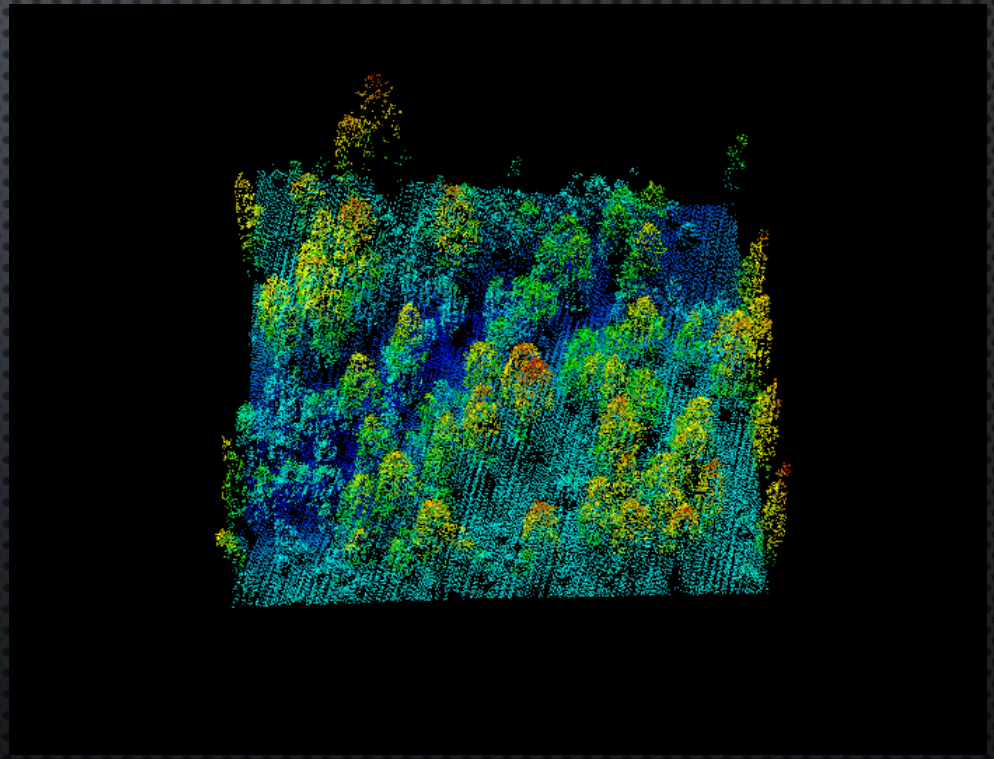
AIRBORNE LIDAR ANALYSIS FOR FORESTED ENVIRONMENTS IN THE SOUTH-EAST OF THE USA

VIRGINIA TECH & THE FOREST PRODUCTIVITY COOPERATIVE

OVERVIEW

- Brief background on LiDAR & its processing;
- Creation of vertical profiles;
- Detection of canopy and understorey;
- Individual tree crown delineation;
- Statistical estimation of Leaf Area Index (LAI).



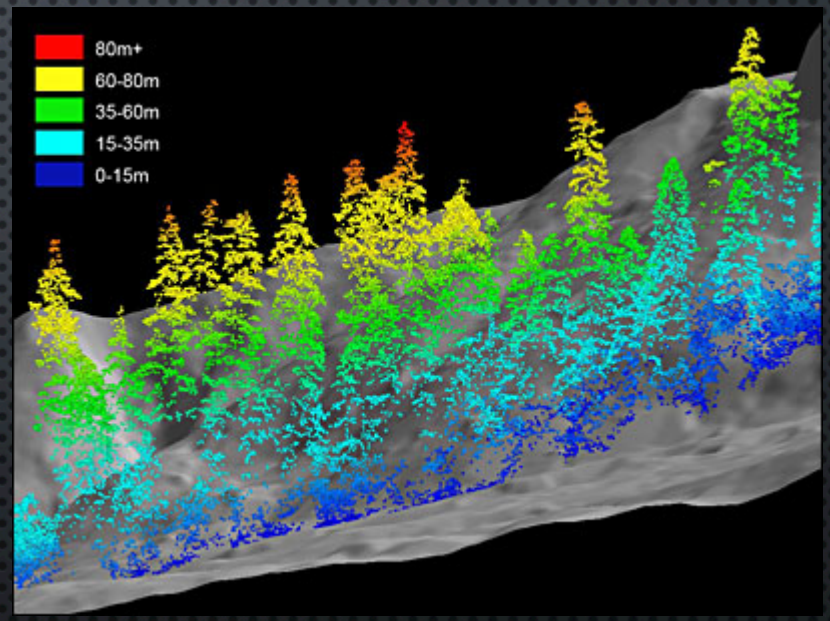
BACKGROUND

LiDAR:

- Light in the form of a pulsed laser to measure ranges;
- Large volume of 3D coordinates;
- Collected by airborne platforms (in this case).

Processing steps:

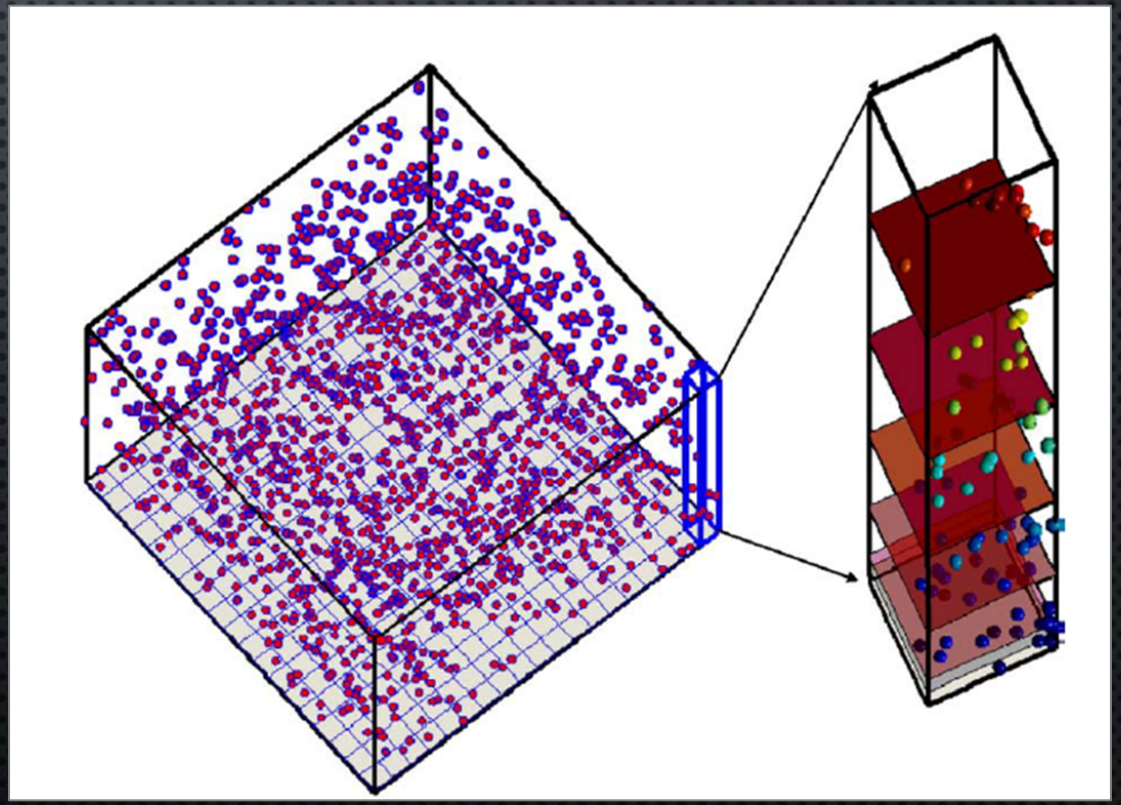
1. Filtering to identify ground points;
2. Calculate above ground heights for all points;
3. Identify and remove buildings (planar surface search);
4. Extract/calculate metrics for analysis of forests.



BACKGROUND

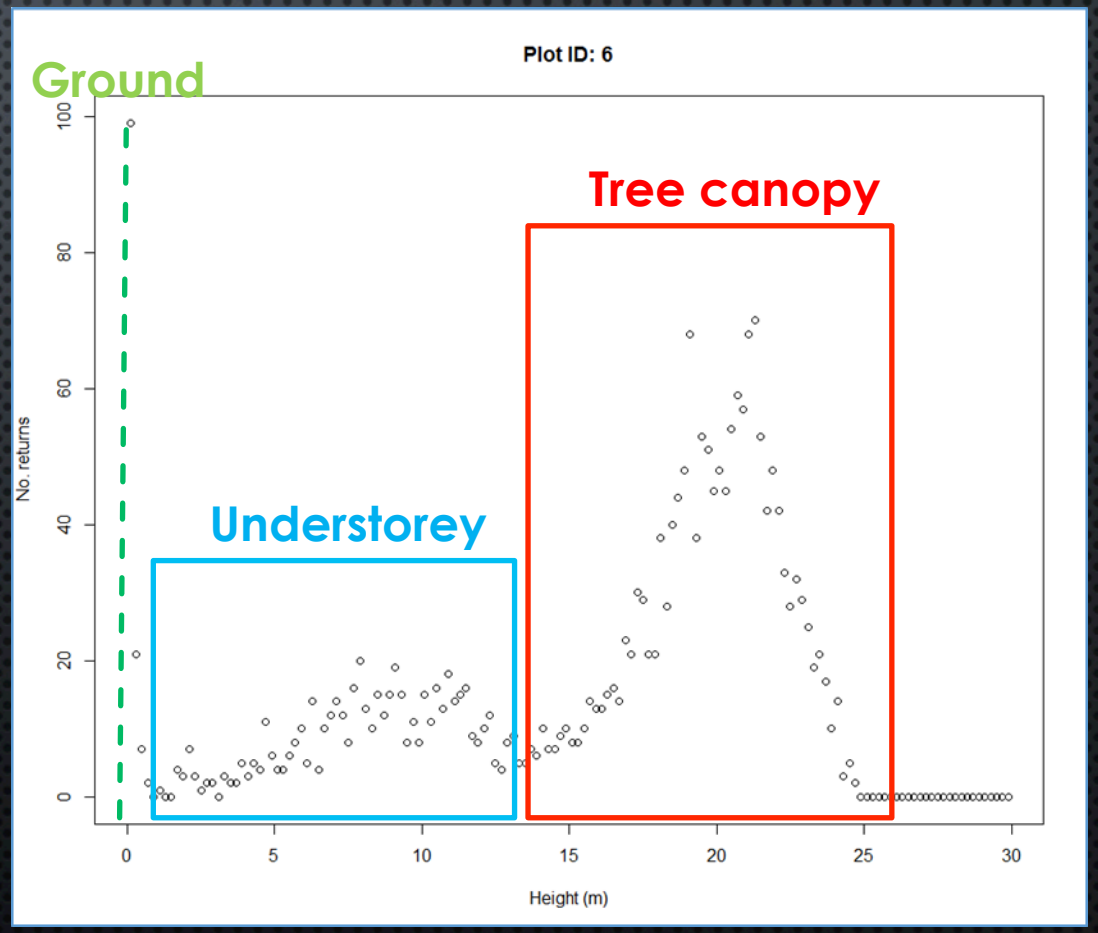
Within this project height bins are calculated.

- Define a 3D grid, e.g. 1m x 1m x 1m
- Sum the number of points within each 3D extent;
- Raster output similar to multispectral image bands.



LIDAR VERTICAL PROFILE
(PLOT SCALE)

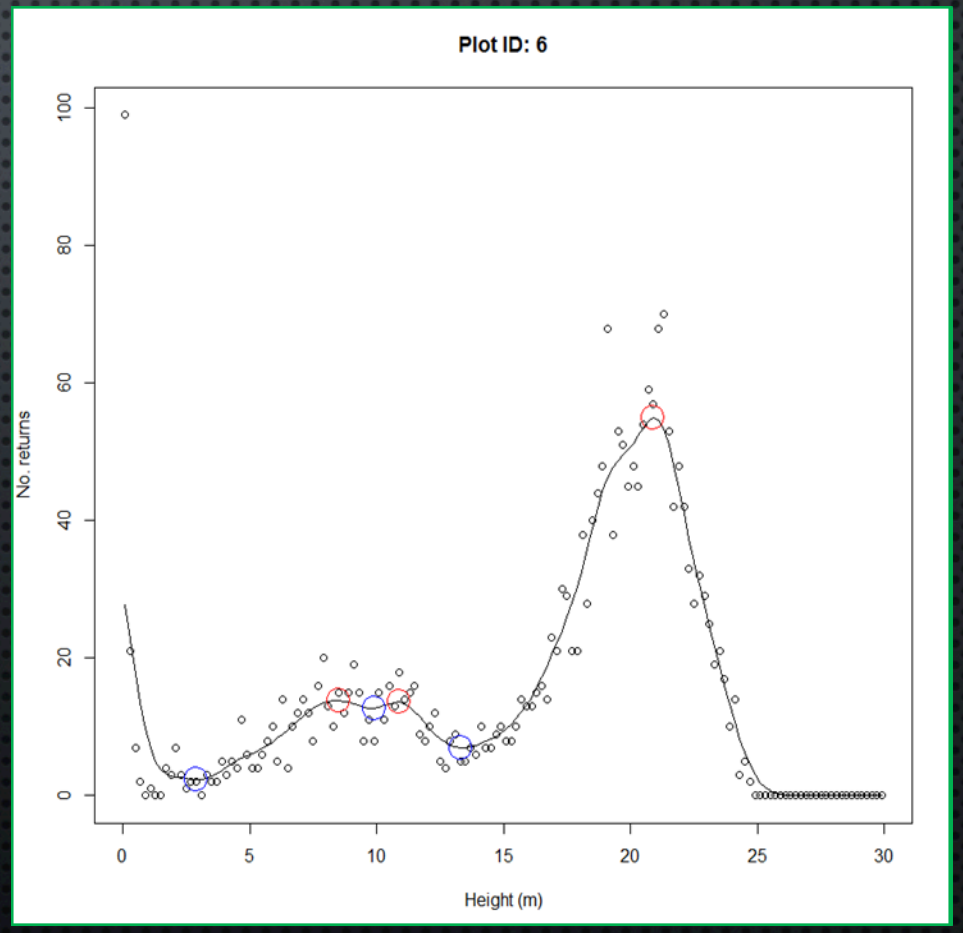
- From archive 2008 field and LiDAR data;
- Pre-processing steps using LAStools (http://www.cs.unc.edu/~isenburg/lastools/)
- A focus on analyzing vertical profiles – e.g. the number of LiDAR returns stratified by height;
- Example at the Henderson site (NC) – plot no. 6 (block A) – Loblolly Pine.
- At the field plot scale (15m x 30m).



DETECTING LAYERS

Developed an automated approach, where:

- Layers can be identified by local maxima and minima;
- Maxima (red) – Minima (blue);
- Estimates of layer height and depth can be made.
- Approach functions with variable plot size and shape



UPPER CANOPY LAYER VALIDATION

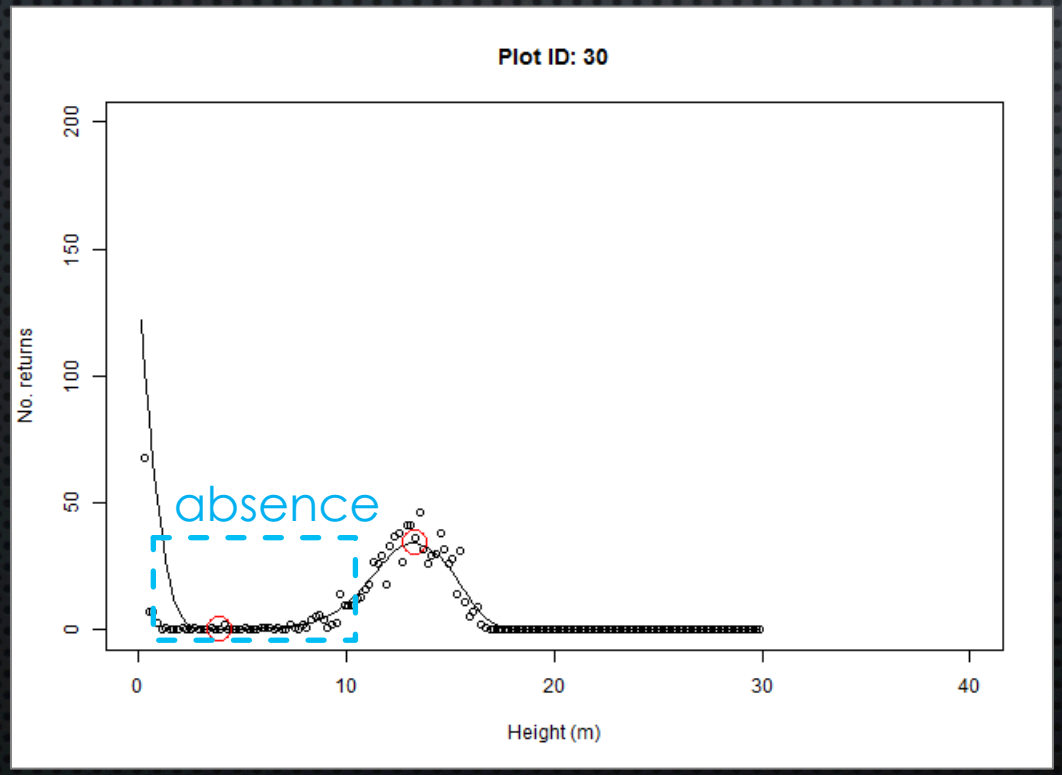
- Estimates of canopy height and height to the living crown (HTLC)
- Note different number of plots and plot sizes between areas

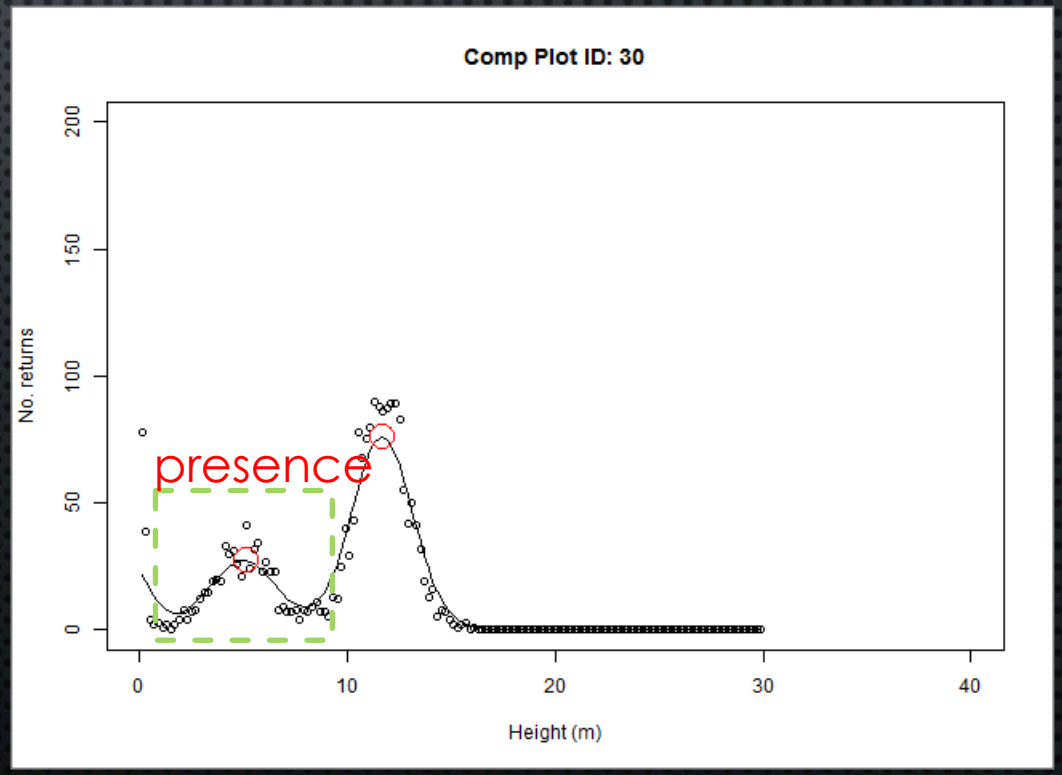
1. Henderson – NC
2. Region Wide 18 – VA
3. *The Southeast Tree Research and Education Site* [SETRES] – NC

Henderson (Vance, NC)		
	Average height(m)	Average HTLC(m)
RMSE	1.13	1.18
NRMSE	0.19	0.20
RW18 (Brunswick, VA)		
	Average height(m)	Average HTLC(m)
RMSE	0.51	1.00
NRMSE	0.20	0.42
SETRES (Scottland, NC)		
	Average height(m)	Average HTLC(m)
RMSE	1.06	1.93
NRMSE	0.14	0.26

UNDERSTOREY DETECTION

Example comparison plot was extracted from 50m to the west of original.
(Left) vegetation control; and (right) no-control.





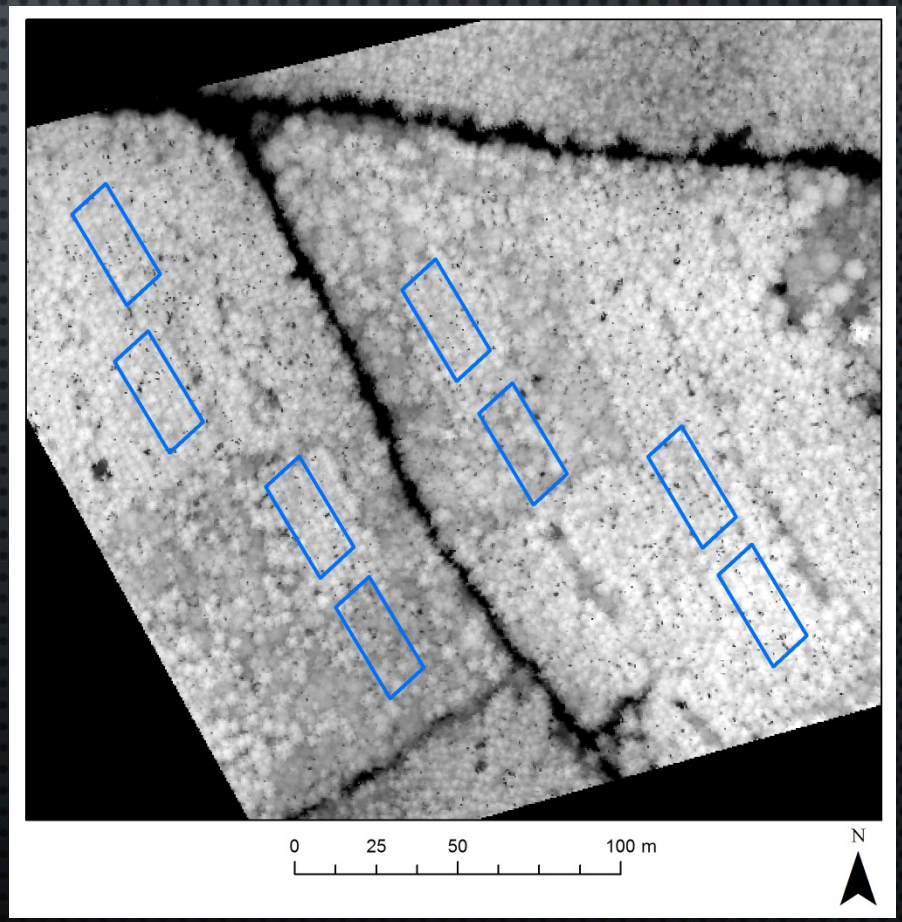
VERTICAL PROFILES UNDER DIFFERENT MANAGEMENT
-HENDERSON (NC): SITE C-

Each pair of plots correspond to a different initial treatment type:

1. Stem removal only + SPD
2. Stem removal only + CD
3. Whole tree removal + SPD
4. Whole tree removal + CD

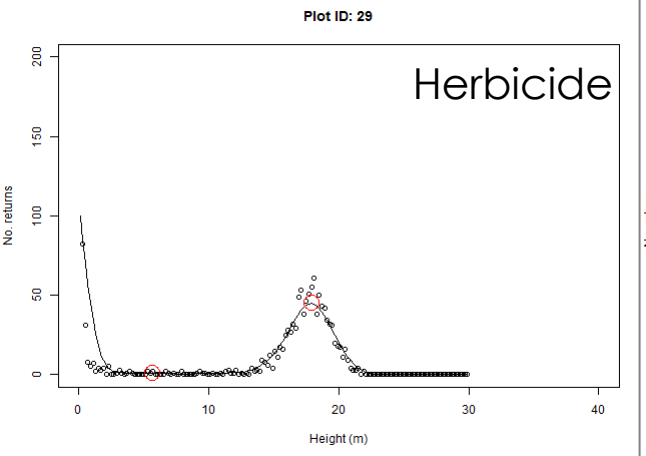
CD = Chopped and burned

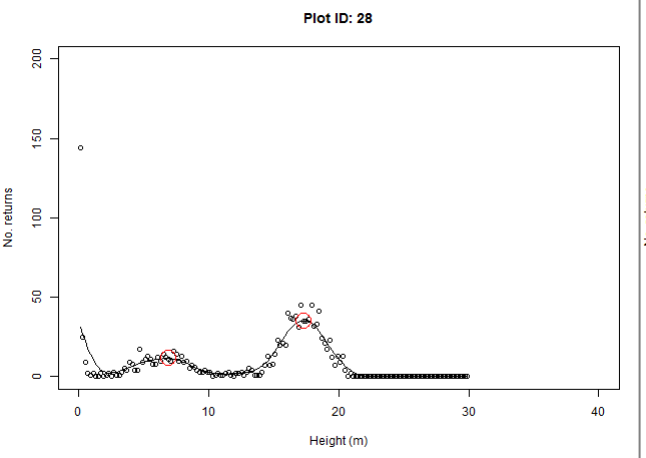
SPD = Shear, pile and disk



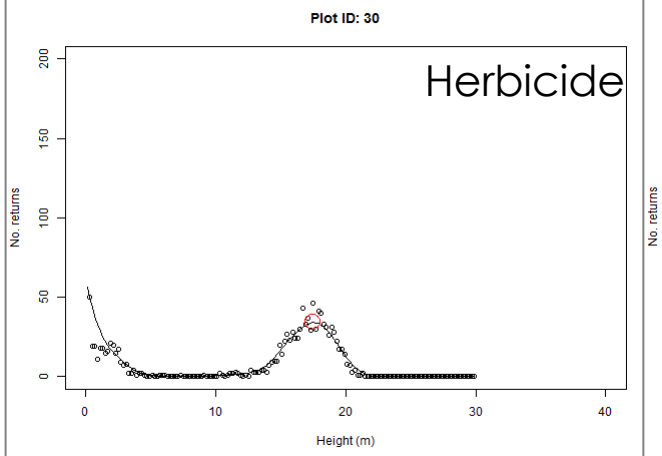
VERTICAL PROFILES UNDER DIFFERENT MANAGEMENT

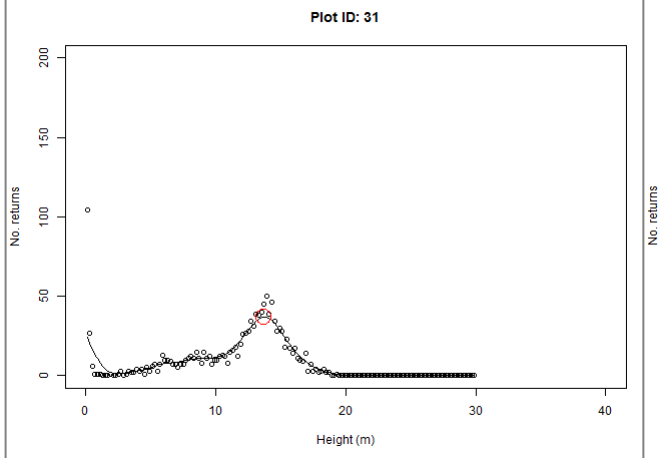
Stem removal only + SPD



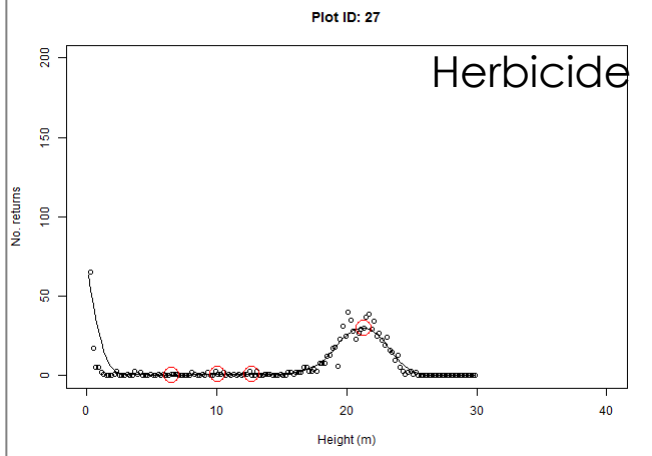


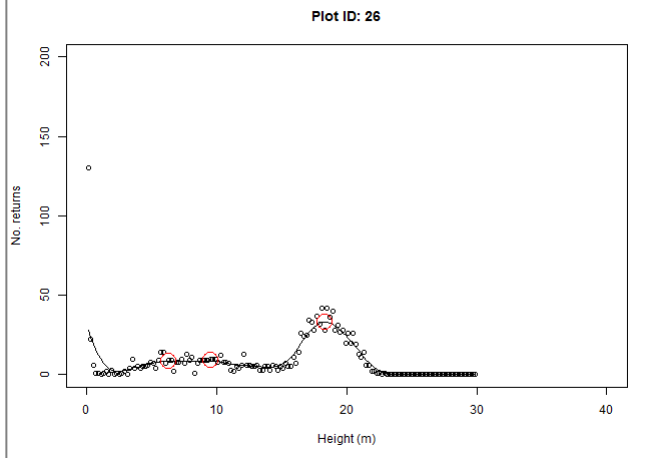
Stem removal only + CD



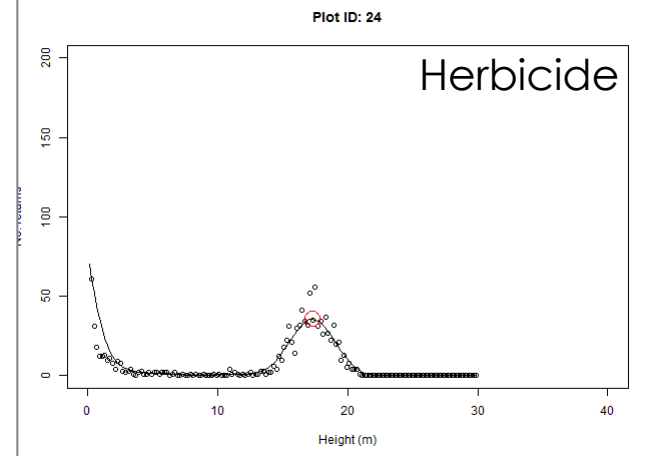


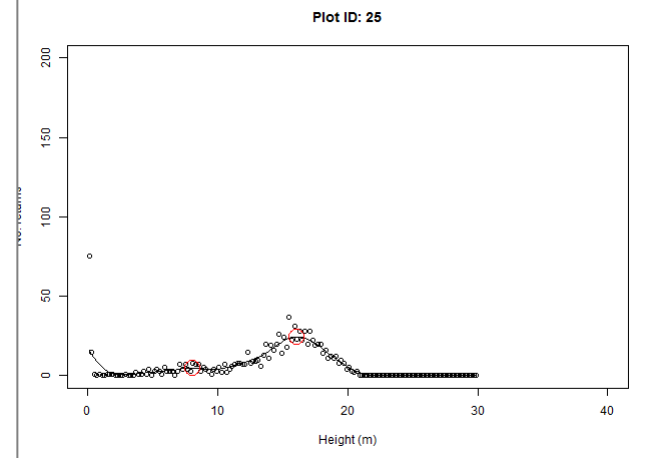
Whole tree removal + SPD





Whole tree removal + CD





MAPPING VERTICAL GAPS
-Height Scaled Canopy Openness Index (HSCOI)-

Developed by: Lee & Lucas (2007) for stem mapping in Queensland, Australlia.

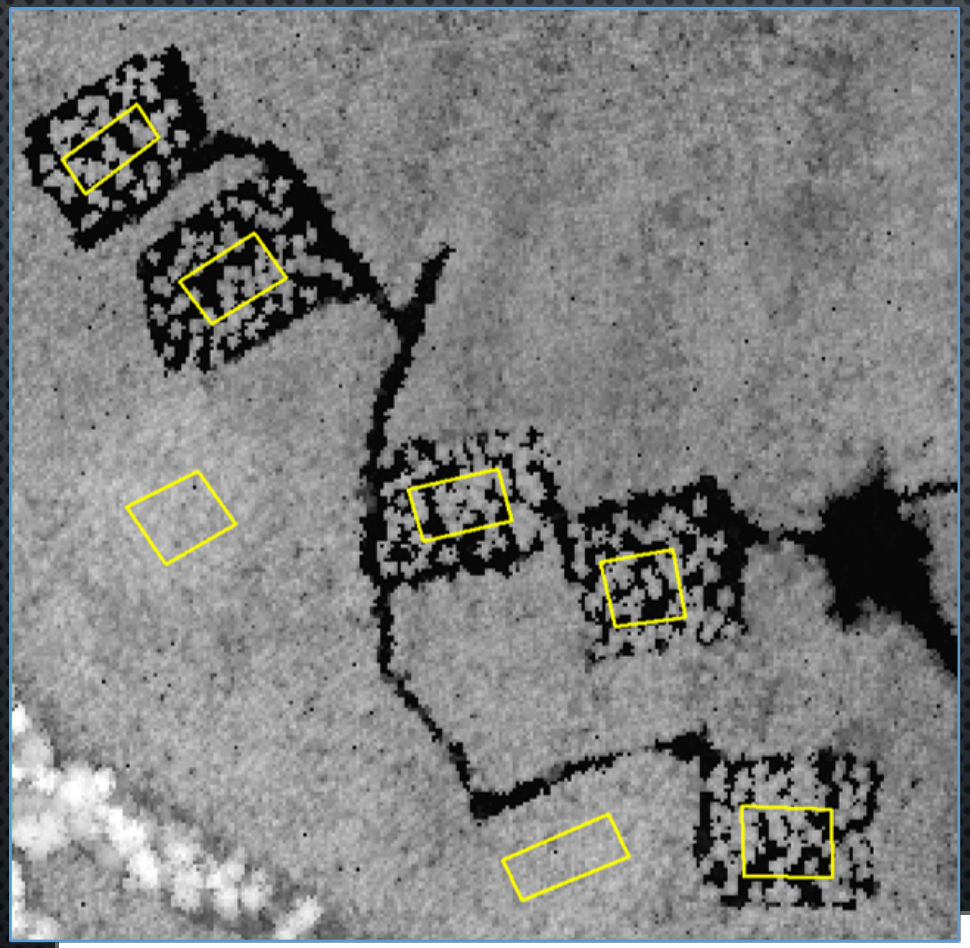
HSCOI calculation:

- Requires height bins/voxels to be computed (e.g. 1m x 1m x1m) – i.e. same as a vertical profile

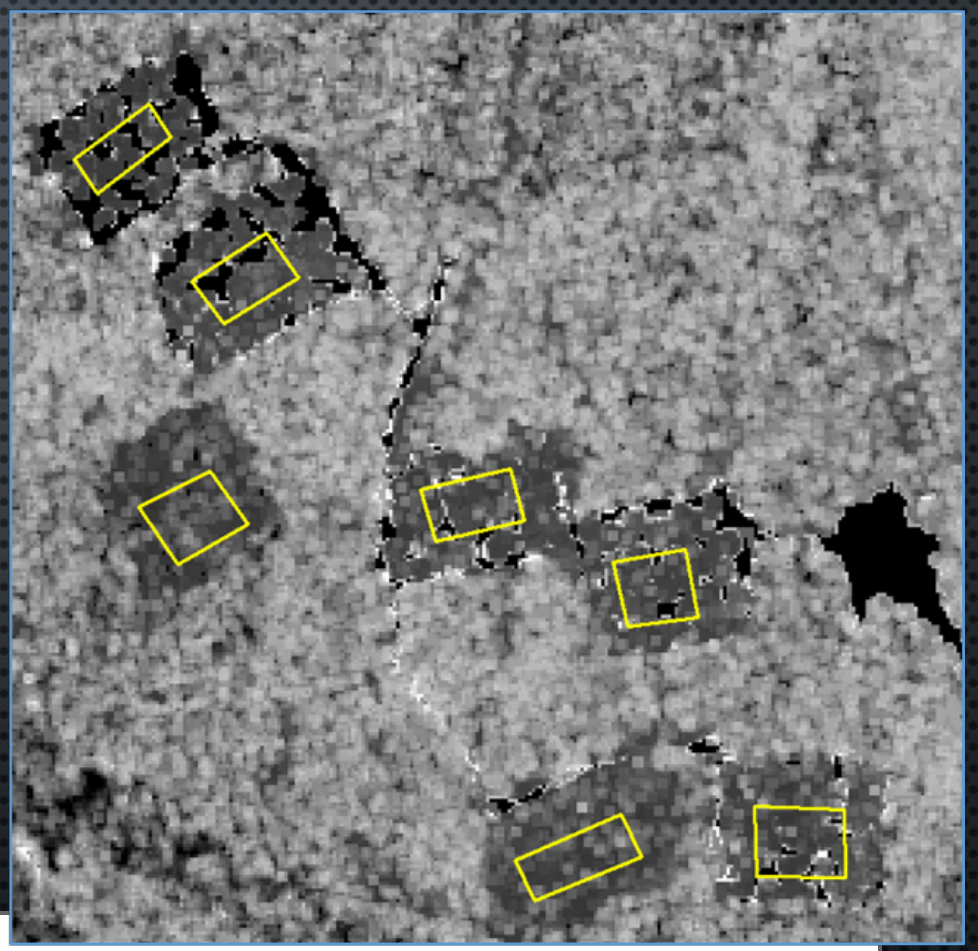
$$HSCOI_{local} = \sum_{n=1}^{n_{voxels}\ (i)>0} \left(\left(\frac{maxht_{local} - voxelht}{maxht_{local}} \right) * \frac{1}{n_{voxel}} \right) * 100$$

Produces a percentage likelihood for each 1x1m area of the laser pulse being intercepted before reaching to the ground.

RW18 example:



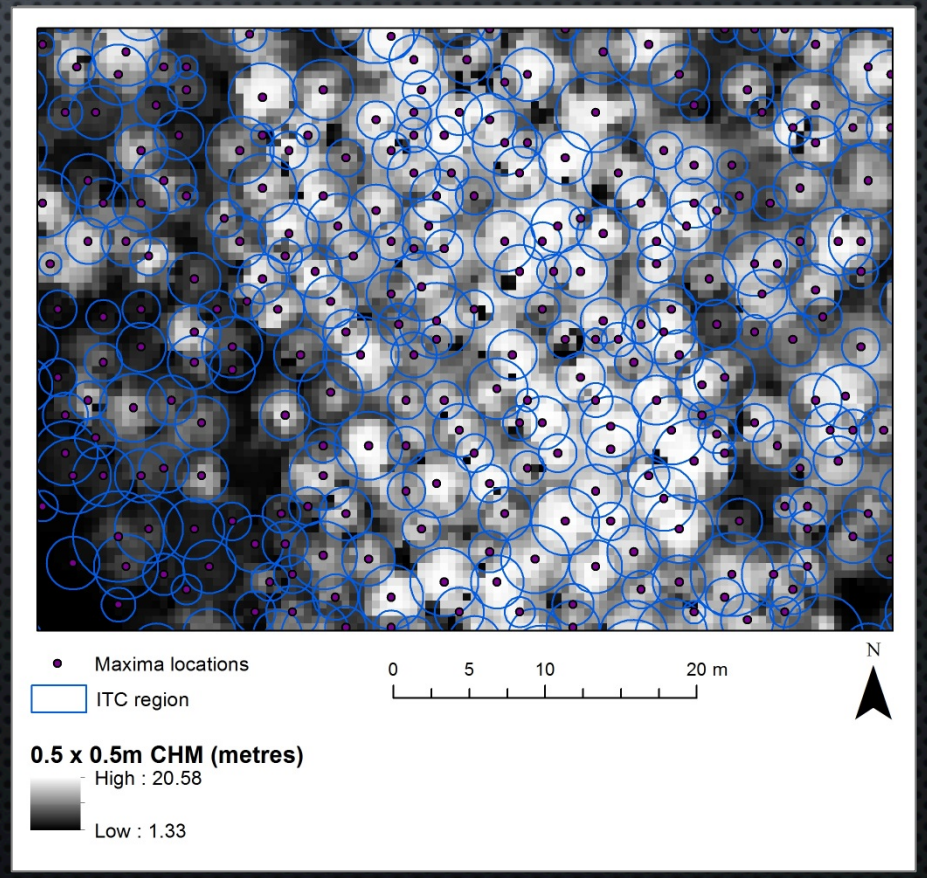
Canopy Height model



HSCOI

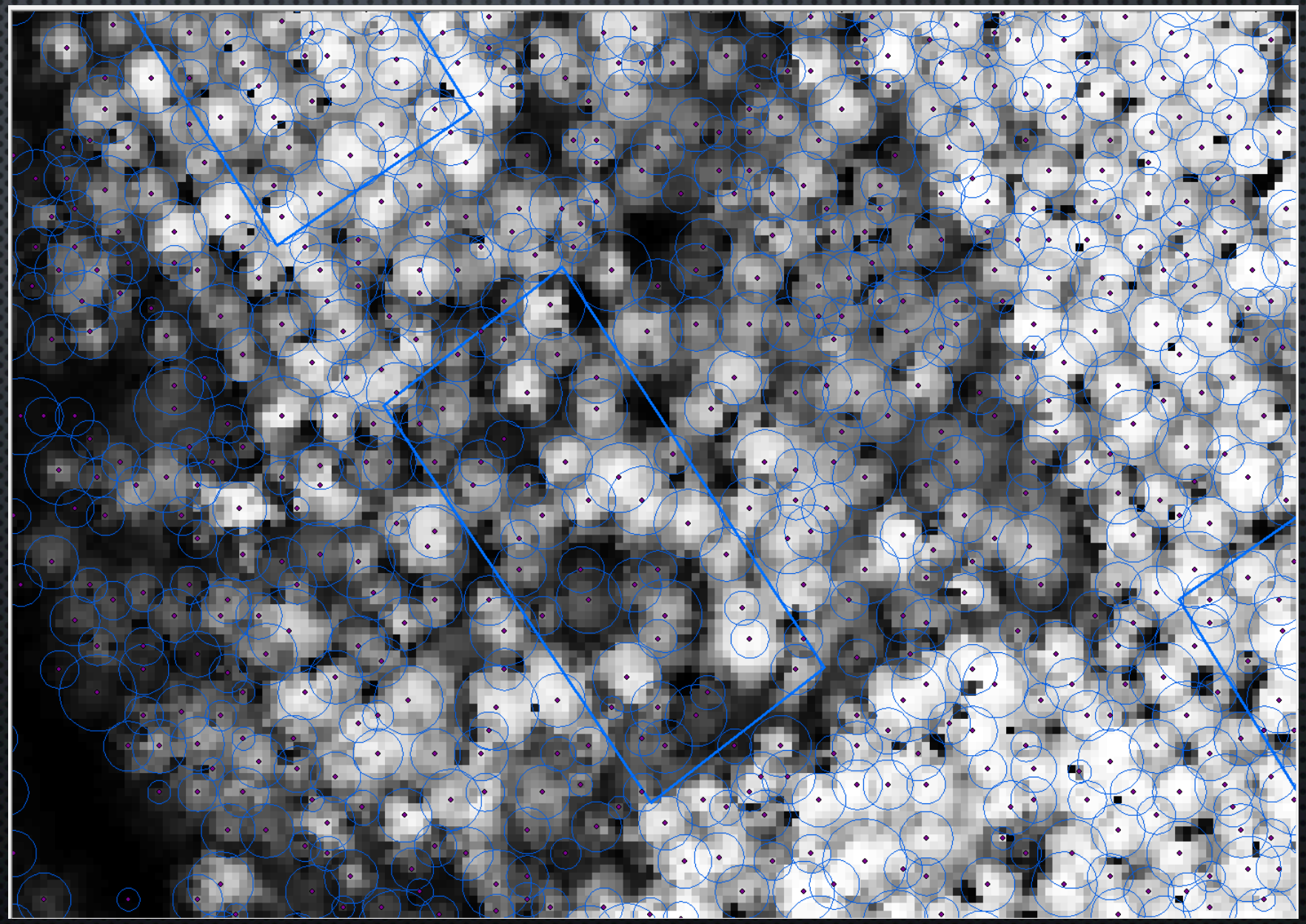
AUTOMATED INDIVIDUAL TREE CROWN DELINEATION

- Produced in R (www.r-project.org)
- Find maximum local heights in a CHM
  - Using a 1.5x1.5m search kernel to identify maxima
  - Create 'seed point'
- Iteratively grow regions around each point
  - Expanding 'object' into surrounding cells of lower elevation…
  - …until stopping criteria are met, e.g. 0m elevation reached.
- Estimate crown radius/area using extent of ITC object



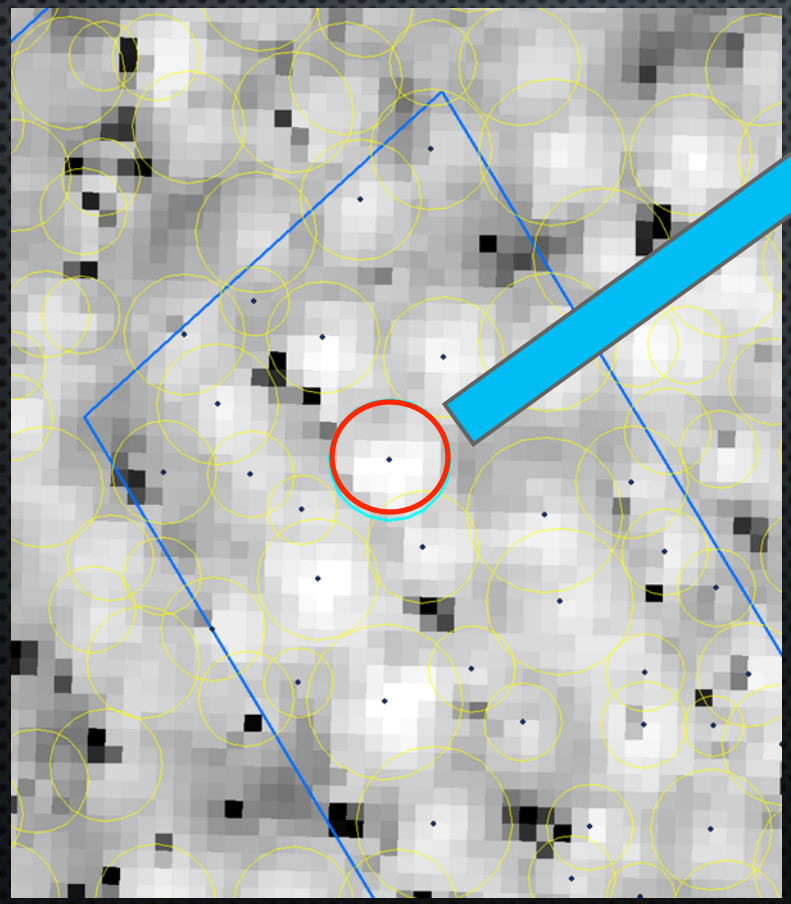
Henderson example:

Stem no. per plot
RMSE: 5-10

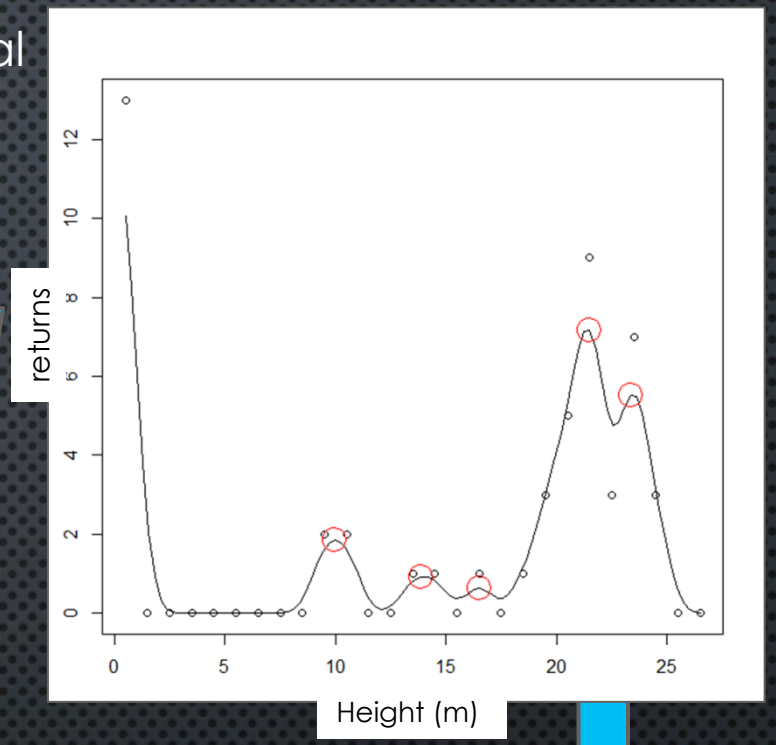


ITC VERTICAL PROFILES
-Work in progress-

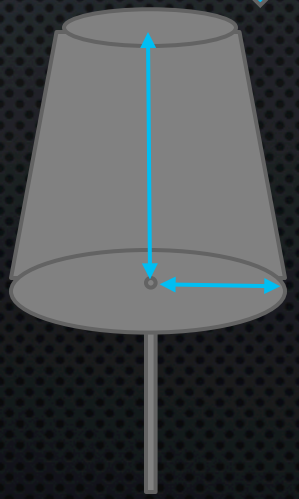
Extract height bins for ITC object



Produce vertical profile



Estimate crown volume



LEAF AREA INDEX (LAI) ESTIMATION

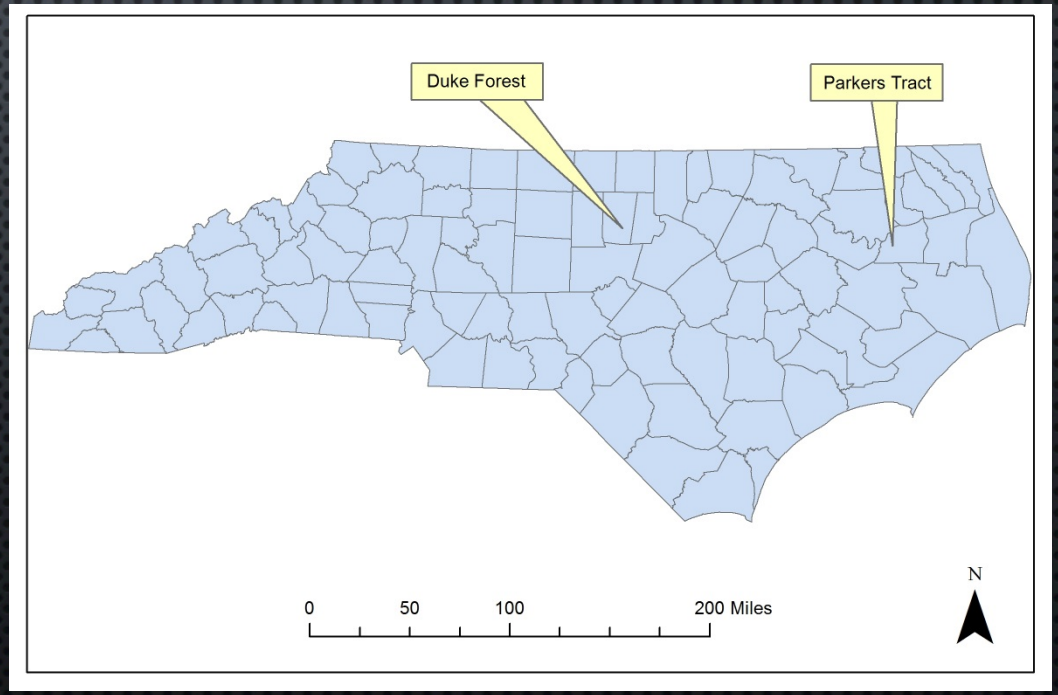
LAI is defined as the leaf area per unit of ground surface area – it ranges from 0 (bare ground) to over 10 (dense forests).

Study sites (October 2013):

- Parkers Tract (Washington - NC)
- Duke Forest (Orange - NC)

LiDAR provided by NASA G-LiHT (Riegl LD321-A40)

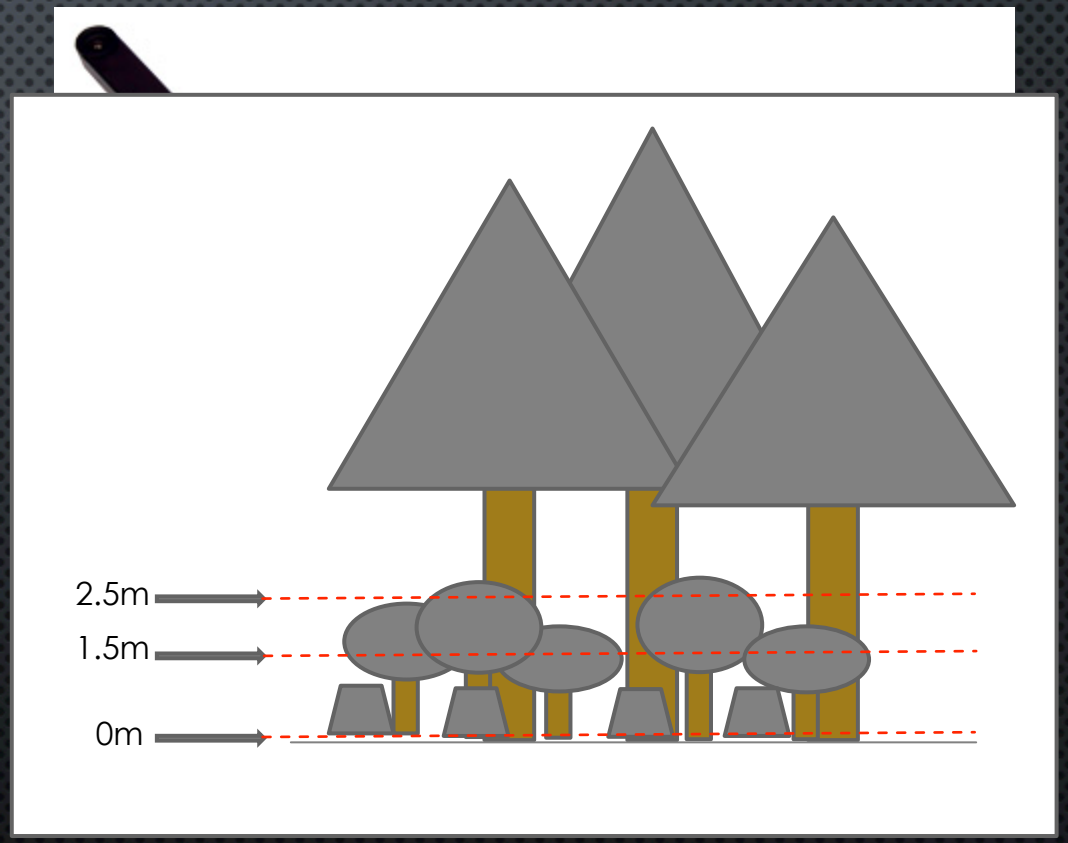
- 1-4 returns per pulse
- ~6 pulses per meters square



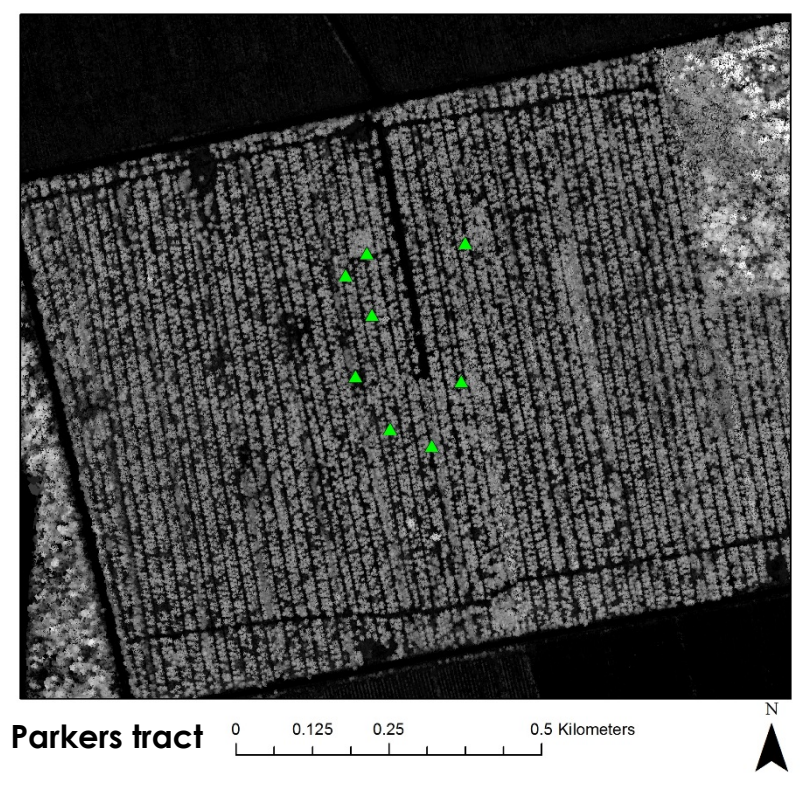
FIELD LAI MEASUREMENT

LAI indirectly sampled using Li-Cor LAI 2200

- under and above the forest canopy;
- at dawn and dusk;
- two 15m transects were conducted at each field plot location;
- horizontal measurements were taken every 1m;
- vertical measurements were taken at:
  - 0 m;
  - 1.5 m;
  - 2.5 m.

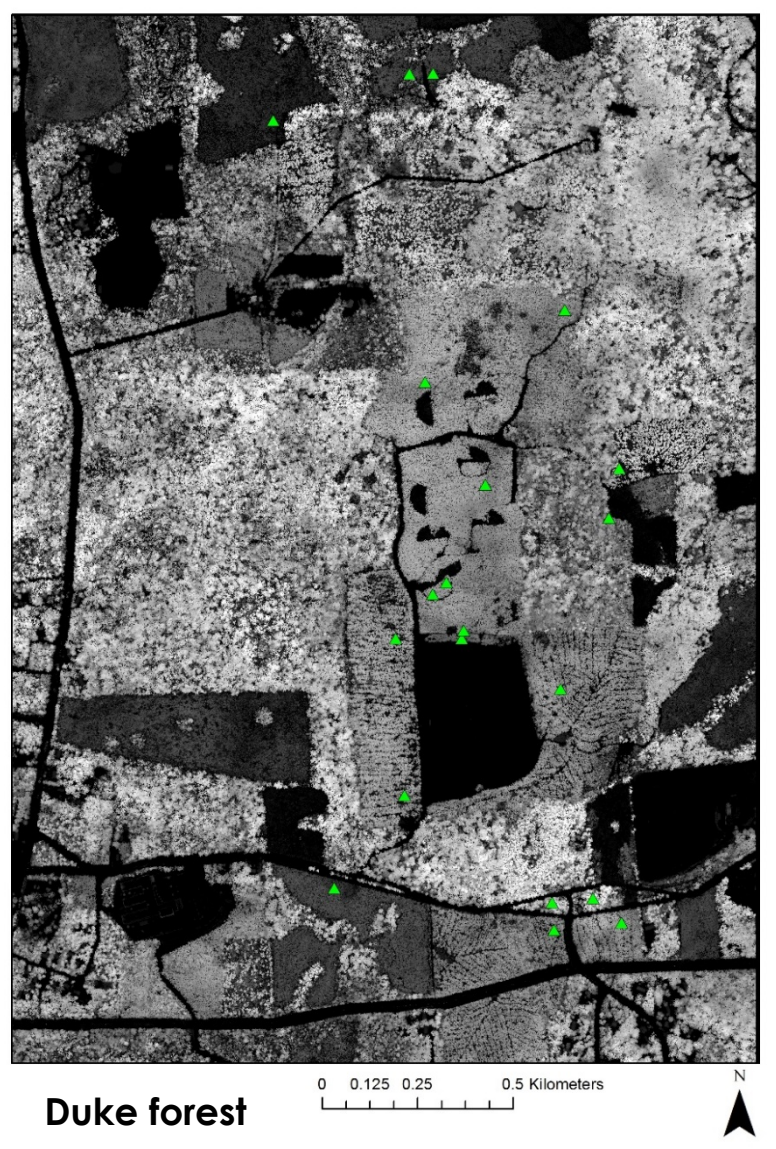


FIELD PLOT LOCATIONS



Parkers Tract – 8 sites:

- High levels of understorey;
- Similar overall structure between plots.



Duke Forest – 20 sites:

- Variety of stand ages;
- Variety of stem spatial arraignments;
- Varying levels of understorey.

LIDAR PROCESSING STEPS

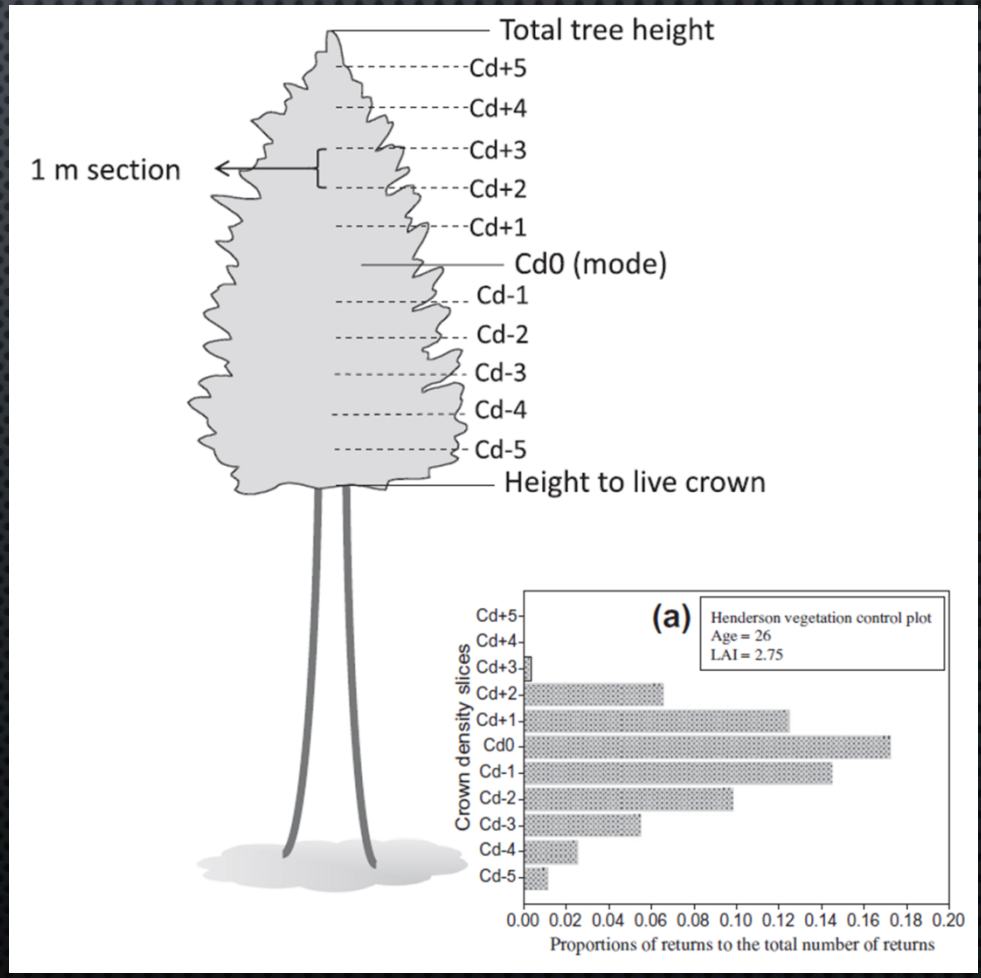
- Filtering, normalization and height bin generation steps completed as before, using LAStools;
- Metrics produced for 20x20m areas centered on plot locations;
- Creation of vertical profiles performed in R;
- ~130 metrics in total generated for input into regression analysis.

Metrics extracted:

- Proportion of returns vs. total(%), Max, min, mean, STD, variance, CV, skewness and kurtosis for :
  - ALL,
  - vegetation (>0.2m),
  - ground (<0.2m),
  - canopy and understorey layers (variable - stratified by layers).
- Percentiles (5^{th}…95^{th}) for All and Veg.
- Cumulative fractional cover (5^{th}…95^{th} percentiles)
- Canopy openness
- LiDAR penetration index (ALL, Canopy & Under.)
- Canopy density slices: +/-5m of canopy mode: mean, STD, variance and CV.

CANOPY DENSITY SLICES

- As outlined in: Peduzzi et al (2012);
- Modified to apply only to dominant canopy returns (as defined by detected layers);
- For each 1m slice, the mean, STD, Var. and CV are calculated.



REGRESSION ANALYSIS

- Stepwise multiple regression approach was implemented using 130 metrics;
- Models produced used inputs from **both** Duke Forest and Parkers Tract;
- Models were produced for:
  - LAI (0m);
  - LAI(1.5m);
  - LAI(2.5m);
- Models were significant ($p<0.05$)

Preliminary results:

y	Model R-squared	Metrics used
LAI (0 m)	0.70	$C3_{mean}$ + $Ground_{prop\%}$ + $Crown_{kurtosis}$
LAI (1.5 m)	0.71	$B2_{std}$ + $Crown_{prop\%}$ + $Ground_{prop\%}$
LAI (2.5 m)	0.76	$C3_{mean}$ + $Crown_{LPI}$ + $40^{th}_{fcov\%}$ + $Under_{CV}$

SUMMARY

- Examination of vertical profiles can estimate plot level height to the living crown to within 2m;
- The presence of understory can be inferred;
- Techniques such as the HSCOI can map understorey absence;
- ITC analysis can estimate stem number;
  - And potentially provide more individual tree metrics;
- LAI can be estimated statistically – where input metrics are linked to canopy layers.