ABSTRACT: ForestSAT 2014

Investigating the relationship between airborne laser scanning derived forest canopy vertical structure and Landsat ETM+ derived indices

Phil Wilkes*[ab], Simon Jones[a], Lola Suarez[a], Andrew Skidmore[b], Andrew Haywood[c], Andrew Mellor[ac], Will Woodgate[a], Mariela Soto-Berelov[a]

[a] School of Mathematical and Geospatial Sciences, RMIT University, GPO Box 2476, Melbourne, VIC 3001, Australia
[b] ITC, University of Twente, PO Box 217, NL-7000 AE Enschede, the Netherlands
[c] Victorian Department of Environment and Primary Industries, PO Box 500, East Melbourne, VIC 3002, Australia
* Corresponding author

Keywords: canopy structure, vertical canopy heterogeneity, Landsat ETM+, ALS, regional scale, OLS regression

Vertical arrangement of forest foliage and branches are fundamental plant traits that determine, amongst others, habitat suitability, fire behaviour and provision of ecosystem services. LiDAR has been shown to provide accurate measurement of three-dimensional (3D) vegetation structure; however the cost of acquisition at the regional scale can be prohibitively expensive. Conversely, passive remote sensing allows the spatially continuous attribution of forests at a fraction of the cost but without direct measurement of 3D structure. We present a comparison of Landsat ETM+ derived vegetation indices and their ability to infer LiDAR derived vertical forest structure.

Discrete return airborne laser scanning data was acquired over ~7500 ha, across three structurally diverse native forested landscapes in Victoria, Australia. Forest vertical structural heterogeneity was characterised at 280 plots (0.04 ha) using three metrics; foliage height diversity (FHD) (MacArthur and Horn, 1969), coefficient of variation (C_v) of return height (Bolton et al., 2013) and a new technique that estimates the number of canopy layers (CL). Three coincident Landsat ETM+ images were pre-processed to surface reflectance (Flood et al., 2013) and Normalised Difference Vegetation Index

(NDVI), Enhanced Vegetation Index (EVI), tasselled cap indices (greenness, brightness and wetness) (Huang et al., 2002) and first and second principal components (PC1 and PC2 respectively) were computed. OLS regression was then used to analyse the relationship between structural and spectral variables.

Explained variance (R^2) is greatest for NDVI > wetness > PC1 > brightness > greenness > EVI > PC2 for all three dependent variables; where NDVI explains 64% ($p \leq 0.05$) of variance in FHD. FHD consistently returns greater correlation coefficients with all spectral indices; it is suggested this is due to the nonlinear relationship between FHD and canopy height (Weishampel et al., 2007) and the subsequent strong relationship between canopy height and spectral indices (Cohen and Spies, 1992; Hudak et al., 2002). C_V and CL are less well explained by spectral indices ($R^2 \leq 0.38$) and this is likely caused by the inability to infer vertical structure from medium resolution Landsat ETM+; indices derived from higher resolution imagery might prove more useful (Pasher and King, 2011). Furthermore, sub-setting datasets by height or canopy cover does not improve regression performance particularly for tall (>30 m) and dense (canopy cover >50%) forests.

Bolton, D.K., Coops, N.C., Wulder, M.A., 2013. Measuring forest structure along productivity gradients in the Canadian boreal with small-footprint Lidar. *Environ. Monit. Assess.* 185, 6617–34.

Cohen, W.B., Spies, T.A., 1992. Estimating structural attributes of Douglas-fir/western hemlock forest stands from landsat and SPOT imagery. *Remote Sens. Environ*. 41, 1–17.

Flood, N., Danaher, T., Gill, T., Gillingham, S., 2013. An Operational Scheme for Deriving Standardised Surface Reflectance from Landsat TM/ETM+ and SPOT HRG Imagery for Eastern Australia. *Remote Sens.* 5, 83–109.

Huang, C., Wylie, B., Yang, L., Homer, C., Zylstra, G., 2002. Derivation of a tasselled cap transformation based on Landsat 7 at-satellite reflectance. *Int. J. Remote Sens.* 23, 1741–1748.

Hudak, A.T., Lefsky, M.A., Cohen, W.B., Berterretche, M., 2002. Integration of lidar and Landsat ETM+ data for estimating and mapping forest canopy height. *Remote Sens. Environ.* 82, 397–416.

MacArthur, R.H., Horn, H.S., 1969. Foliage Profile by Vertical Measurements. *Ecol. Soc. Am.* 50, 802–804.

Pasher, J., King, D.J., 2011. Development of a forest structural complexity index based on multispectral airborne remote sensing and topographic data. *Can. J. For. Res.* 41, 44–58.

Weishampel, J.F., Drake, J.B., Cooper, A., Blair, J.B., Hofton, M., 2007. Forest canopy recovery from the 1938 hurricane and subsequent salvage damage measured with airborne LiDAR. *Remote Sens. Environ.* 109, 142–153.