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Characterising Vegetation Structural Differences Across Australian Ecosystems From a Network of Terrestrial Laser Scanning Survey Sites & Airborne & Satellite Image Archives

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Aims and Objectives

Vegetation structural information is critical for environmental monitoring, modelling, management and compliance assessment, from continental to global scales.

We refer to vegetation structural properties as their vertical, horizontal and volumetric dimensions, including: canopy height; amount and distribution of vegetation by height.

Our **aim** was to determine if there were significant differences between select vegetation structural properties across 11 ecosystems in Australia as measured by Auscover's terrestrial laser scanner (TLS) structure metrics.

TERN Auscover and The Joint Remote Sensing Research Program

Auscover is a national collaborative research infrastructure facility that enables all levels of government, research institutions, private companies and Not-for-Profit Groups to work together. Its focus is on building and delivering validated continental scale biophysical map products from current- and next-generation satellite image data sets and field data. It is part of Australia's Terrestrial Ecosystem Research Network (TERN, Fig.1).

TERN Auscover builds on the Joint Remote Sensing Research Program's activities – linking research applications in the university to operational applications in government using satellite and airborne imaging to map, monitor and model our ecosystems and their dynamics.

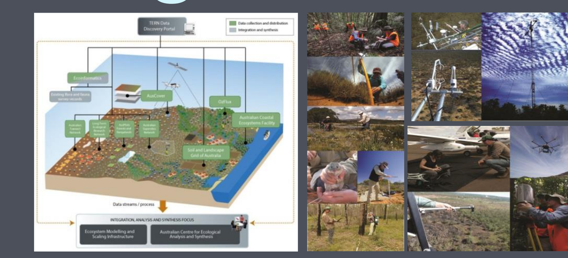

Figure 1: Australia's Terrestrial Ecosystem Research network (TERN)'s structure

Vegetation Structure Over Australia

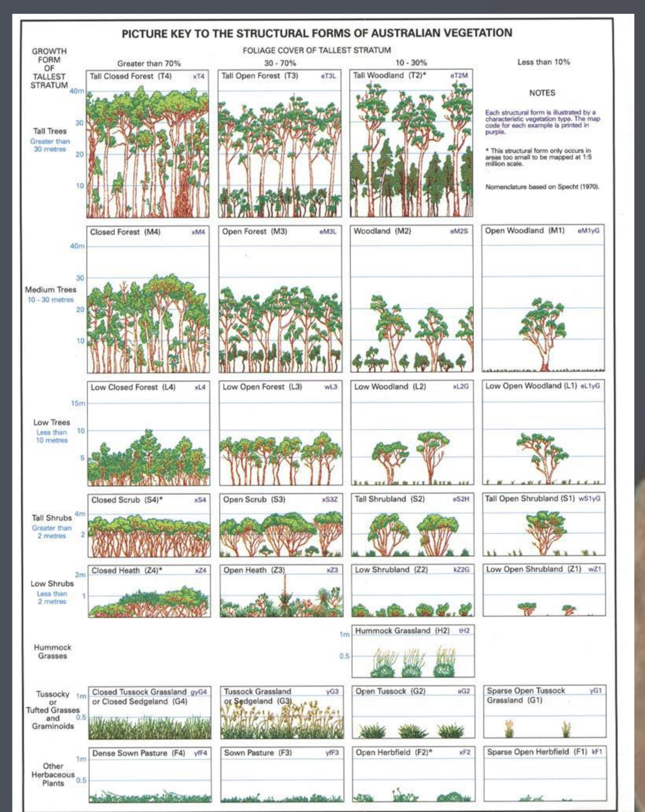

Figure 2: Vegetation structural forms, cross section of examples, based on Specht (1970) from www.appliedecology.com.au and mapped by NVIS (2015)

Vegetation structure in Australia (Fig.2) is the basis for our national vegetation community map, national vegetation information systems NVIS (Fig.3a) and is a regularly monitored parameter for local , regional, state and national governments.

It is challenging to repeat the NVIS process, and the increasing need to monitor structural changes requires more accurate and efficient mapping processes.

Field based terrestrial laser scanning surveys across our vegetation communities can be used to drive new approaches to satellite mapping of vegetation – this poster shows some of our progress.

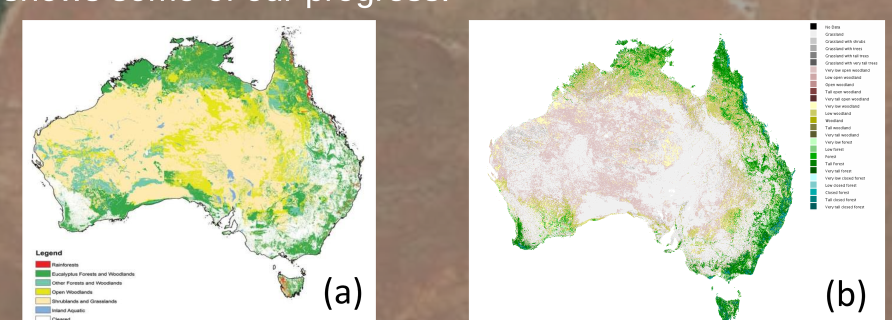

Figure 3: Australian vegetation communities based on structural information, (a) continental structural and floristic groups from NVIS (2012); (b) vegetation height class map combining Landsat fractional cover, Icesat GLAS, ALOS PALSAR and airborne lidar to map vegetation height; (Armston et al. 201, poster B21D-0483: Continental Scale Vegetation Structure Mapping Using Field Calibrated Landsat, ALOS PalsarGLAS ICESat).

Measurement and mapping of vegetation structure over Australia has traditionally been the domain of forestry, plot based ecological studies and aerial photograph interpretation. We can now measure vegetation height and other properties at a site scale (m^2), in a form that can be directly linked to airborne and satellite image data to calibrate and validate mapping algorithms.

Airborne lidar is an operational method, with data available over Australia for a range of purposes (Fig.5). We have now systematically collected it over a range of ecosystems with detailed monitoring programs that are part of the TERN Auscover network (Fig's. 4 and 5). The TERN Supersites focus ecological and biophysical data collection within a 5km x 5km area, allowing exhaustive sampling of fauna and flora, along with detailed micro-meteorological surface energy and gas fluxes. (Fig. 5).

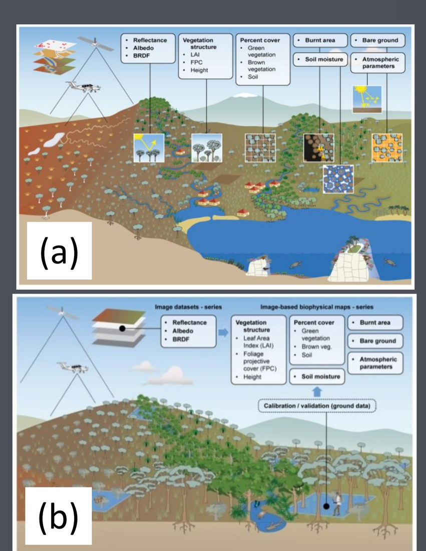

Figure 4: Structure of Australia's TERN Auscover Facility (a) Satellite image products; and (b) Ground sampling products.

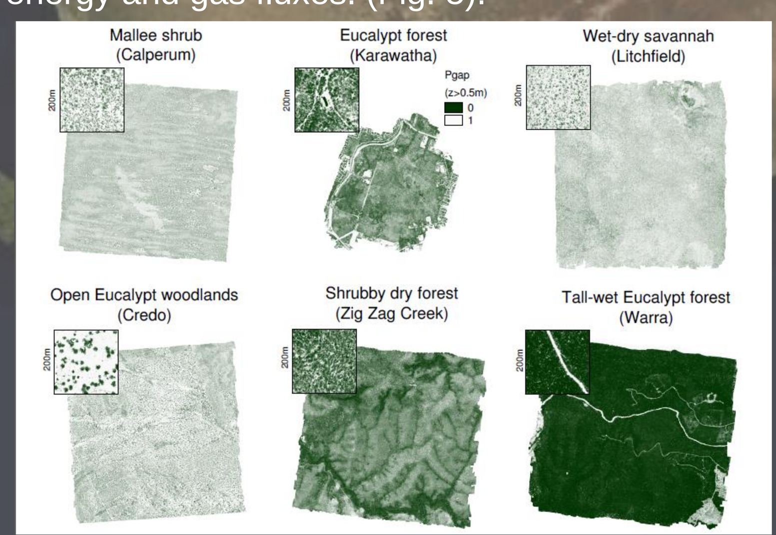

Figure 5: Estimates of directional gap probability (Pgap) from airborne waveform lidar at 1m over Litchfield, Warra, Credo, Alice Mulga, Rushworth, and Zig Zag Creek TERN Auscover 5km by 5km supersites (Armston et al., 2015). The angular and vertical distribution of Pgap underpins the estimation leaf area index and plant area volume density profiles from airborne laser scanning.

References:

Specht, R.L. (1970) Vegetation. Pages 44–67 in Leeper, G.W. (ed.), "Australian Environment", 4th ed. Melbourne University Press, Melbourne.

NVIS 4.1 (2015) www.environment.gov.au/land/native-vegetation/national-vegetation-information-system/data-products#mvg41

Armston, J., Scarth, P., Lucas, R.M., Lewis, P., Disney, M. and Phinn, S. (2015). Validation of continental scale vertical plant profile mapping using waveform lidar airborne airborne laser scanning. Silvilaser, 2015

Terrestrial Laser Scanning

The field measurement process at each Auscover site was part of a systematic and intensive ground and airborne image acquisition campaign across Australia, built on the field sampling protocols developed through the Queensland Government Remote Sensing Centre and data preprocessing systems (Bunting et al., 2013). The field sampling protocols used are explained in Armston et al. (2009), Held et al. (2015) and at www.auscover.org.au/xwiki/bin/view/Product+pages/TLS+Products .

Fig. 6 shows the layout used across multiple ecosystems for measuring foliage projective cover, TLS, hemispheric photography and LAI. The sites sampled covered the full range of structural variation in Australian vegetation communities (Fig.'s 3 and 8) . Coincident with field data collection - airborne hyperspectral (SPECIM Hawk+Eagle sensors) and full-waveform lidar (Riegl 560) were collected.

All data have been processed, QA/QC' d and are accessible at www.auscover.org.au/data/product-list.

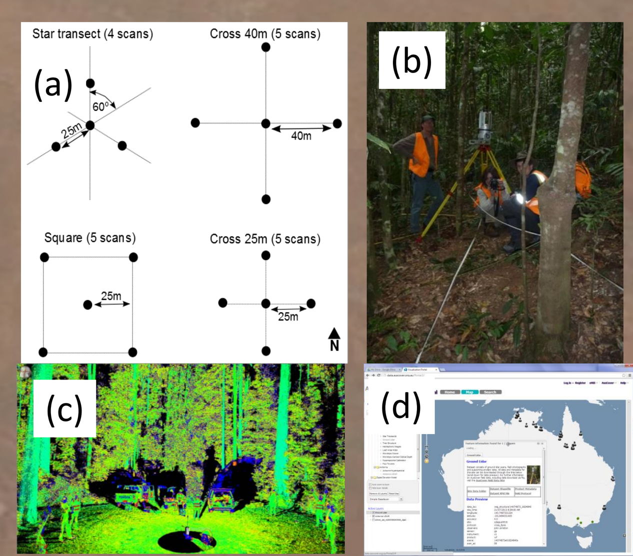

Figure 6: Terrestrial laser scanning: (a) field deployments layouts used in all TERN Auscover sites; (b) Robson Ck scan setup; (c) Warra point-cloud; (d) Auscover TLS data download page.

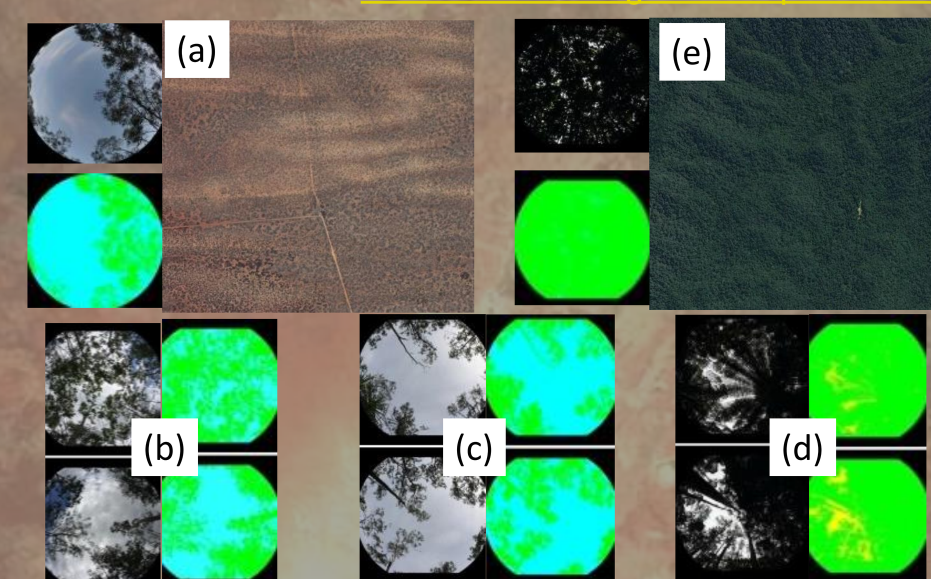

Figure 7: Selected hemispheric photos for (a) Calperum mallee woodland site, 5kmx5km Quickbird image (b) Litchfield wet-dry savannah, (c) Karawatha eucalypt forest, (d) Warra tall and wet eucalypt forest, and (e) Robson Creek notophyll vine forest, 5kmx5km Quickbird image .

The main structural differences in terms of canopy height, vegetation substrata, leaf/canopy morphology and ground cover are evident in the photospheres for each site (Fig. 8). Phenological differences also occur between vegetation communities at each site, affecting the amount of canopy, mid-storey and ground biomass at different times of year.

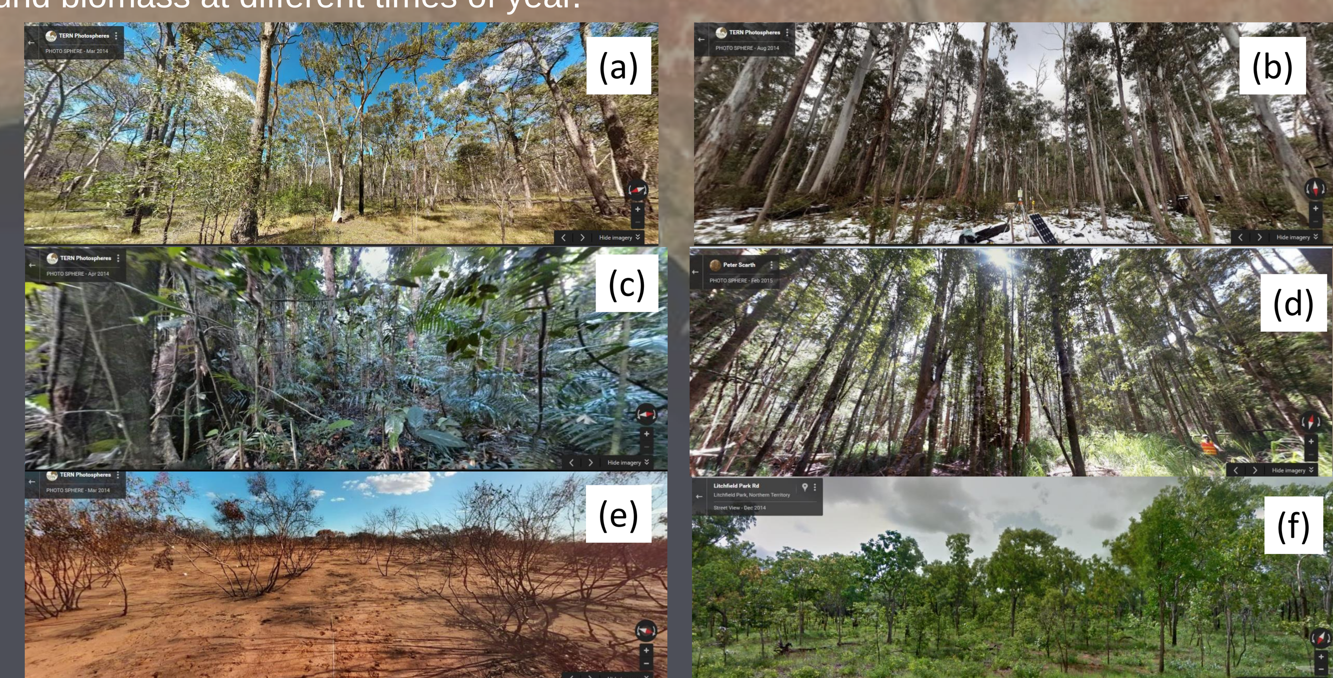

Figure 8: Photospheres for each sample site: (a) Karawatha subtropical eucalypt forest, (b) Tumbarumba wet eucalypt forest, (c) Robson Creek notophyll vine forest, (d) Warra wet eucalypt forest, (e) Calperum mallee scrub and (f) Litchfield wet-dry tropical savannah.

References:

Armston, J. D., Denham, R. J., Danaher, T. J., Scarth, P. F., & Moffiet, T. N. (2009). Prediction and validation of foliage projective cover from Landsat-5 TM and Landsat-7 ETM+ imagery. Journal of Applied Remote Sensing, 3(1), 033540-033540.

Bunting, P., Armston, J., Lucas, R., Clewley, D. 2013. Sorted Pulse Data (SPD) Library. Part I: A generic file format for LiDAR data from pulsed laser systems in terrestrial environments. Computers & Geosciences. http://dx.doi.org/10.1016/j.cageo.20

Held, A., Phinn, S., Soto-Berelov, M., & Jones, S. (Eds.) (2015). AusCover Good Practice Guidelines: A technical handbook supporting calibration and validation activities of remotely sensed data products. Version 1.1. TERN AusCover, ISBN 978-0-646-94137-0.

Vegetation Structure Differences

Vertical profiles of PAVD (plant area volume density) were derived from the RIEGL VZ400 data using procedures described in Calders et al. (2014) from upright and tilted scans at each of the sites (Fig 4).

To link ALS/TLS measurements at some TERN sites (e.g. Ethabuka), we extended the method to derive PAVD to ground level. methods to quantify PAVD to ground level are needed for the assessment of understorey, pasture biomass, and vegetation structural complexity.

Individual site PAVD and site average and standard deviation PAVD vertical profiles are shown in Fig. 9. Significant differences in the vertical distribution of foliage were evident between sites and conform to the structural form classification system developed by Specht (1970).

Within site PAVD variation was minimal for savannah and shrubland sites due to consistency in vertical stratification. Maximum variation was observed at the wet and vine forest sites due to their varied disturbance history evident in range of ground to mid-story (20m) profiles.

The hemispheric photos (Fig.7) and derived average bidirectional gap fraction plots (Fig.9) reflect similar variations to the PAVD profiles -significant differences in canopy open-ness between sites.

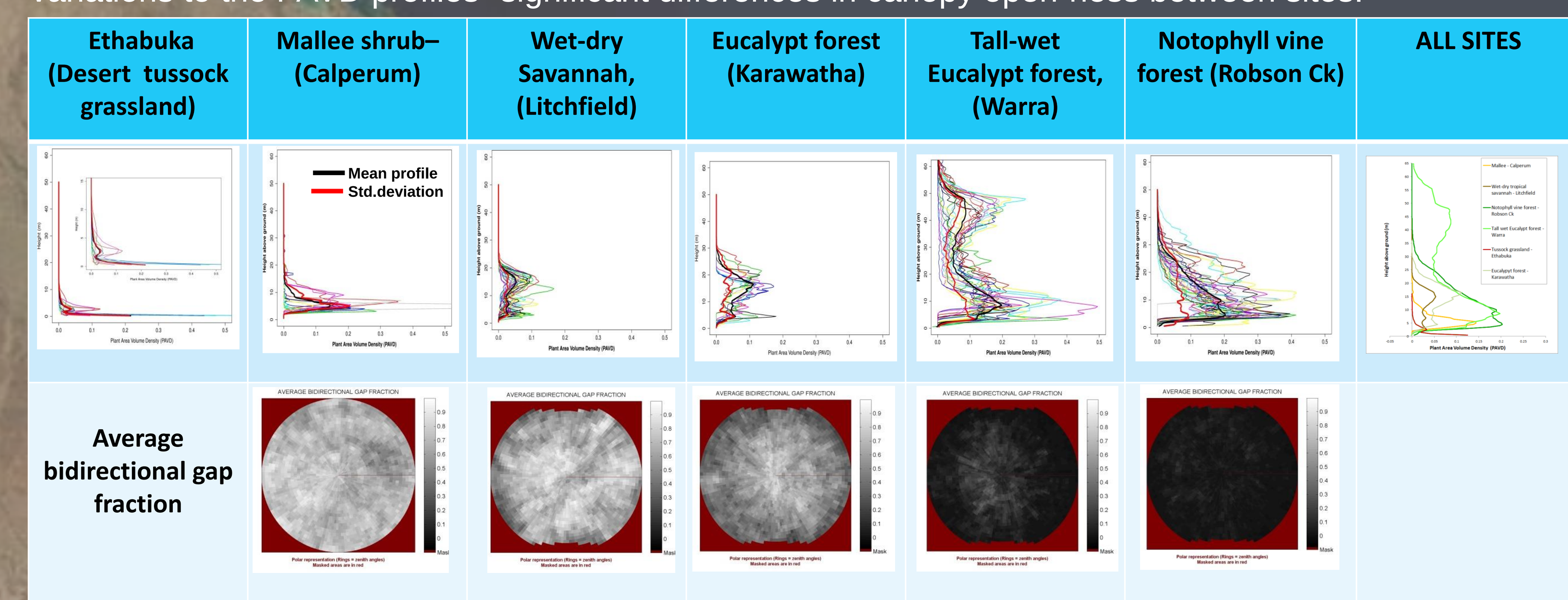

Figure 9: Plant area volume density curves (top row) derived from Riegl VZ400 and average bidirectional gap fraction (bottom row) derived from hemispheric photographs, along a structural gradient of vegetation communities: (a) Mallee scrub –(Calperum); (b) wet-dry tropical savanna(Litchfield); (c) sclerophyll eucalypt forest(Karrawatha); (d) tall-wet eucalypt forest(Warra), and (e) notophyll vine forest(Robson Ck).

Access These Data and Use Them !

All data presented are part of our national ecosystem research infrastructure and are open for use . Our results showed the answer to a simple ecological question and comparison across ecosystems. The vegetation structure data shown in this poster are suited to calibration and validation of local to national (Fig.10) and global scale airborne, and satellite data processing streams and also for a range of ecosystem models. **Please use the data, provide feedback and add your own !**

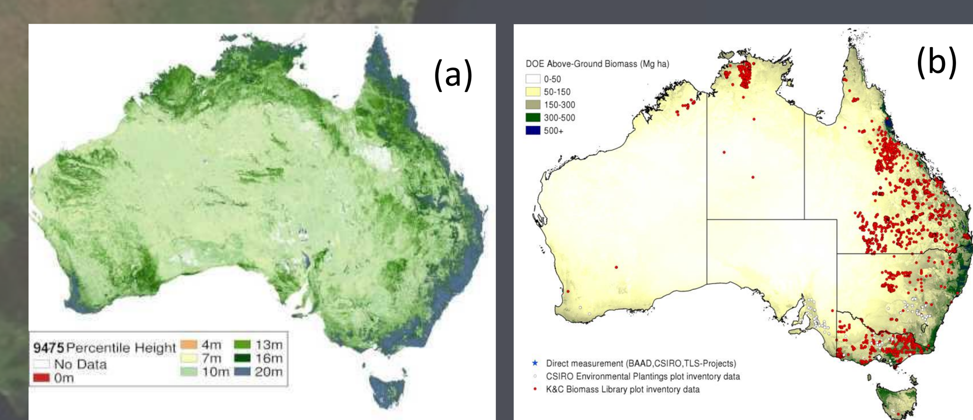

Figure 10: Example national projects using the vegetation structural information: (a) current draft of national height map; and (b) current status of large area collation of plot inventory data for allometric estimation of biomass.

TLS data

All data

References:

Calders, K., Armston, J., Newnham, G., Herold, M., & Goodwin, N. (2014). Implications of sensor configuration and topography on vertical plant profiles derived from terrestrial LiDAR. Agricultural and Forest Meteorology, 194, 104-117.

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TERN Terrestrial Ecosystem Research Network; Remote Sensing Research Centre; Joint Remote Sensing Research Program

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