# Estimating vegetation vertical structural complexity at a regional scale

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

[a]RMIT University, Melbourne [b]ITC, Enschede [c]DEPI, Melbourne. *phil.wilkes@rmit.edu.au

## Introduction

Vertical structural complexity describes the arrangement and quantity of leaves, branches and stems along the vertical axis and is a key descriptor of forest structure. Owing to non-linear succession in native forests stands, vertical structure is not a function of age or height and therefore can not be assumed. Characterising forest structure over regional areas requires a tool that makes no assumptions regarding forest type or structure *a priori*. Here we present *COVVES*, a method for characterising canopy complexity from LiDAR, and a method to up-scale *COVVES* across a regional area using Landsat.

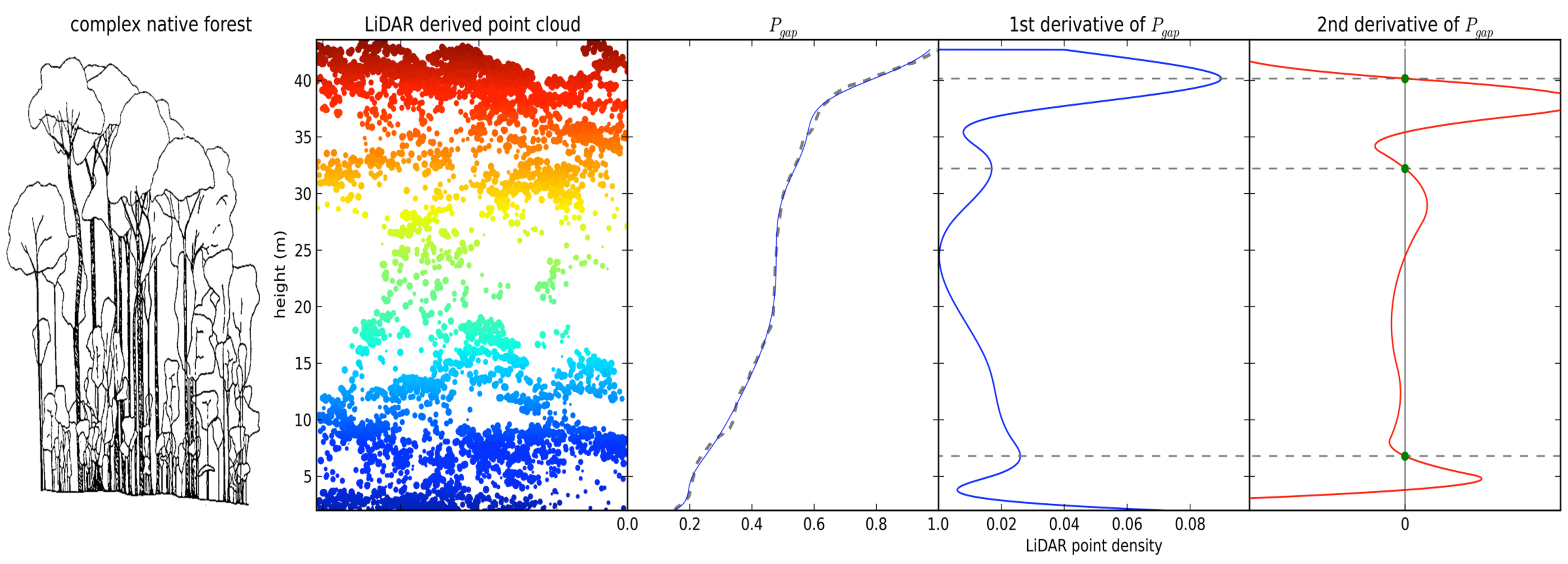


Figure 1. The derivation of *COVVES* from small footprint discrete return LiDAR.

## Up-scaling: pilot study

A total of 250 LiDAR plots were extracted across three study sites (Figure 3). Multiple regression and PCA was used to evaluate the statistical association between *COVVES* and Landsat ETM+ bands and indices, however results suggest that this is poor ($r^2$ <0.4). Instead forest was classified into single and multilayer classes. Three classification techniques were tested (*k*-NN, SVM and Random Forest), RF performed the best reporting an accuracy of 85% (kappa 0.66) when the model was applied to a further 250 plots. The SWIR and red bands were ranked with the highest importance. Figure 2 demonstrates that brighter pixels represent simple plots whereas darker pixels indicate more complex forest.  This suggests soil brightness and multi-scattering are the primary drivers.  Differentiating between forest with ≥2 layers was unsuccessful owing to similar reflectance values (Figure 2B).

## What is *COVVES*?

Complexity from Vegetation VErtical Structure (*COVVES*) is a novel technique to estimate canopy complexity from small-footprint discrete-return LiDAR gap probability ($P_{gap}$). Noise is removed from the $P_{gap}$ signal with a nonparametric cubic spline regression (Figure 1). Number of canopy layers is calculated from a count of positive zero-crossings of the $P_{gap}$ second derivative. Application of the spline transformation rescales analysis from that at which the data is captured (~0.1 m) to the top-to-bottom canopy scale, where canopy scale features dominate.

Estimation of *COVVES* at three structurally different forest types (Figure 3) revealed a good agreement with a forest inventory based estimate of complexity. For this the smoothing coefficient was determined with a supervised classification. This allowed attribution without the requirement to recalculate the smoothing coefficient dependent on forest type. Correlations with other LiDAR derived structure metrics was moderate ($r^2$ ≤0.5), suggesting *COVVES* offers a further source of information for describing forest structure.

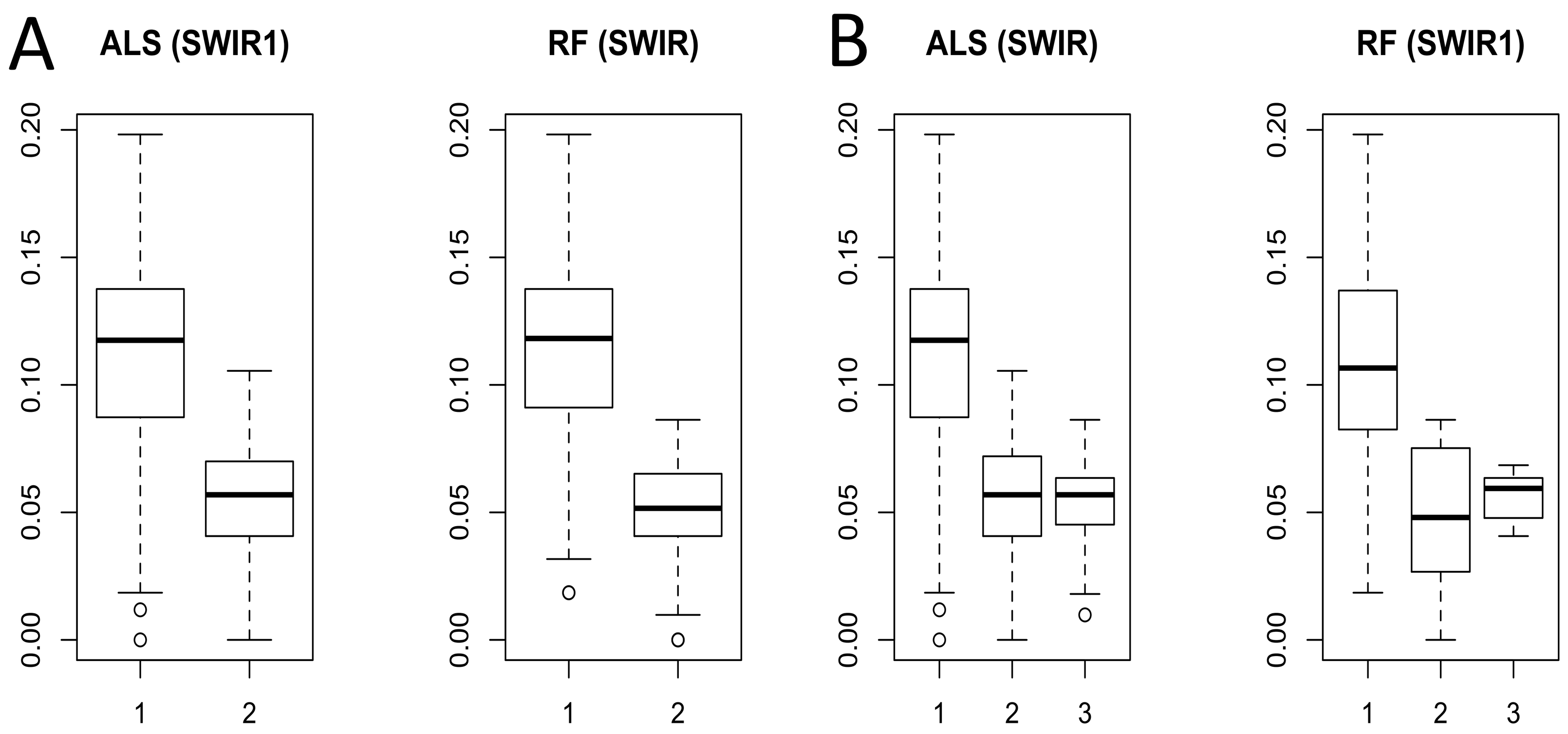


Figure 2. Boxplots for the range of SWIR reflection values that correspond to different levels of canopy complexity derived using ALS and Random Forest. [A] Forest classified into single (1) and multilayered (2) forest. [B] Classified into single (1), two canopy layers (2) and >2 canopy layers (3)

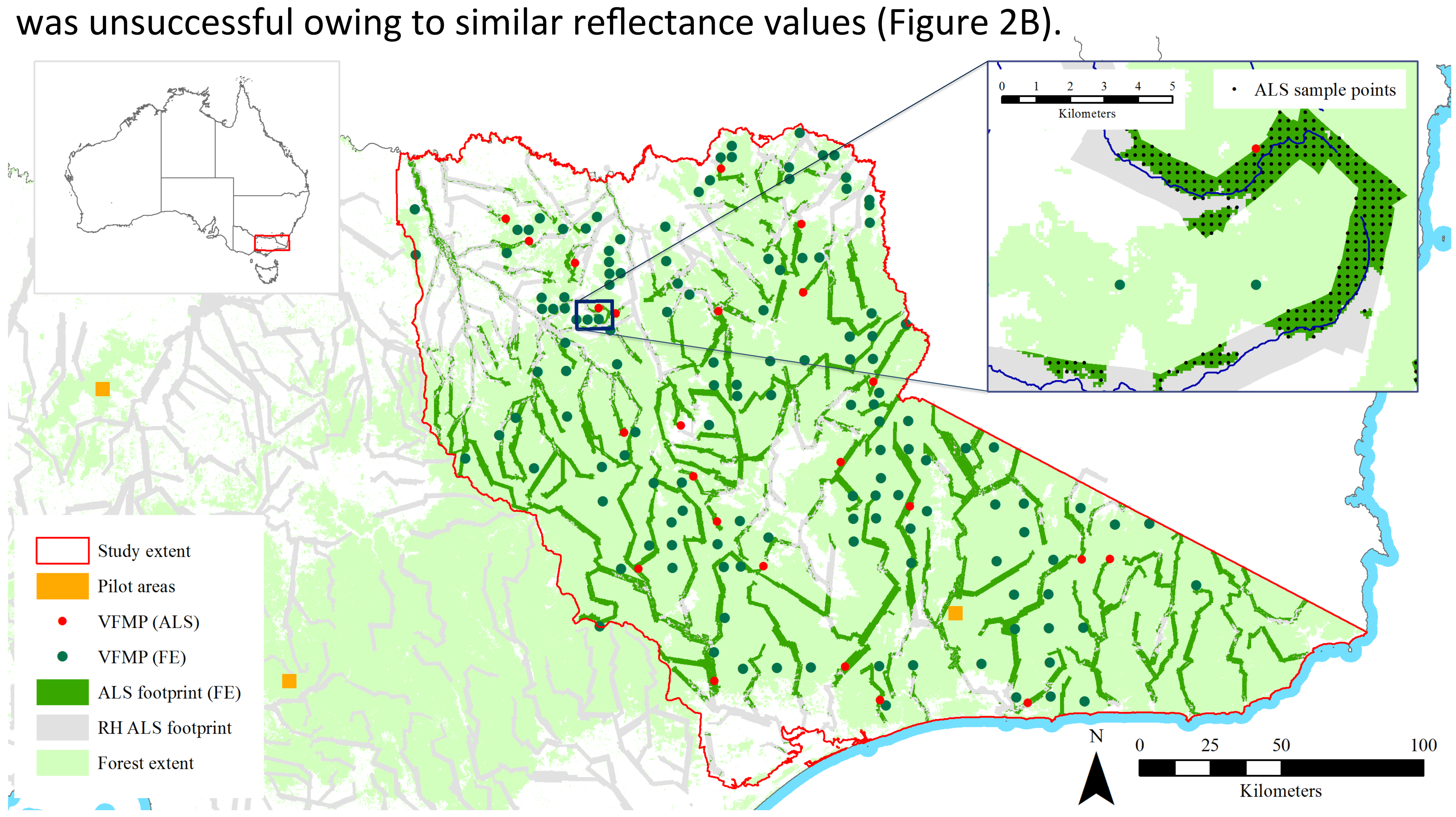


Figure 3. Map of eastern Victoria with the proposed extent for up-scaling. The DEPI River Health (RH) LiDAR dataset is clipped to forest extent (FE). Location of 161 DEPI VFMP plots are shown. Inset: grid highlighting LiDAR plots where training data is extracted from RH dataset.

## Up-scaling: application to a regional area

The next stage is to upscale estimation of canopy complexity to an area of ~20,000 km² in eastern Victoria (Figure 3).  This will be achieved by extracting ALS plots from DEPI River Health LiDAR dataset which will be used to train the RF model.  Landsat 8 band reflectance will be used as predictor variables.  Modelled output will be validated using the DEPI Victorian Forest Monitoring Plots forest inventory data. Anticipated challenges include the mixed disturbance history (fire and logging) not present in the pilot areas.

For more information see: Wilkes et al. *COVVES*: a novel LiDAR derived metric for the assessment of vegetation vertical structural complexity. Under review with *RSE*

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