CRC for SPATIAL INFORMATION

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# CRCSI 2.07. AUSTRALIAN WOODY VEGETATION LANDSCAPE FEATURE GENERATION FROM MULTI-SOURCE AIR-BORNE AND SPACE-BORNE IMAGING AND RANGING DATA


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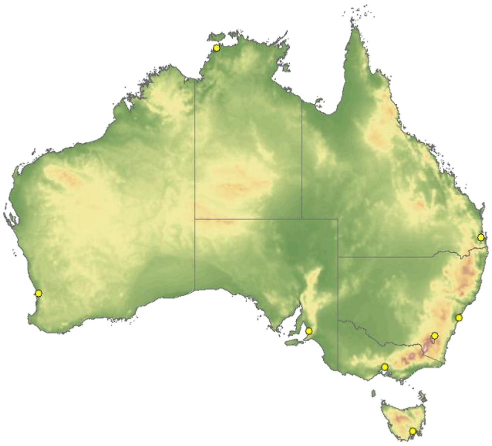
# BACKGROUND



State and Commonwealth land management agencies are mandated by law to map and report on Australian native woody vegetation. They all therefore have the common need for tools that can effectively attribute large areas of forest.
This project was founded as a collaborative framework to address these common needs and provide a set of tools that can be used for forest attribution at the large-area scale.
A novel approach was undertaken by defining a set of primary descriptors for woody vegetation attribution that can be derived at the landscape scale. A next step will be to combine these into more complex attribution metrics such as biomass or canopy condition.

**AIM**
Develop processes to characterise woody vegetation ecosystems through automated feature generation, using a combination of ground (field), airborne and space-borne image and ranging data.

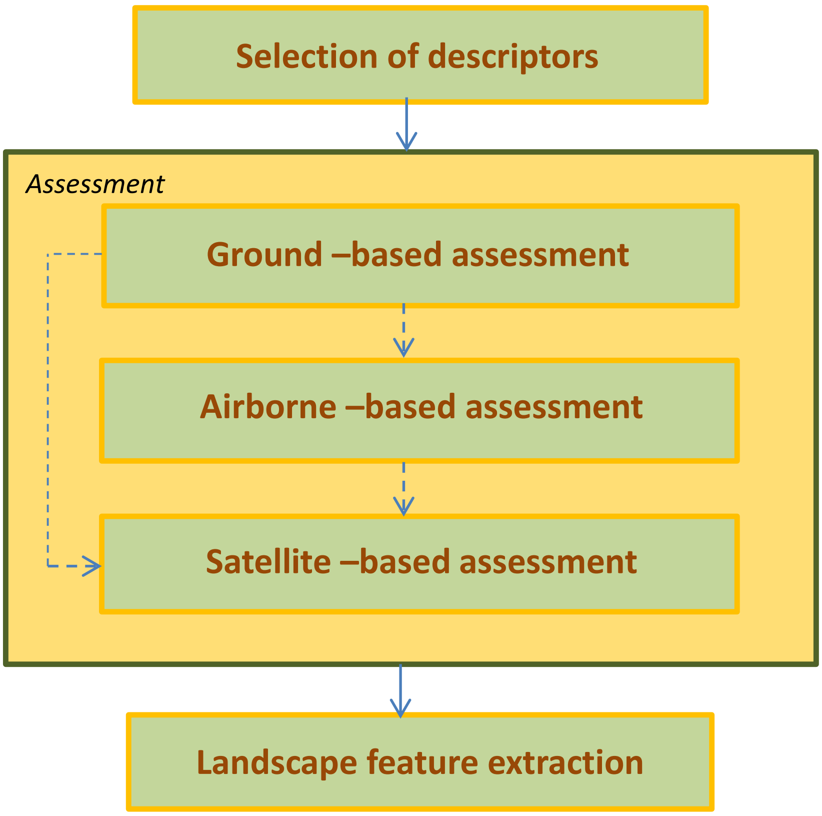



Figure 1. Flowchart describing the main steps of CRCSI 2.07 project.

# Selection of Primary descriptors

A set of descriptors was selected based on international policy and protocols and a survey of stake holder's needs. The procedure consisted of three steps (Figure 2):

- The descriptors selected for international directives were identified
- A preliminary priority list was created through a survey of Australian and New Zealand stake holders from education, research and industry sectors. For more information please see Axelsson et al. (2012).
- A final set of descriptors was selected in a workshop held with Australian federal and state agency representatives. A comprehensive review of the main descriptors can be found in Jones et al (2013).

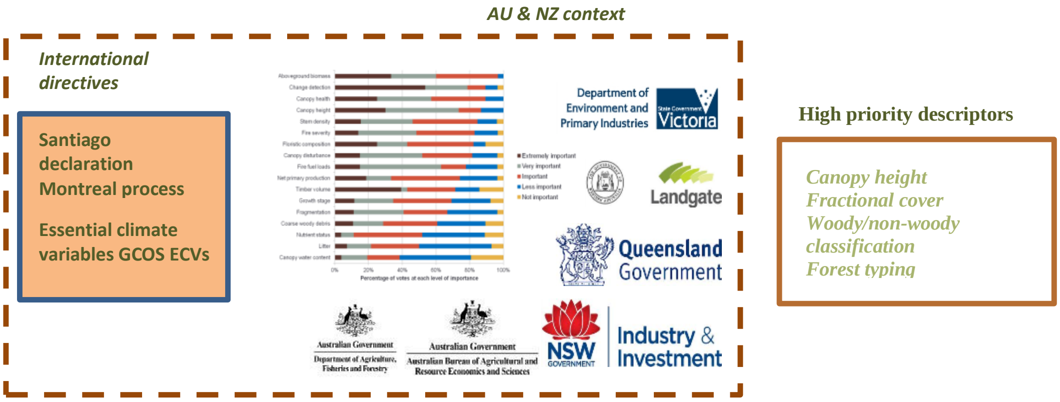



Figure 2. Summary procedure used to derive the descriptors for woody vegetation attribution that are high priority for project partners and end users.

# Ground-based assessment

## *Traditional forest mensuration*

Twenty seven field monitoring plots were established in 3 reference (5kmx5km) sites chosen as being representative of a common forest type and having vertical forest structure representing a unique structural class (Figure 3). Additional sites located throughout Australia were also sampled in collaboration with the Australian Terrestrial Ecosystem Research Network (TERN-Auscover) (Figure 3). Concurrent airborne LiDAR capture over each site and ground data collection was conducted following standard protocols and guidelines developed by project partners and TERN-Auscover. When a suitable protocol was not available, it was developed by the project team. The final list of measurements comprised structural and physiological canopy properties as well as general plot characterisation.

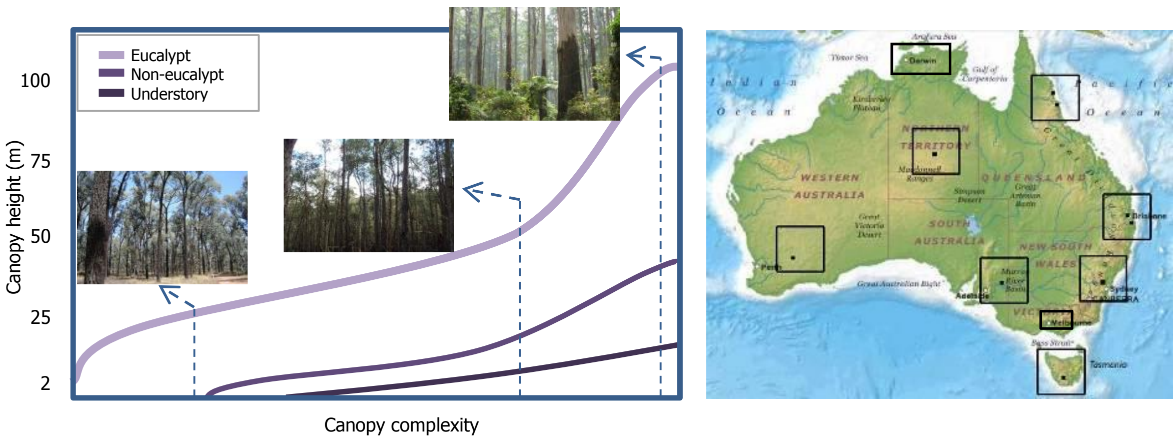



Figure 3. Canopy composition existing in the three Victorian sites (Left) and location of the reference sites along with TERN-Auscover validation sites where the same set of data was collected (Right).

## *In-situ remote sensing techniques*

The performance of commonly used ground-based methods (low- and high- resolution hemispherical photography, LAI-2200 and TLS) for leaf area index estimation were evaluated (Figure 4). The results indicate that a level of caution should be taken when using common passive optical techniques as a reference estimate due to the high sensitivity to changing illumination and sky conditions. Plot mean RMSE was within 20% of the HR-DHP(S) reference in only 46% of the cases. This is especially relevant as common validation practices often assume negligible uncertainty levels for in- situ reference estimates. Further information about this work can be found in Woodgate et al (Agriculture and Forest Meteorology, in press, 2015).

Rushworth forest, one of the Victorian reference sites, has been fully-reconstructed using 3D ray tracing radiative transfer modelling (Librat, Disney et al. (2006)*). This high level of detail reconstruction is the first of its kind in Australia. It allowed the examination of the canopy elements separately. Simulations were conducted to study both the theoretical performance of each method and the impact of intra-crown clumping and leaf angle distribution (LAD) on the assessment of LAI using the gap fraction method (Figure 5). Each step in the LAI retrieval method has been investigated and updated including a new variable in the formulation (e.g. woody component angular distribution). This has improved the accuracy of LAI retrieval up to 25% (results can be found in Woodgate et al, submitted to Agriculture and Forest Meteorology, 2015) (Figure 5).

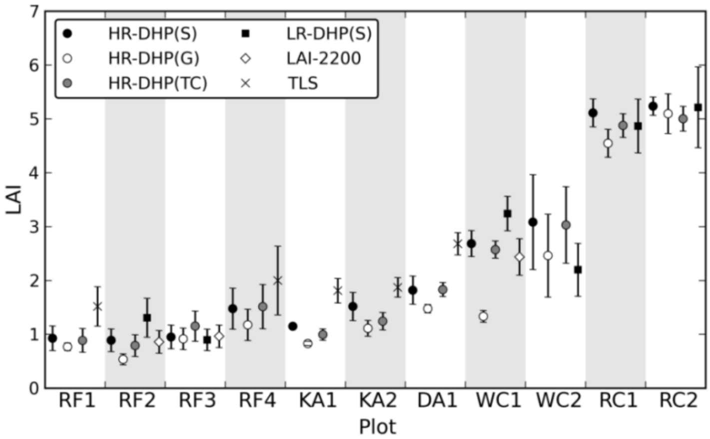



Figure 4. Mean LAI plot values for each method at eleven sites located on throughout the South Eastern coast of Australia. The error bars denote ±1standard deviation of individual plot LAI measurements. Instrument abbreviations: high/low resolution (HR/LR) digital hemispherical pho-tography (DHP). Classification method abbreviations for DHP: supervised (S), global(G), and two-corner (TC). From Woodgate et al., 2015.

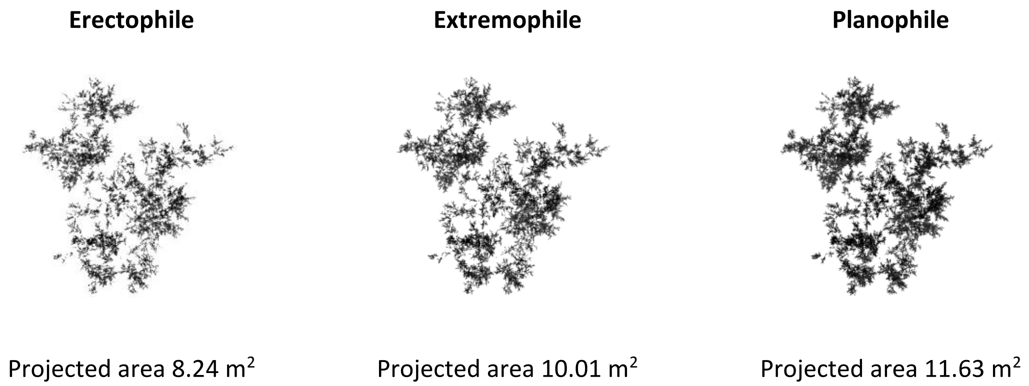



Figure 5. Simulations of projected crown area of leaf-only scenarios for a single tree with erectophile, extremophile, and planophile leaf angle distributions. Differences in total projected area show the level of influence of the leaf angle distribution on vegetation fractional cover retrieval.

## Airborne-based assessment

*Disney, M., Lewis, P., & Saich, P. (2006). 3D modelling of forest canopy structure for remote sensing simulations in the optical and microwave domains. *Remote Sensing of Environment, 100*(1), 114-132.

Key canopy descriptors (canopy height, canopy cover and vertical canopy structure) layers were derived from discrete return airborne laser scanning (Riegl LMS-Q560). Figure 6 presents the resulting information layers which were later used as training and validation data for woody attribution using satellite sensors. The assessment of canopy structural variables from airborne imagery was an intermediate step towards the large area attribution using satellite imagery. The high range of variability present in the three Victorian sites allowed the construction of a very robust training data set for the upscaling of vegetation descriptors (Figure 6).

Canopy dominant height was derived at a 25 m spatial resolution for three 5km x 5km sites representative of Australian sclerophyll forest (Figure 6). A DTM model was subtracted from the total height at each point. The DTM model was calculated as an irregular triangulated network of ground returns rasterised at 1 $m^2$ spatial resolution (Wilkes et al., 2012). Vertical canopy structure was derived as a proxy of canopy complexity by means of the average number of canopy layers. Finally canopy cover was assessed as a function of gap probability (Wilkes et al., 2013; Wilkes et al., submitted to Methods in Ecology and Evolution). The whole procedure has been executed in an open-source software environment and tested for numerous study sites (Figure 3). The tool was presented and shared with project partners during the project roadshow in 2014 and is accessible through https://phil_wilkes@bitbucket.org/phil_wilkes/forestlas.git.

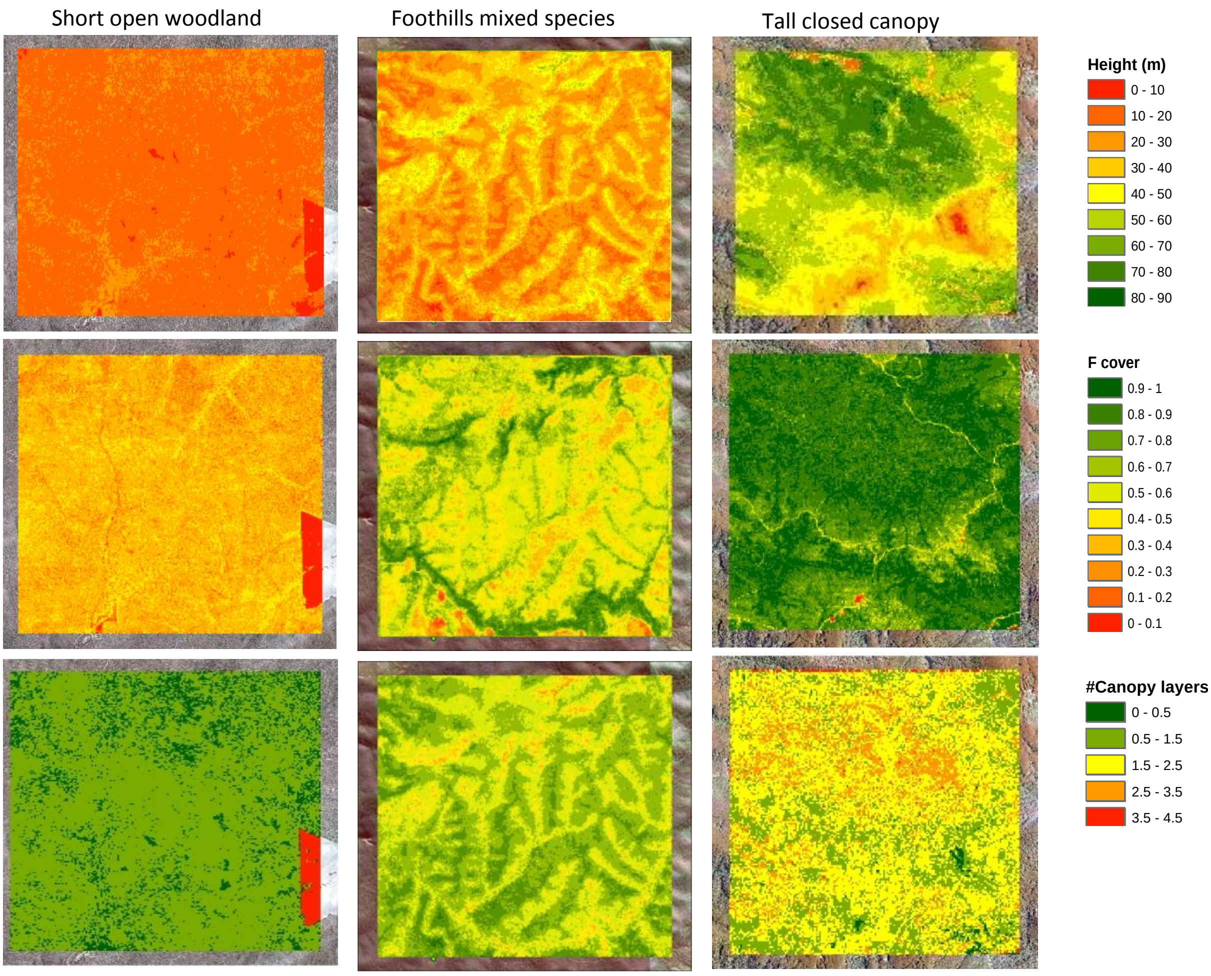



Figure 6. Canopy height, vegetation fractional cover and number of canopy layers derived from LiDAR data for the three Victorian sites (Short open woodland, Foothills mixed species forest and Tall closed canopy forest).

## Satellite-based assessment

Landsat, MODIS and Rapideye imagery were used for the large area assessment of woody vegetation. An ensemble model regression method was developed using the LiDAR derived products as a training dataset. This methodology, coupling LiDAR-derived estimates and satellite imagery, allows the assessment of large area woody vegetation using satellite imagery. This is an affordable and repeatable solution for state agencies.

Using LiDAR as “sampling” tool or “training” data source offers the possibility of enlarging the descriptor value input range and volume to large scale assessment models. The method has proved successful for canopy height and canopy cover assessments, yielding RMSE within 6m and 6% respectively.

The derivation of canopy height was conducted using Landsat top-of-canopy reflectance data and MODIS NDVI time series and a set of ancillary data layers (e.g. elevation, temperature, rainfall, soil type). The method was applied to an area of 2.9 million hectares in Eastern Victoria (Figure 7).

The same method was applied to Top-of-Atmosphere (TOA) reflectance Rapideye data to derive fractional cover over the three Victorian sites. The use of TOA reflectance allows the application of the method without needing any atmospheric data, under the assumption that the Blue band information would account for atmospheric differences between image tiles. The bidirectional reflectance distribution function (BRDF) effects were kept to a minimum using imagery acquired within 1 month of each other.

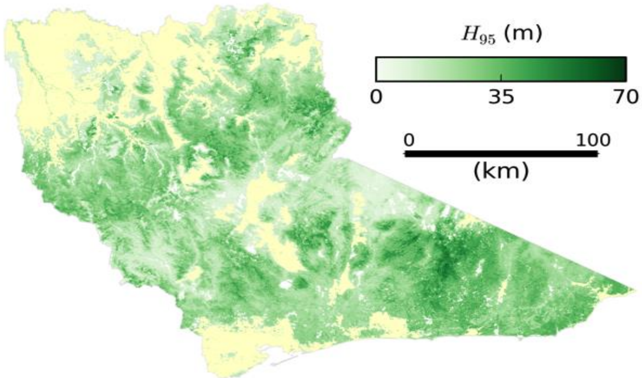



Figure 7. Canopy height derived from satellite imagery over an area of 2.9 million hectares in Eastern Victoria (spatial resolution 30m). More information can be found in Wilkes et al. (submitted to Remote Sensing, 2015).

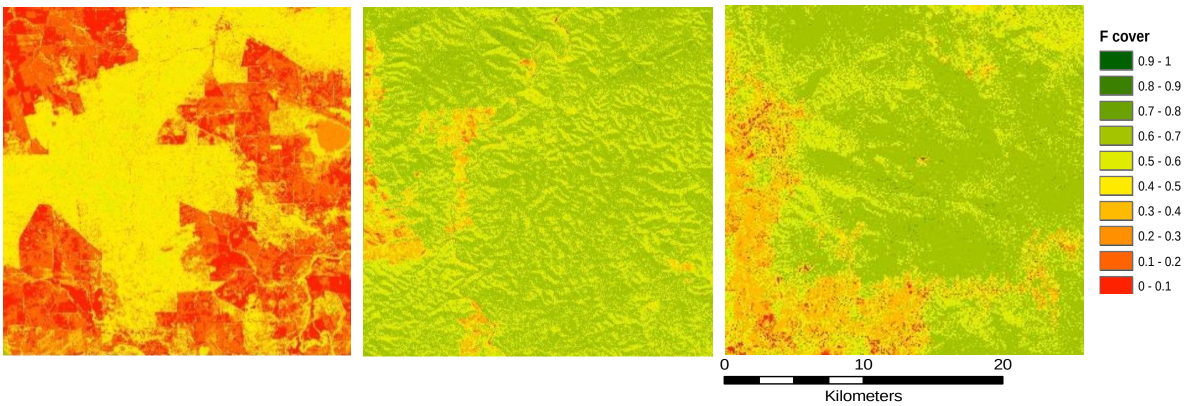



Figure 8. Fractional cover derived from Rapideye TOA reflectance data over three 25x25 km areas in Victoria (spatial resolution 25m).

## Landscape feature extraction

Automatic segmentation approaches were undertaken for large-area mapping, characterising features or homogeneous areas. An automatic isodata segmentation was applied to the large area information layer followed by the removal of features under 100 hectares (as minimum interest feature size). The resulting map shows the segmentation of the 63 thousand hectares area surrounding the Rushworth reference area according to canopy cover derived from Rapideye imagery (Figure 9).

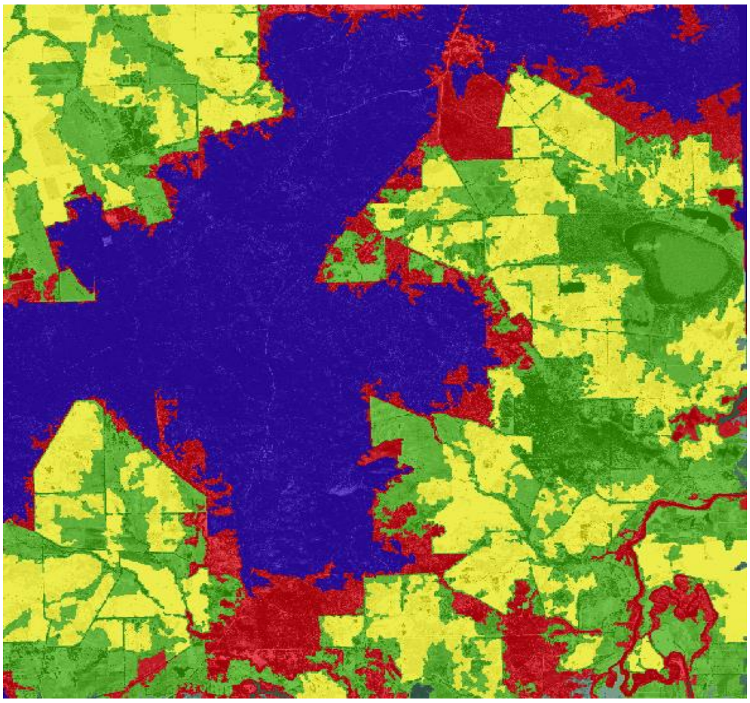


Figure 9. Segmentation for the area around Rushworth forest. Four automatic fractional cover (Fc) levels have been detected represented in yellow, green, red and blue (in order of increasing Fc).

## Communication flow and dissemination activities

| Project meetings: | Workshops: | Roadshow: |
|---|---|---|
| Quarterly report meetings | Canberra, 21st Feb 2013<br>Melbourne, 26th Aug 2014 | Brisbane, 11th June 2014<br>Parramatta, 17th June 2014<br>Melbourne, 30th June 2014 |

Student placements:
Phil Wilkes was hosted by DELWP, Victoria to assist in the development of bushfire burn severity tools.
Will Woodgate was hosted by DSITI, Queensland to implement a method to benchmark biophysical parameters in a 3D simulation and modelling framework.

## Publications/Reports/Protocols*

*All documents are available in the project website: http://www.crcsi.com.au/research/2-rapid-spatial-analytics/2-07-woody-vegetation/


Phil Wilkes, Simon D. Jones, Lola Suarez, Andrew Haywood, Andrew Mellor, William Woodgate, Mariela Soto-Berelov, Andrew K. Skidmore. Mapping canopy height over a regional area with two-stage sampling using airborne LiDAR and multispectral imagery. Submitted to *Remote Sensing*

William Woodgate, Mathias Disney, John D. Armston, Simon D. Jones, Lola Suarez, Michael J. Hill, Phil Wilkes, Mariela Soto-Berelov, Andrew Haywood, Andrew Mellor. Quantifying the impact of woody material and within-crown clumping on estimation of forest canopy gap fraction and Leaf Area Index. Submitted to *Agriculture and Forest Meteorology*.

Phil Wilkes, Simon D. Jones, Lola Suarez, et al. Using discrete-return ALS for the assessment of vertical canopy structure across diverse forest types. Submitted to *Methods in Ecology and Evolution*.

2015. Phil Wilkes, Simon D. Jones, Lola Suarez, Andrew Haywood, Andrew Mellor, William Woodgate, Mariela Soto-Berelov, Andrew K. Skidmore. Understanding the effects of ALS pulse density for metric retrieval across diverse forest types. *Photogrammetric Engineering & Remote Sensing*. (in-press).

2015. Woodgate, W., Jones, S.D., Suarez, L., Hill, M.J., Armston, J.D., Wilkes, P., Soto-Berelov, M., Haywood, A., Mellor, A. (2015). Understanding the variability in ground-based methods for retrieving canopy openness, gap fraction, and leaf area index in diverse forest systems. *Agricultural and Forest Meteorology*, 205(0), 83-95. doi: http://dx.doi.org/10.1016/j.agrformet.2015.02.012

2015. Held, A., Phinn, S., Soto-Berelov, M., Jones, S. Introduction. In AusCover Good Practice Guidelines: A technical handbook supporting calibration and validation activities of remotely sensed data products. Edited by Alex H., S. Phinn, S. Jones and M. Soto-Berelov.

2015. Soto-Berelov, M, Jones, S, Farmer, E , Woodgate, W. Review of validation standards of Earth Observation derived biophysical products. In AusCover Good Practice Guidelines: A technical handbook supporting calibration and validation activities of remotely sensed data products. Edited by Alex H., S. Phinn, S. Jones and M. Soto-Berelov.

2015. Schaefer, M.T., Farmer, E., Soto-Berelov, M., Woodgate, W., Jones, S. Validation of LAI and FPAR products. In AusCover Good Practice Guidelines: A technical handbook supporting calibration and validation activities of remotely sensed data products. Edited by Alex H., S. Phinn, S. Jones and M. Soto-Berelov.

2015. Suarez, L., Restrepo-Coupe, N., Hueni, A., Chisholm, L.A. Vegetation spectroscopy. In AusCover Good Practice Guidelines: A technical handbook supporting calibration and validation activities of remotely sensed data products. Edited by Alex H., S. Phinn, S. Jones and M. Soto-Berelov.

2015. Suarez, L, Haywood, A, Jones, S, Wilkes, P, Woodgate, W, Soto-Berelov, M, Mellor, A. Australian Large Area Woody Vegetation Assessment. ANZIF 2015. Beyond tenure. Managing forests across the landscape. 13-15 April 2015, Creswick (Australia).

2014. Wilkes, P., Jones, S.D., Suarez, L., Haywood, A., Mellor, A., Woodgate, W., Soto-Berelov, M., Skidmore, A. Estimating vegetation vertical structure at a regional scale. ForestSat, Riva del Garda, Italy. 4 - 7th November 2014.

2014. Lola Suarez, Simon Jones, Andrew Haywood, Phillip Wilkes, William Woodgate, Mariela Soto-Berelov, Andrew Mellor (2014). Australian Large Area Woody Vegetation Assessment. Recent Advances in Quantitative Remote Sensing Symposium, September 2014, Valencia (Spain).

2013. Barbara A. Rasaiah, Tim J. Malthus, Chris Bellman, Laurie Chisholm, John Gamon, Andreas Hueni, Alfredo Huete, Simon D. Jones, , Cindy Ong, Stuart Phinn, Chris Roelfsema, Lola Suarez, Philip Townsend, Rebecca Trevithick, Mat Wyatt. Approaches to establishing a metadata standard for field spectroscopy datasets. Proceedings of the 33rd IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2013), July 2013, Melbourne.

2013. William Woodgate, Mathias Disney, John Armston, Simon Jones, Lola Suarez, Michael Hill, Phillip Wilkes, Mariela Soto-Berelov, Andrew Haywood, Andrew Mellor. The impact of sensor characteristics for obtaining accurate ground-based measurements of LAI. Proceedings of the 33rd IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2013), July 2013, Melbourne.

2013. Simon Jones, Andrew Haywood, Lola Suárez, Phil Wilkes, William Woodgate, Mariela Soto-Berelov, Andrew Mellor, Christoffer Axelsson (2013). Literature review for determining optimal data primitives for characterising Australian woody vegetation and scalable for landscape-level woody vegetation feature generation. CRCSI Project Report, 53 pages, January, 2013. http://www.crcsi.com.au/getattachment/63059502-5159-409b-8643-5aef9aa8f720/Australian-Woody--Vegetation-Landscape--Feature-Ge.aspx

2013. Phillip Wilkes, Simon Jones, Lola Suarez, Andrew Haywood, Andrew Mellor, Mariela Soto-Berelov, William Woodgate. MAUP and LiDAR derived canopy structure (A CRCSI 2.07 Woody Attribution paper). IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2013), July 2013, Melbourne.

2013. Phillip Wilkes, Simon Jones, Lola Suarez, Andrew Haywood, Andrew Mellor, Mariela Soto-Berelov, William Woodgate. Derivation of canopy complexity with LiDAR at the landscape scale. Cooperative Research Centre for Spatial Information Annual Conference, 19-21 November, Christchurch, New Zealand.

2013. William Woodgate, Simon Jones, Lola Suarez, Mariela Soto-Berelov, Phil Wilkes, Andrew Haywood, Andrew Mellor. (2013). P 2.07 Australian woody vegetation landscape feature generation: Ground-based LAI retrieval comparison. Poster presented at the CRC-SI annual conference, Christchurch, NZ.

2013. William Woodgate, Mariela Soto-Berelov, Lola Suarez, Simon Jones, Michael Hill, Chris Axelsson, Phil Wilkes, Andrew Haywood, Andrew Mellor. (2013). Representativeness and comparability of ground-based Leaf Area Index measurements across a number of TERN/AusCover study sites. Poster presented at the TERN symposium, Canberra, Australia

2013. Mariela Soto-Berelov, Simon Jones, Andrew Mellor, Darius Culvenor, Andrew Haywood, Lola Suárez, Phillip Wilkes, William Woodgate, Glenn Newnham. A collaborative framework for vegetated systems research: A perspective from Victoria, Australia. IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2013), July 2013, Melbourne.

2013. Lola Suarez, Simon Jones, Andrew Haywood, Phillip Wilkes, William Woodgate, Mariela Soto-Berelov, Andrew Mellor. Woody vegetation landscape. Woody vegetation landscape feature generation from multispectral and LiDAR data (A CRCSI 2.07 Woody Attribution paper). IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2013), July, Melbourne.

2012. Hueni, A., Chisholm, L., Suarez, L., Ong, C., Wyatt, M. Spectral Database Development for Australia. Proceedings of the Geospatial Science Research Symposium GSR2, December 2012, Melbourne. ISBN: 978-0-9872527-1-5. (Proceeding 5)

2012. Suárez, L., Youngentob, K., Jones, S., Soto-Berelov, M., Wilkes, P., Axelsson, C., Woodgate, W., Haywood, A., Mellor, A. Field sampling protocol for foliage chemistry assessment: Applicability over varied forest sites in Australia. GSR2, December 2012, Melbourne. ISBN: 978-0-9872527-1-5.

2012. Axelsson, C., Jones, S., Haywood, A., Suarez, L., Wilkes, P., Woodgate, W., Soto-Berelov, M.,Mellor, A. Key attributes for monitoring and assessing Australian forests: a land management perspective. GSR2, December 2012, Melbourne.

2012. Woodgate, W., 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. GSR2, December 2012, Melbourne.

2012. Wilkes, P., Jones, S., Suarez, L., Haywood, A., Soto-Berelov, M., Mellor, A., Axelsson, C., Woodgate, W. Deriving metrics of vertical structure at the plot level for use in regional characterisation of S.E. Australian forests. GSR2, December 2012, Melbourne. ISBN: 978-0-9872527-1-5.

***Tools/ Exemplar datasets and guidance documents***

Python tools for assessing forest vertical structural complexity: https://phil_wilkes@bitbucket.org/phil_wilkes/forestlas.git

An exemplar dataset and processing steps to derive canopy height and fractional cover will be provided shortly and available in the project webpage.

***Protocols***

Establishing a monitoring plot

Recording Physical and Biotic Characteristics

Characterisation of large trees

Characterisation of small trees

Understorey vegetation and ground cover parameters

Leaf Area Index measurement

Measuring coarse woody debris and stumps

Measuring post-fire forest recovery

Leaf sampling (sampling & processing)

Leaf spectra measurement

Field spectroscopy

Use of Rapideye TOA reflectance imagery for mapping vegetation fractional cover