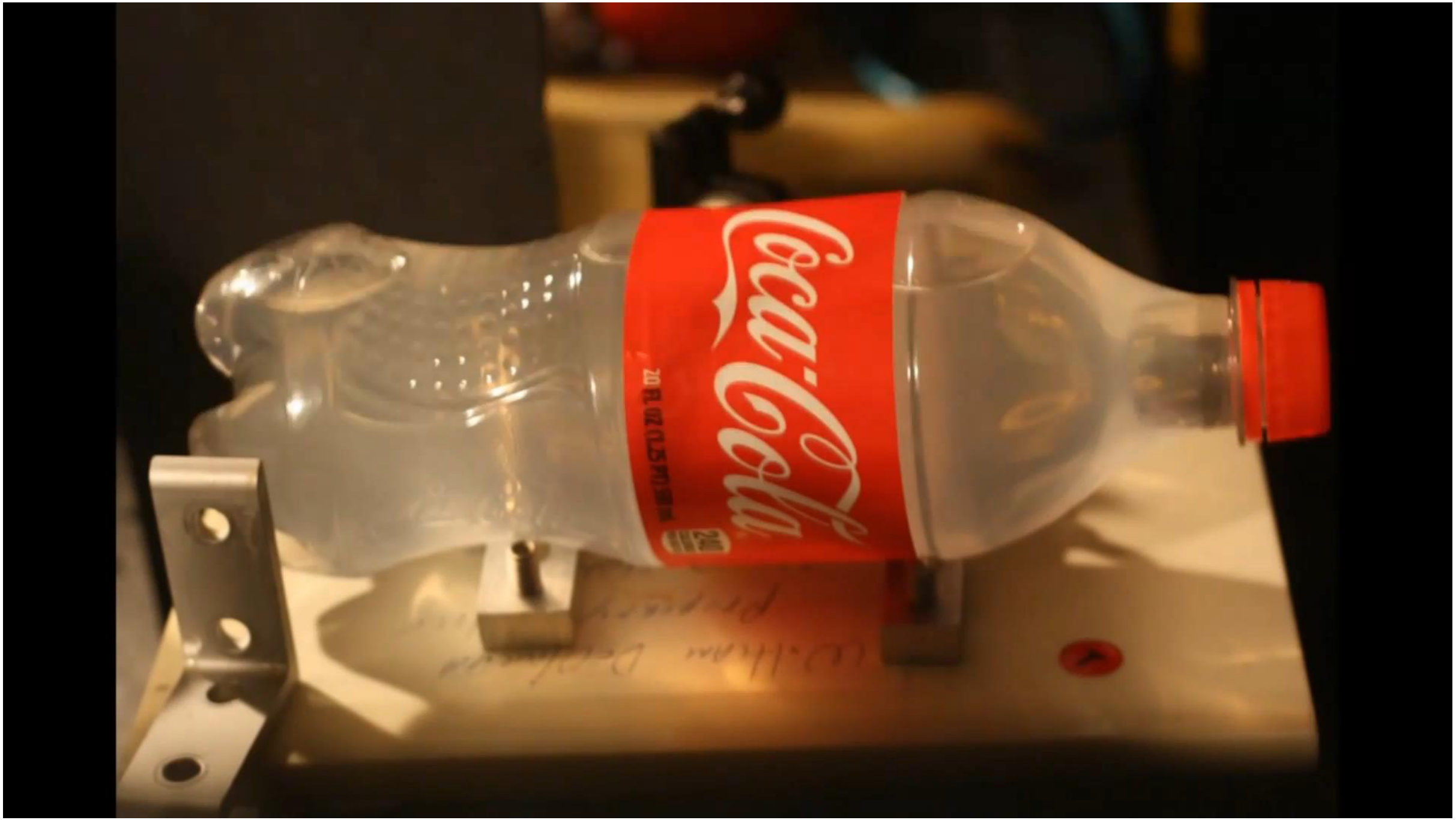
1063 nm



1545 nm



SALCA Normalised Difference Index


Coca-Cola

Laser light is fast!

Speed of light = 299,792,458 m s^{-1}
and in water about 225,000,000 m s^{-1}
Length of Coke bottle 30 cm or 0.3 m

Time travelled 1.33 x 10^{-9} seconds

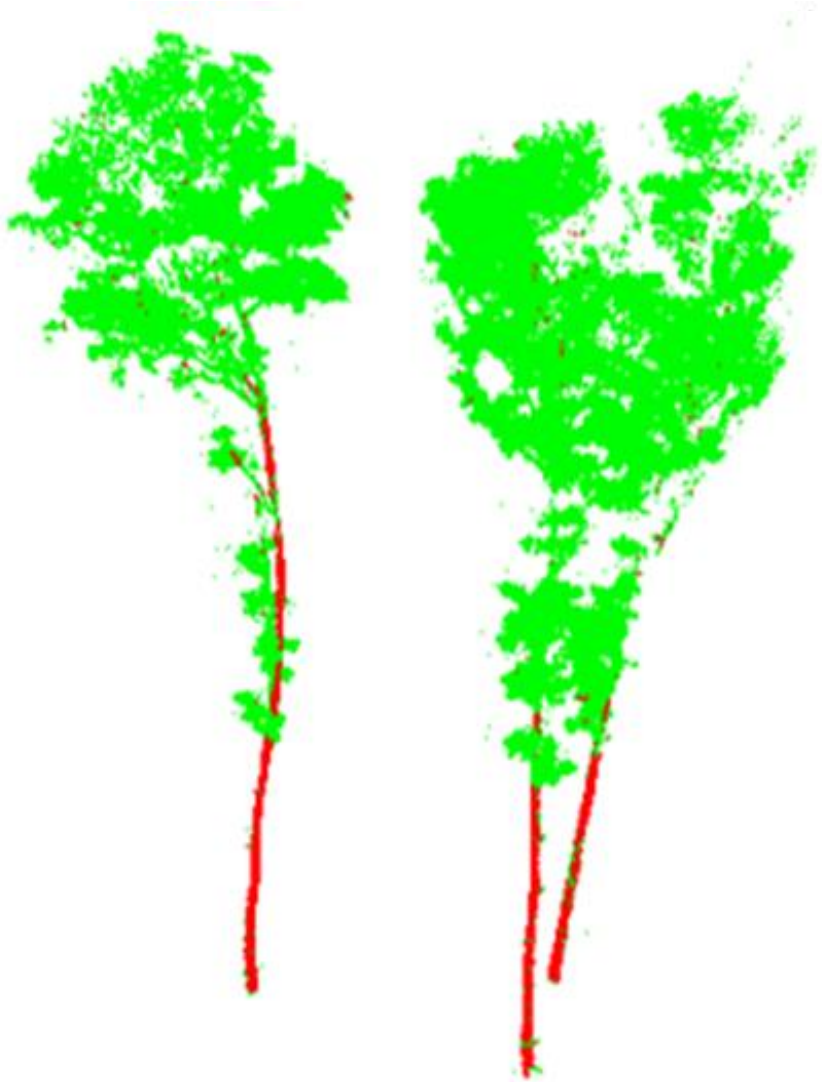
Slow it down for the video 10 billion times (1 x 10^{-10})

Makes it about 13 seconds.....

Camera used half a trillion frames per second

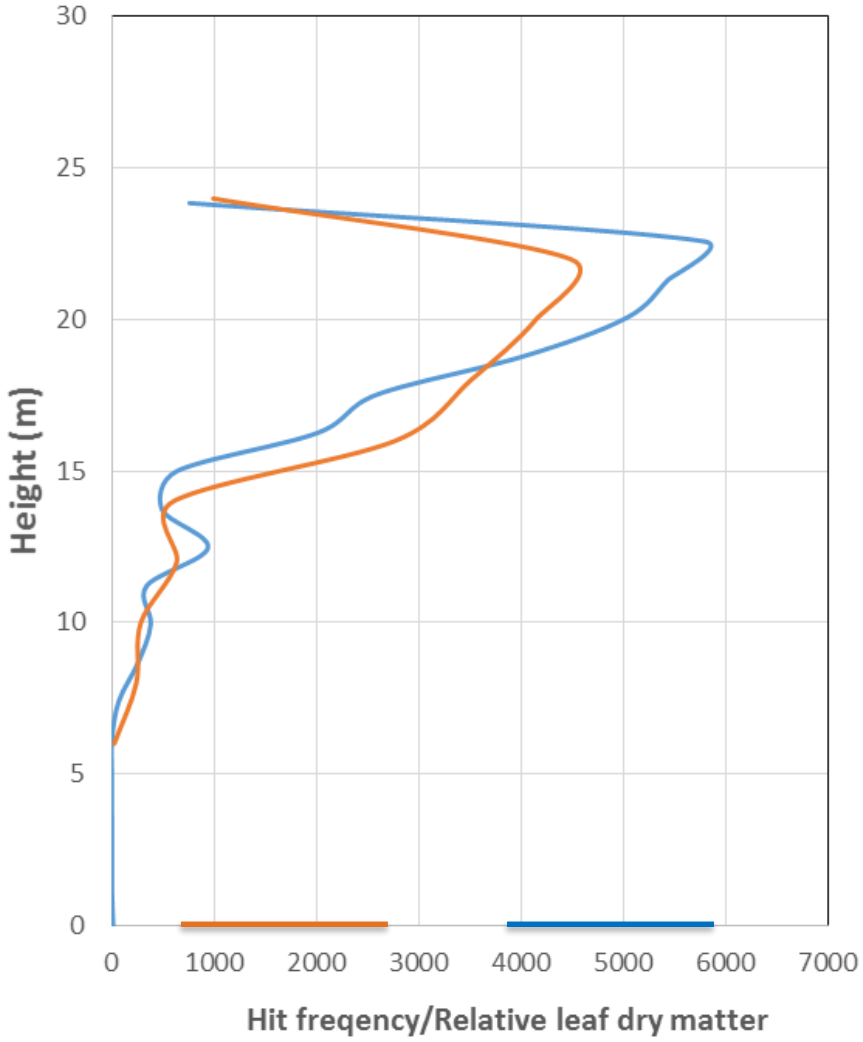
If a bullet was fired through the bottle at 1000 m s^{-1} and was filmed at the same speed – how long would the bullet take to pass through the bottle?

Harvard Forest 2017

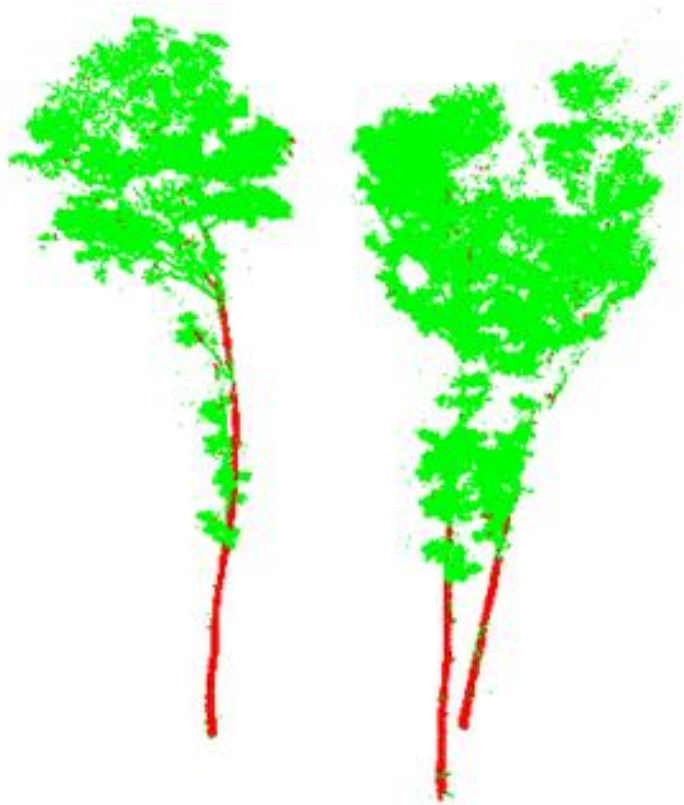


SALCA foliage/wood classification

Vertical leaf mass distribution

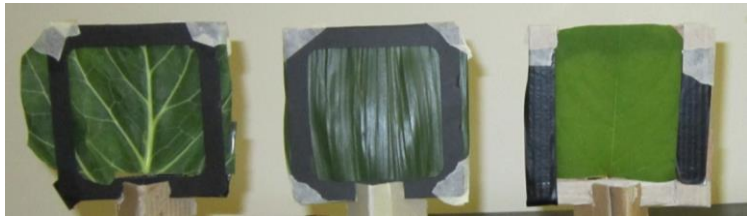


SALCA classifier

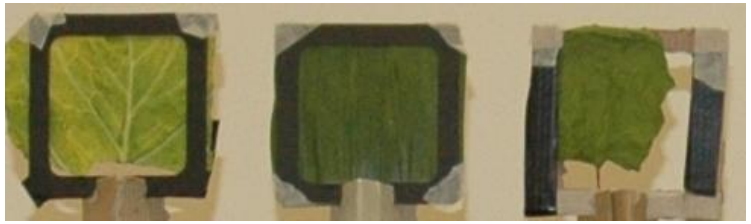


Leaf water content estimation

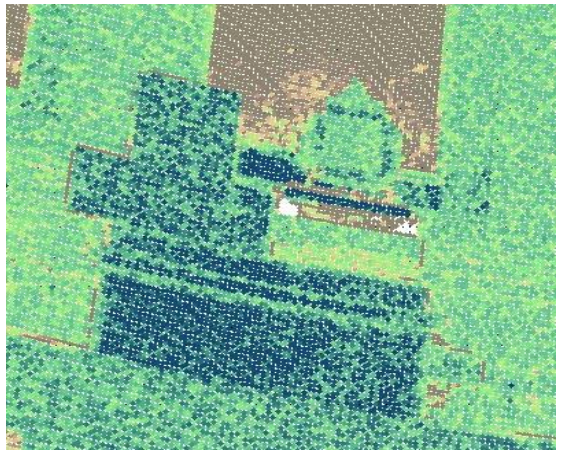
Start:

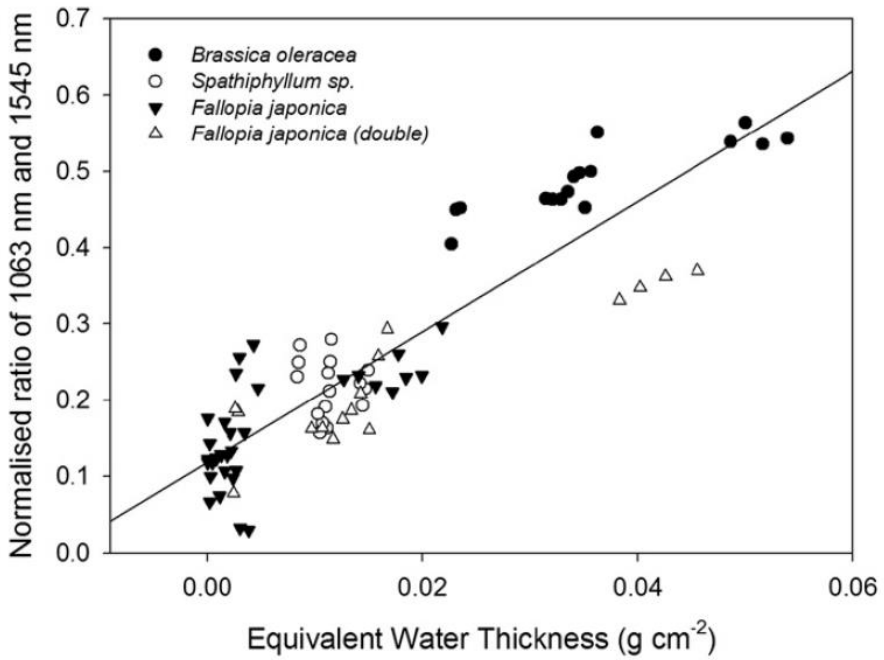


End:



Repeat SALCA scans





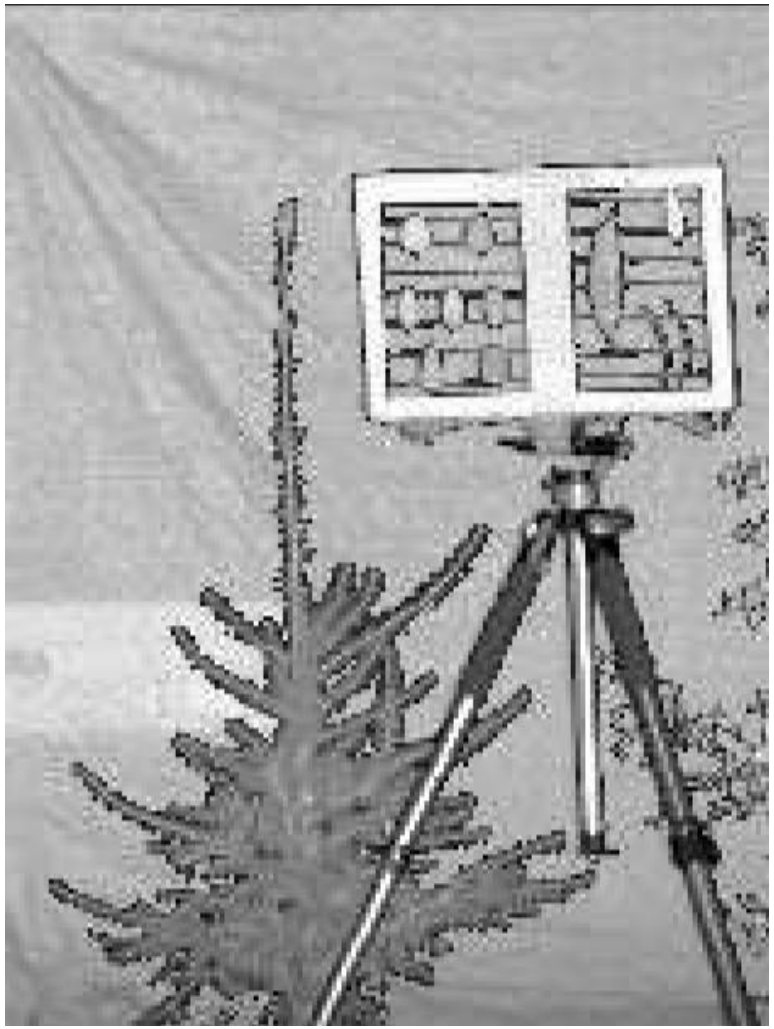
RMA regression results showing the relationship between SALCA-derived reflectance and spectral indices and EWT (g cm^{-2}) of leaf samples. RMSE values were obtained through model inversion and leave-one-out cross validation.

Dependent variable	Slope	Intercept	R^2	RMSE (g cm^{-2})
SNRI	9.5825**	0.1029	0.7959	0.0069
SSRI	−12.2207**	0.8242	0.7879	0.0070
1545 nm[a]	−1.4144**	0.6450	0.6556	0.0080
1063 nm[a]	−0.7329*	0.707	0.0343	0.0184

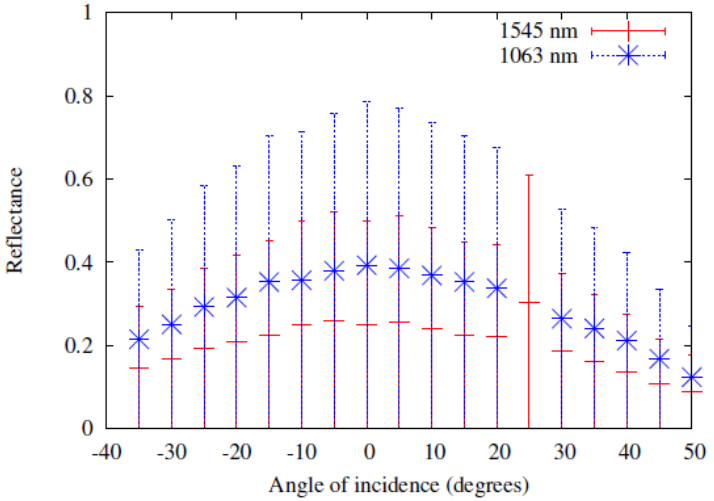
[a] X and Y variables square root transformed before regression.
* Significant at a $P<0.05$ level.
** Significant at a $P<0.01$ level.

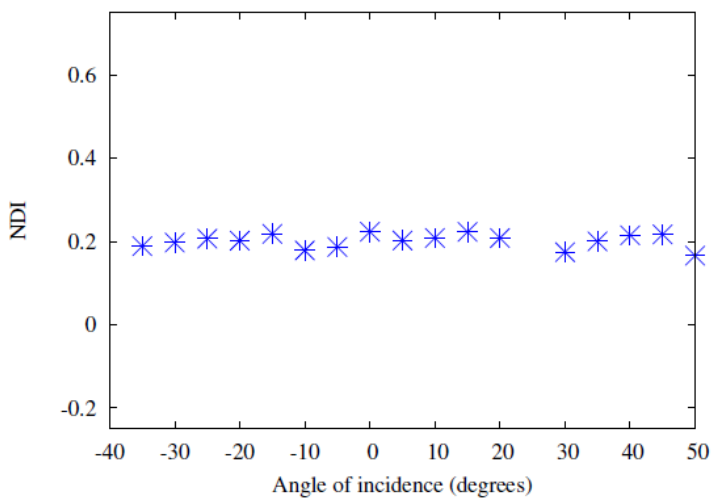
Gaulton, R, Danson, FM, Ramirez Cardozo, FA and Gunawan, OT 2013, 'The potential of dual-wavelength laser scanning for estimating vegetation moisture content' , Remote Sensing of Environment, 132 , pp. 32-39.

View angle effects in SALCA data



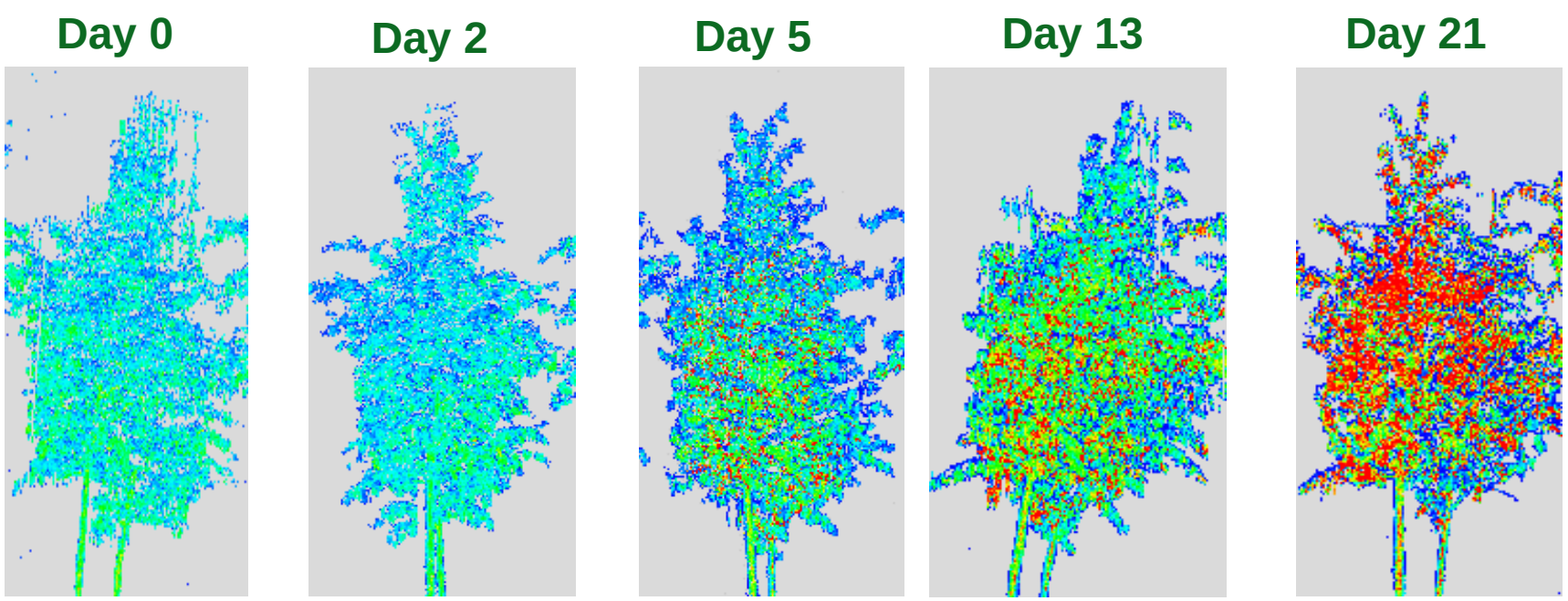
Eucalyptus

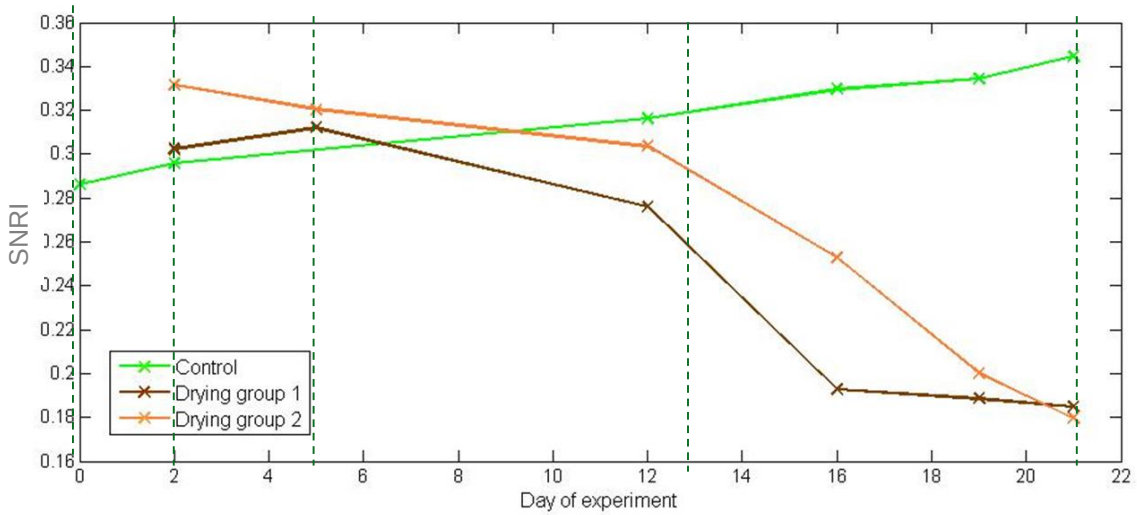




Hancock, S., Gaulton, R., & Danson, F.M., 2017 Angular reflectance of leaves with a dual-wavelength terrestrial lidar and its implications for leaf-bark separation and leaf moisture content estimation. IEEE Transactions Geoscience and Remote Sensing (in press)

SALCA measures FMC variation





Newcastle University
School of Civil Engineering &Geosciences

Rachel Gaulton
and Steve Hancock

TLS for monitoring forest FMC: a proposal

SALCA

VEGNET- CSIRO

(a)

(b)

Automated *In-Situ* Laser Scanner for Monitoring Forest Leaf Area Index

Darius S. Culvenor [1,2], Glenn J. Newnham [1,*], Andrew Mellor [3], Neil C. Sims [1] and Andrew Haywood [3]

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Dr Mat Disney, UCL and NERC National Centre for Earth Observation, UK

Dr Rachel Gaulton, University of Newcastle, UK

Professor Crystal Schaaf, University of Massachusetts Boston, USA

http://salca-salford.blogspot.com