Voxelised metrics for forest inventory

Grant Pearse – Phenotype Cluster Group Meeting – April 2018

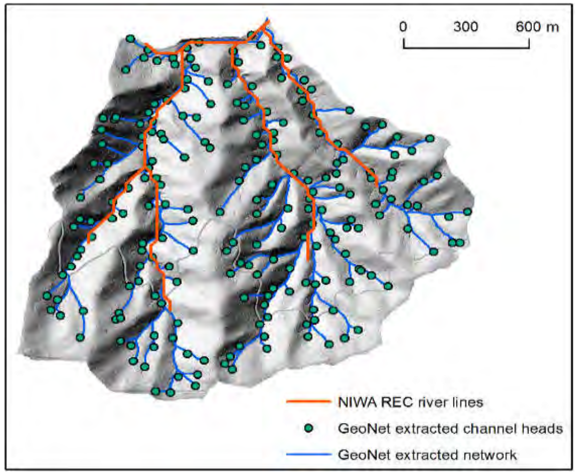
Overview

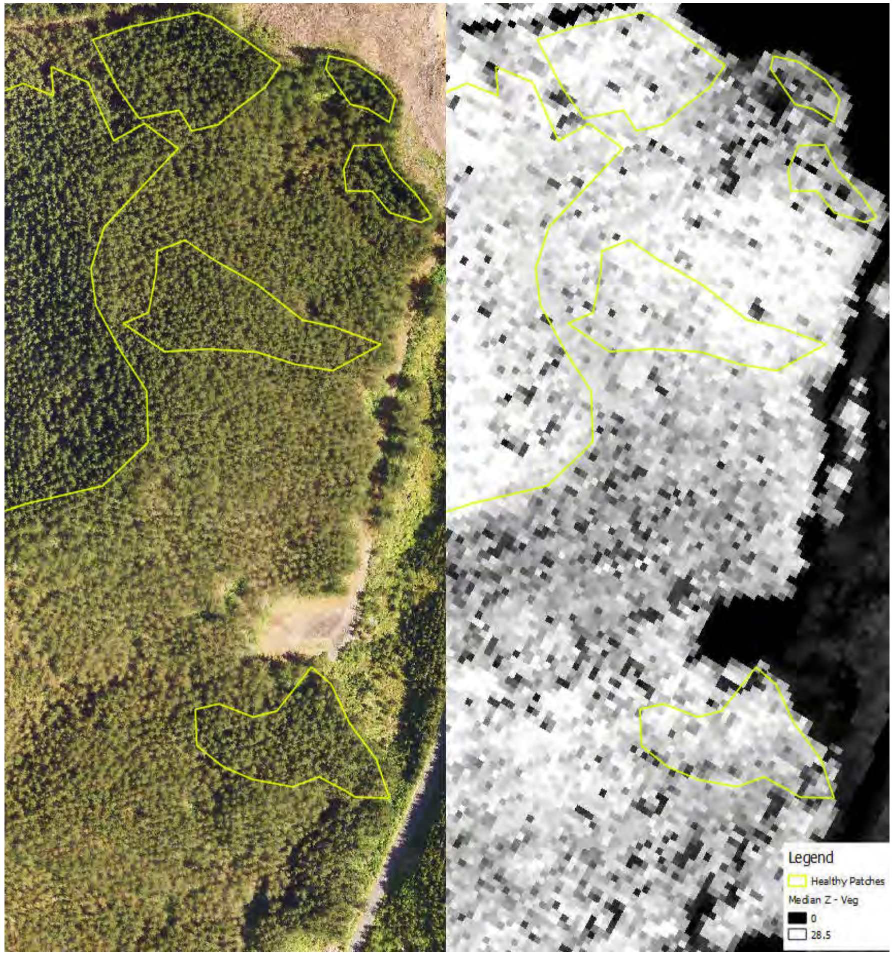
- Voxelisation for forest inventory
- Background on LiDAR metric analysis
- Voxelisation – what and why?
- Results from FWPA project: "Optimizing remotely acquired dense point cloud data for plantation inventory”
- Implementation of voxelised metrics
- Future work and caveats

Background: LiDAR in forestry

Terrain

- Roads
- Harvest planning
- Hydrology
- Disease mapping

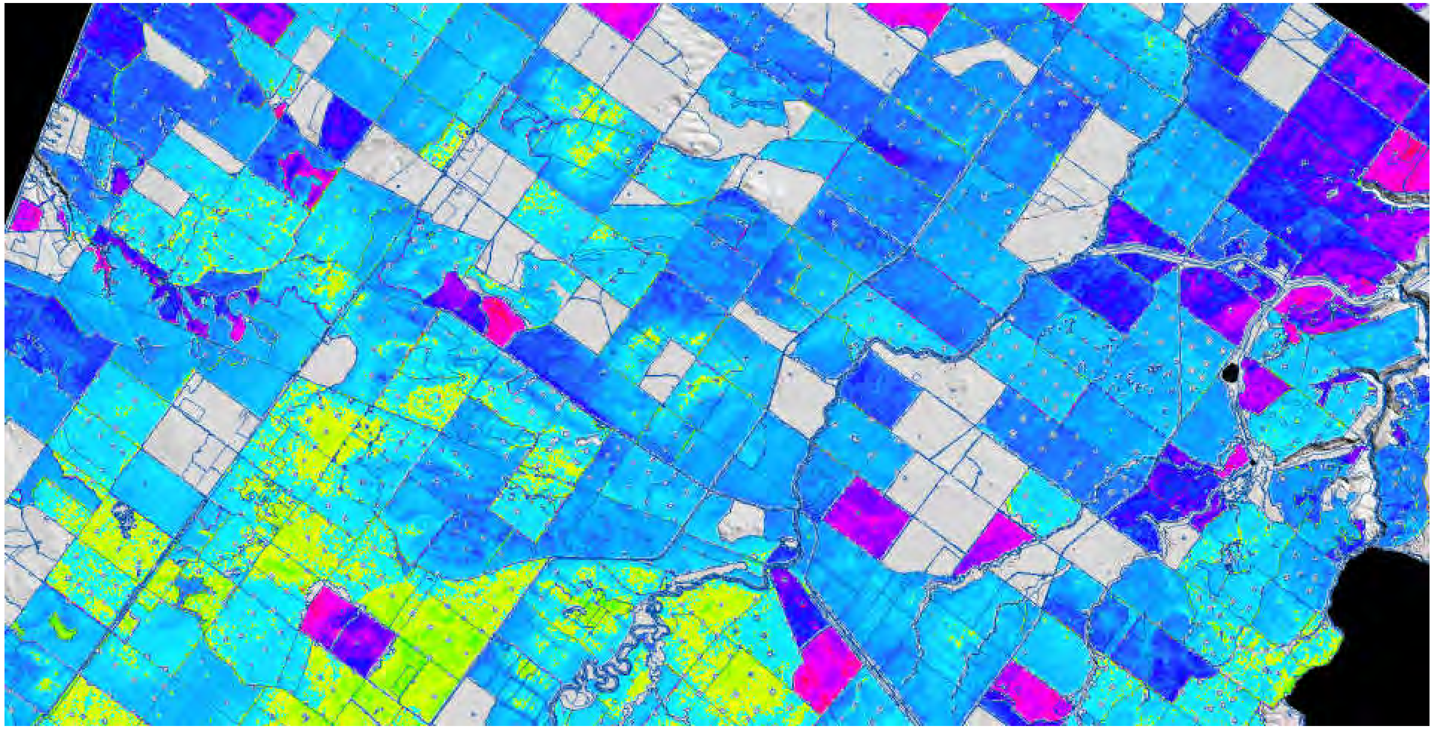




Background

LiDAR in forestry

- Design Inventory
- Collect LiDAR
- Model Relationships
- Apply to Large Areas



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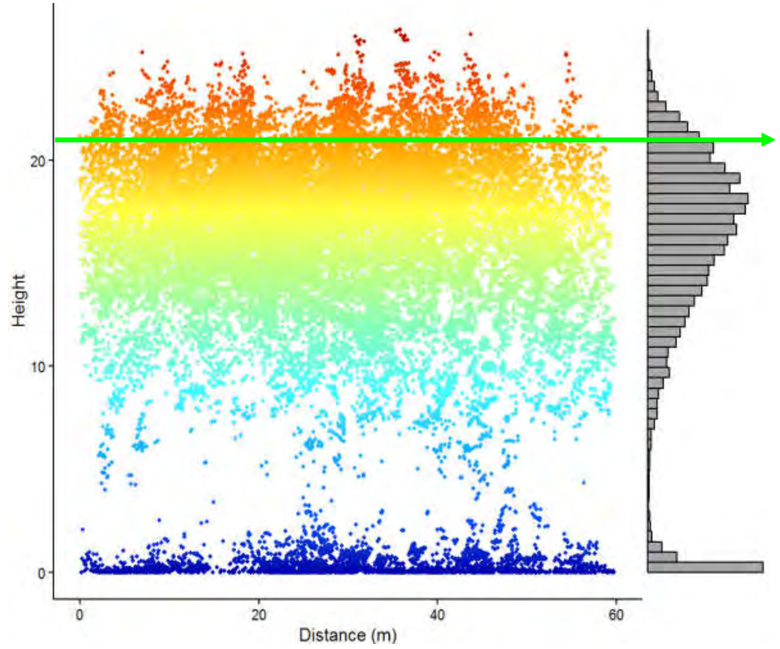
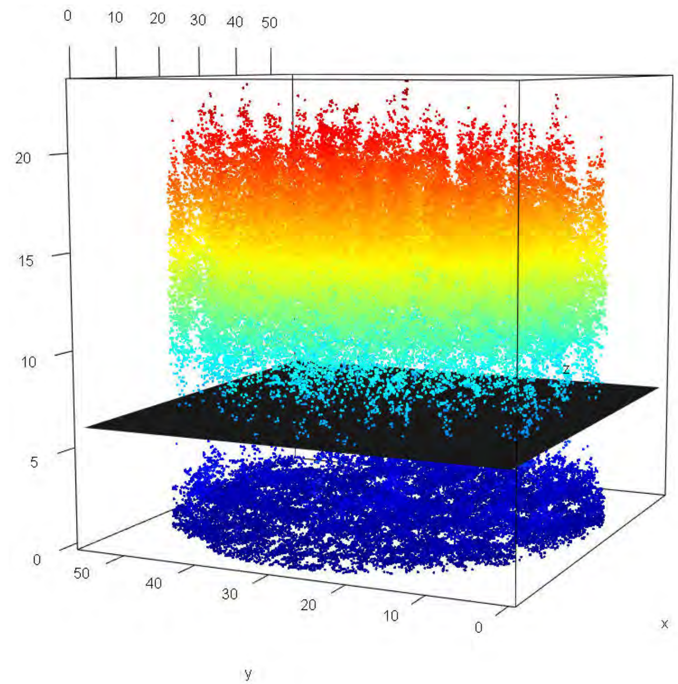
How do we characterise the point cloud?

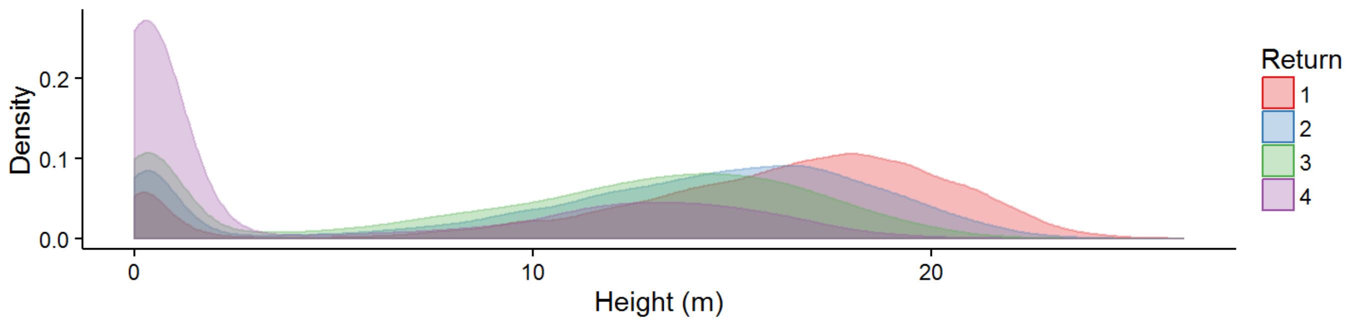
- First step in modelling
- Descriptive statistics
- Cover metrics
- Distributional metrics
- Voxelised metrics
  - TLS, high-density ALS



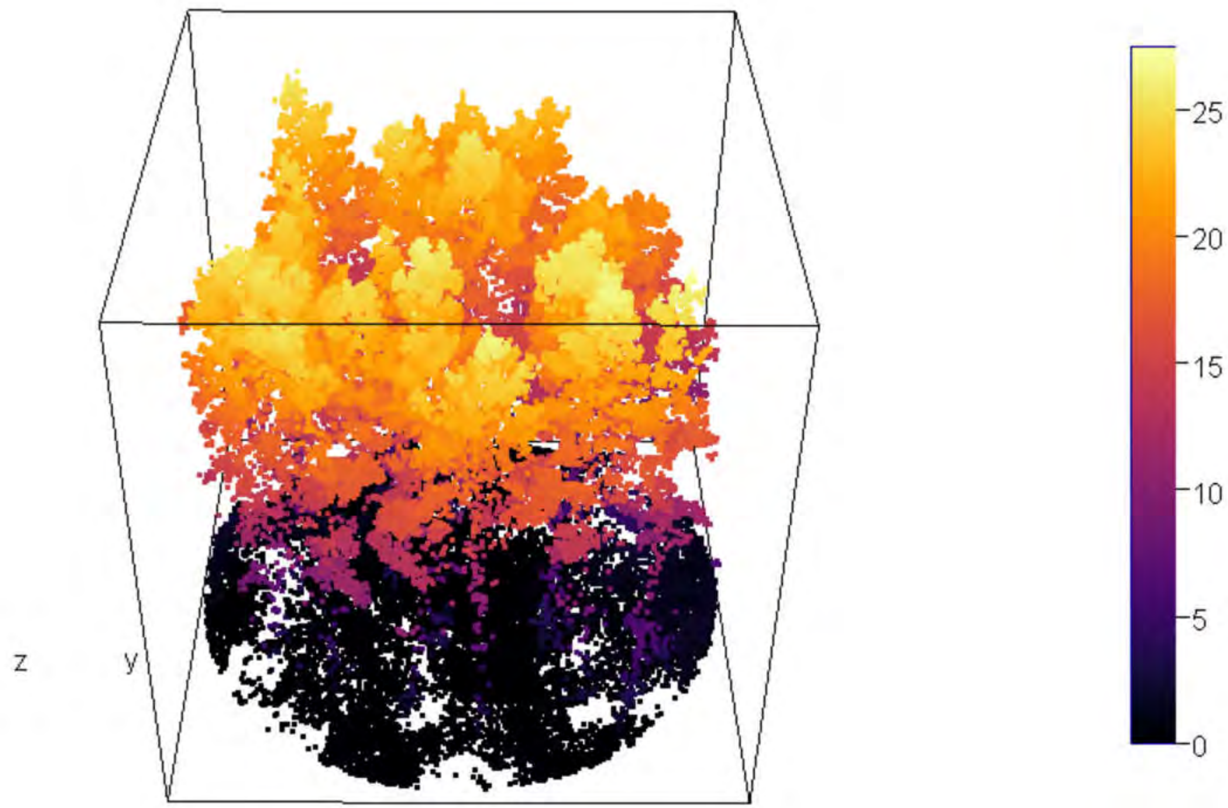
90th Height Percentile = 21 m



fCover = 0.81



Process of voxelisation



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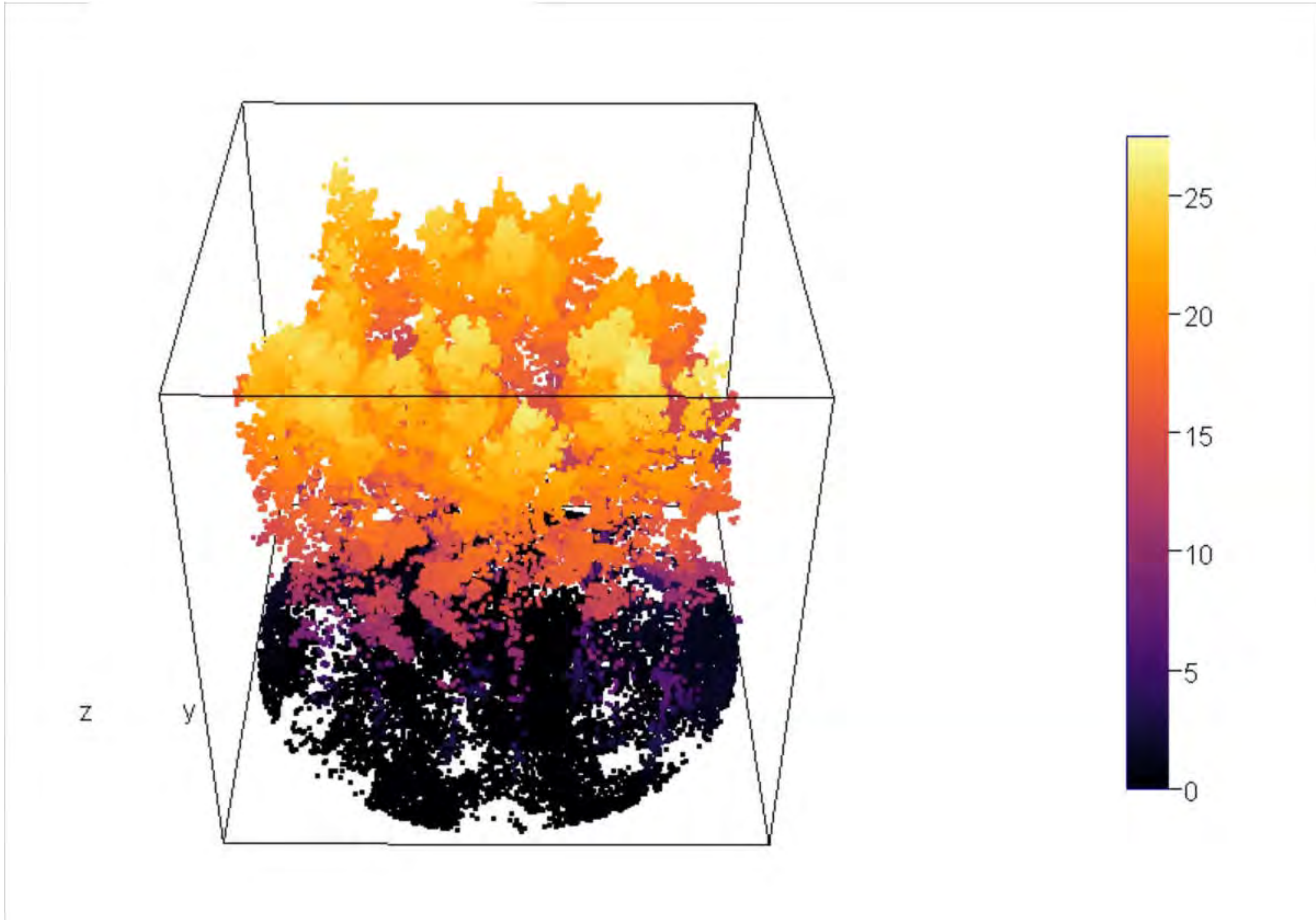
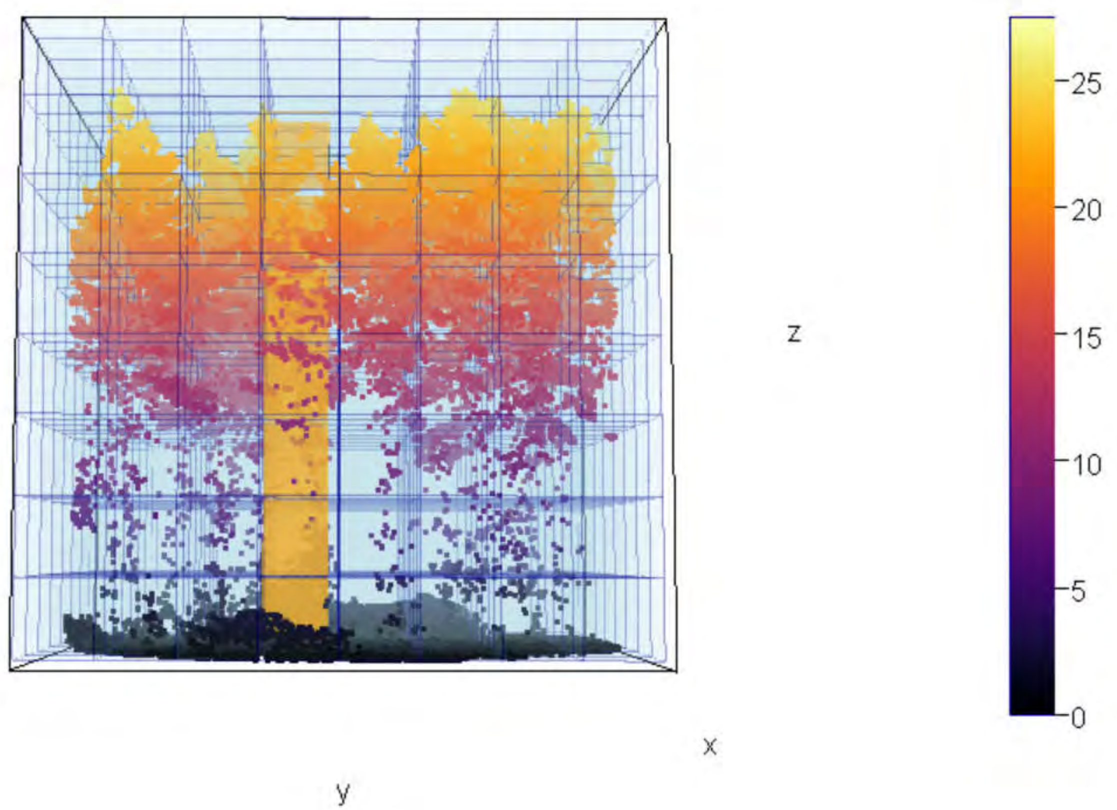
Process of voxelisation

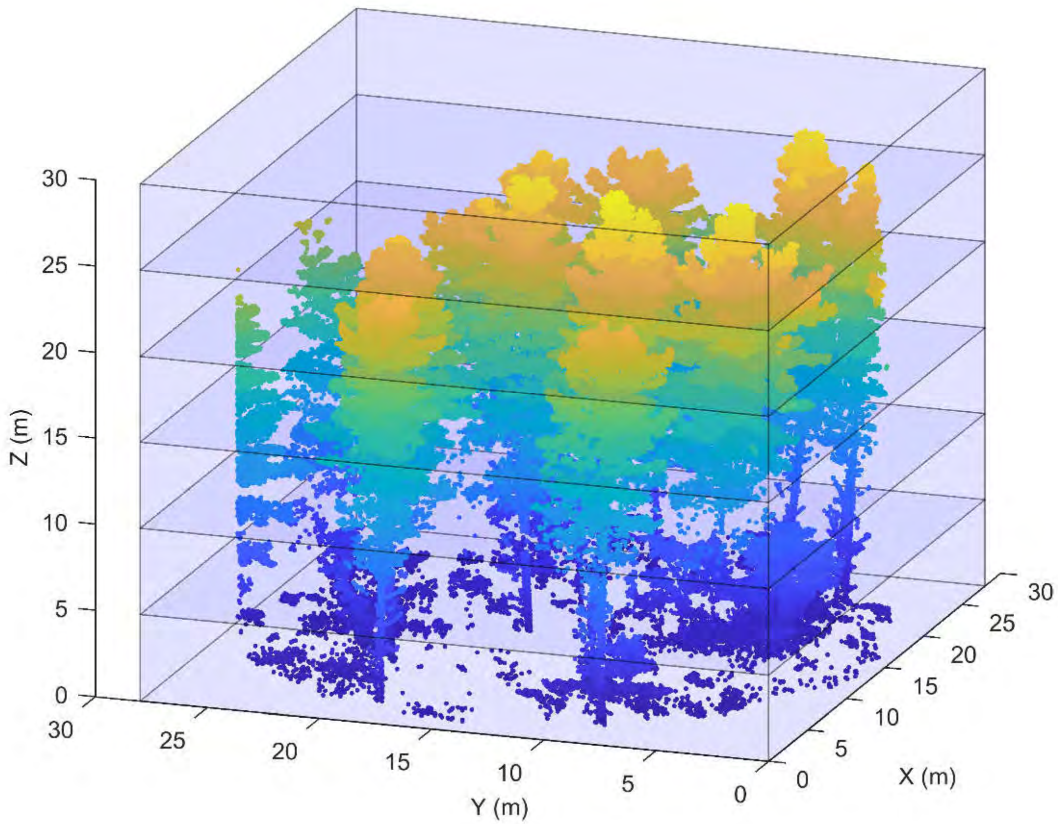


Process of voxelisation



Voxelisation strategies: univariate

- Number of dimensions
- Univariate voxelisation
  - Layers or strata
  - Vertical complexity index
- $VCI = \frac{-\sum_{i=1}^{HB}(p_i(\ln(p_i)))}{\ln(HB)}$



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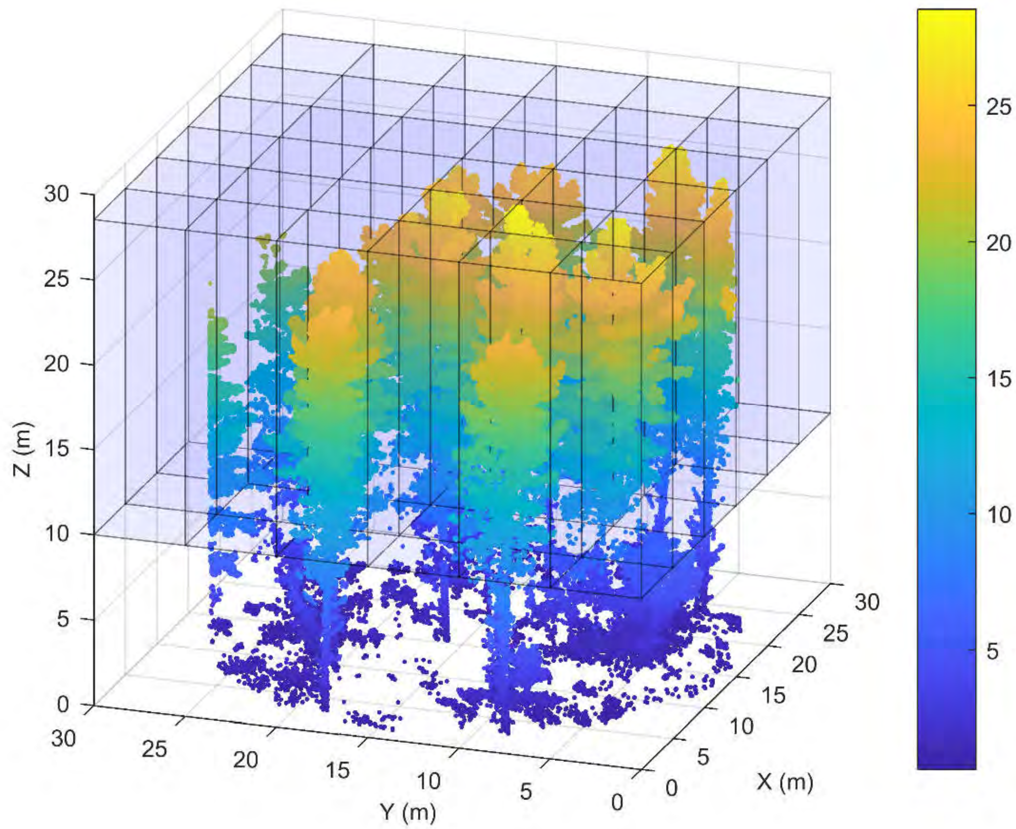
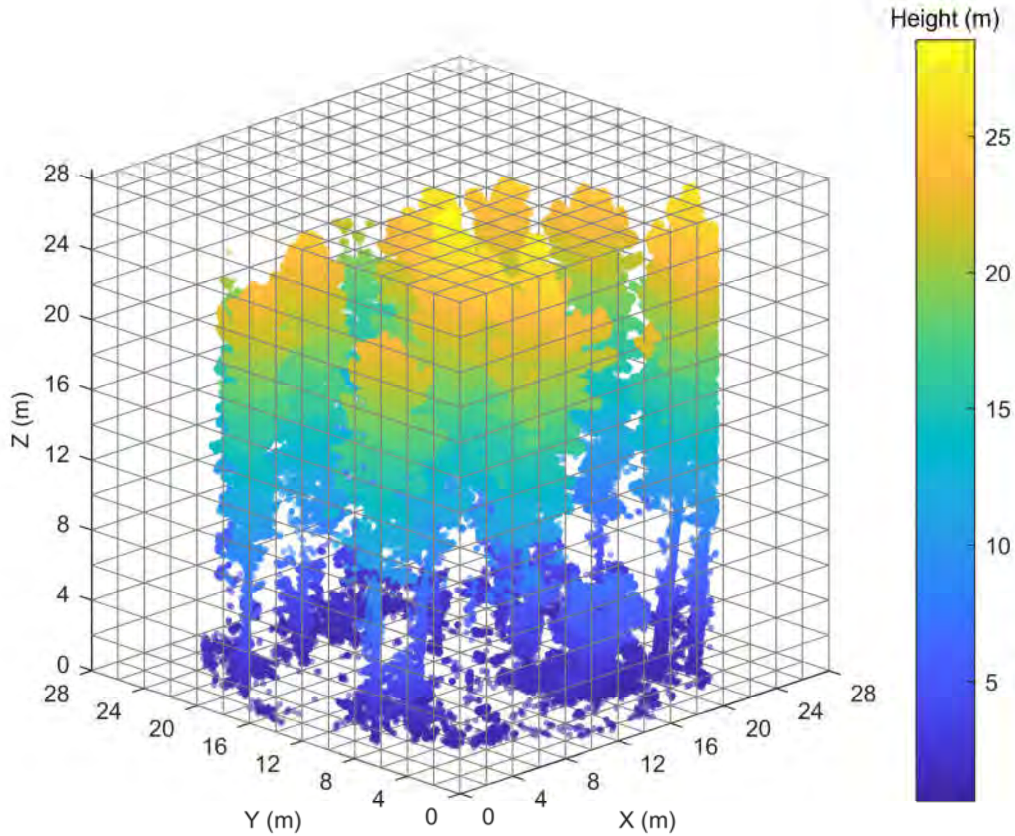
Voxelisation strategies: bivariate

- Sub-plot or sub-pixel metrics
- Divide main plot into grid
- Example:
- Pope and Treitz (2012)
  - Sub-plot canopy closure
  - How many empty columns at 5m 10m, 15m?



Voxelisation strategies: 3-dimensional

- Division along all 3 axes
- Divide into 3-D cells
- Relative frequency



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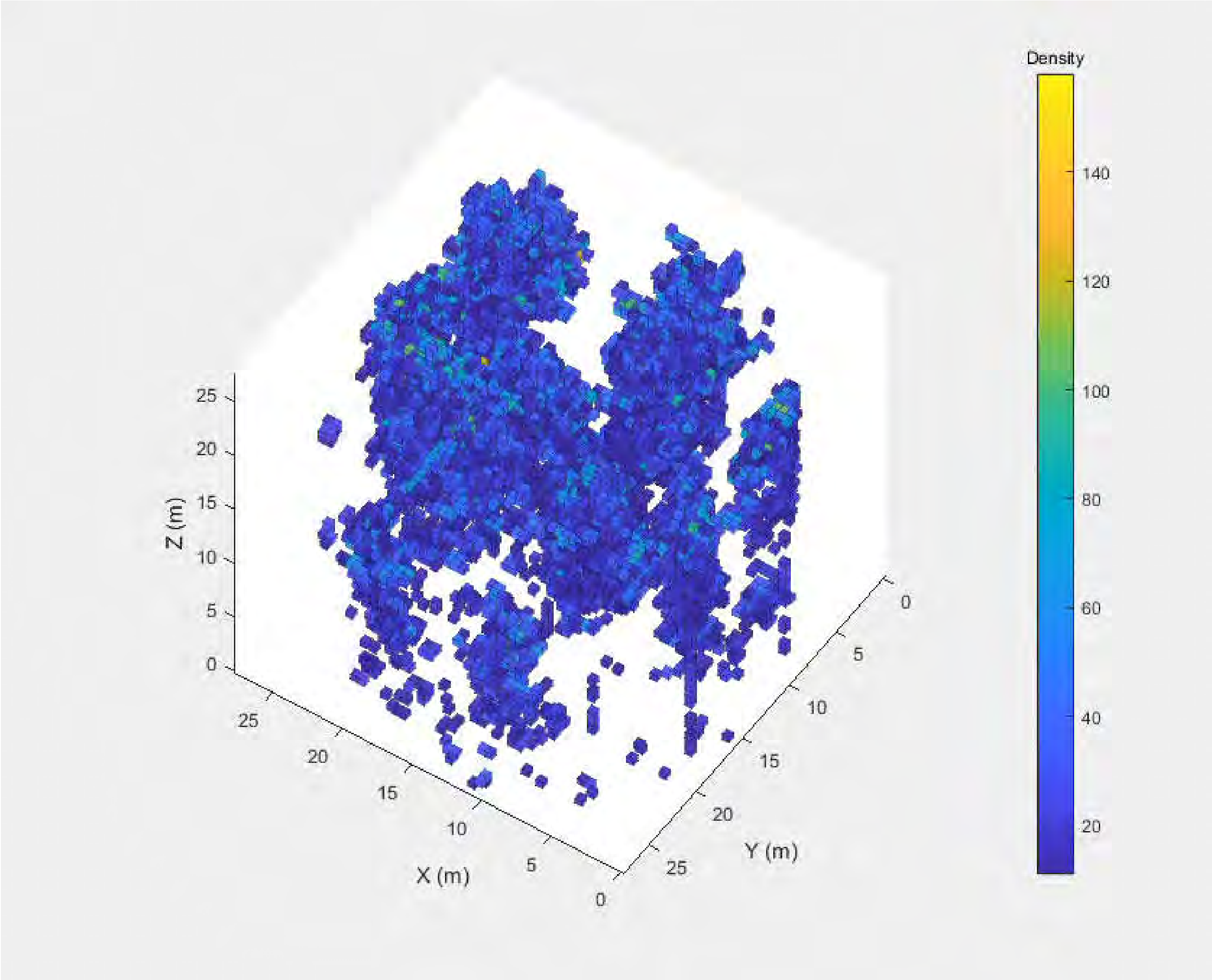
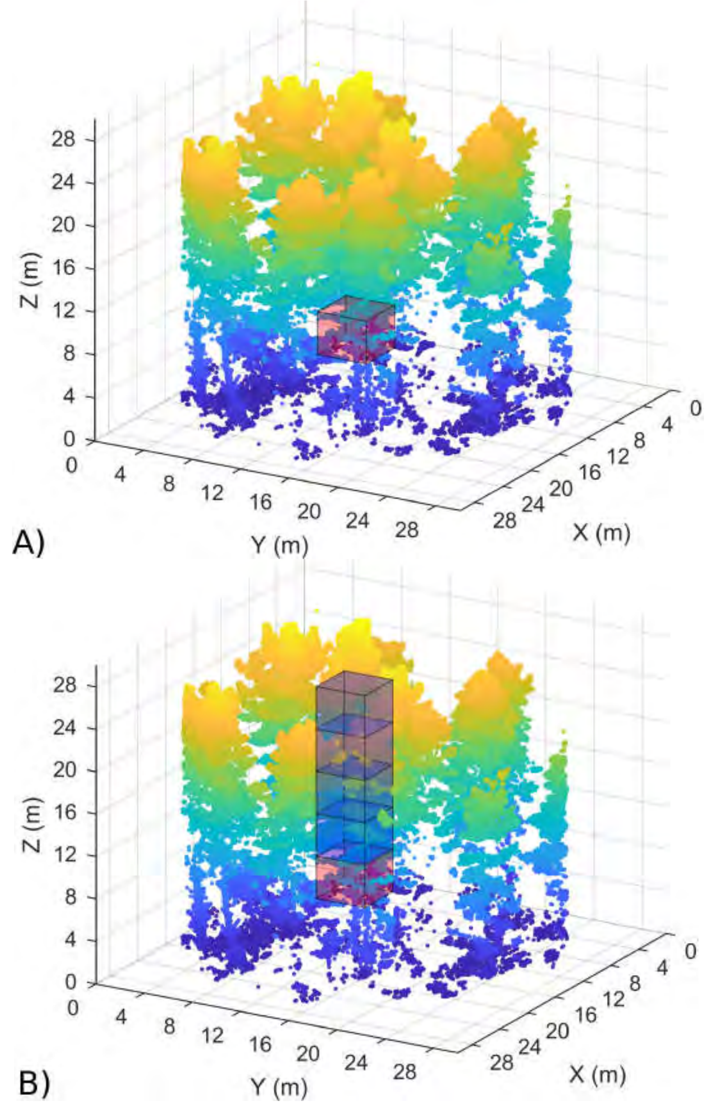
Voxelisation: 3-d histogram



Voxelisation strategies: Dynamic

- Dynamic processes determine voxels or metrics
- Location of voxel with max density (A)
- Iterative search for sequence of empty voxels (B)
- Empty voxel count

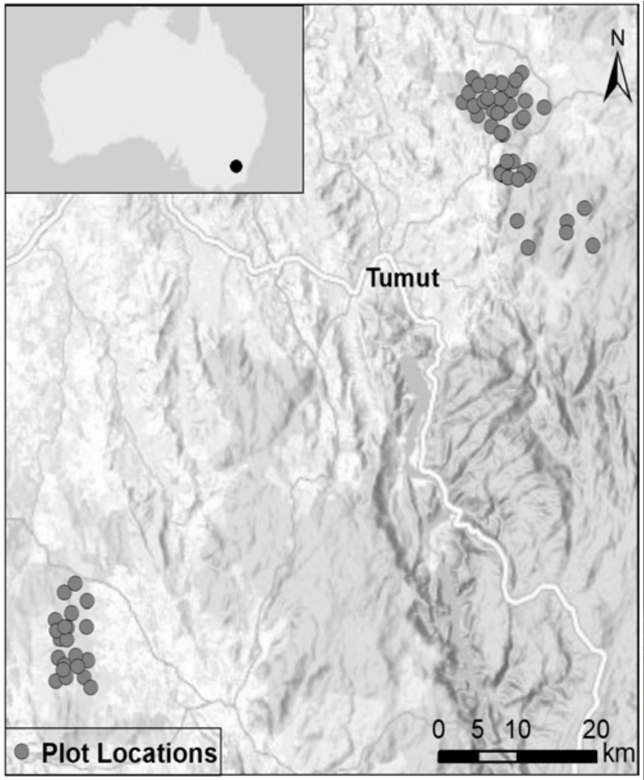


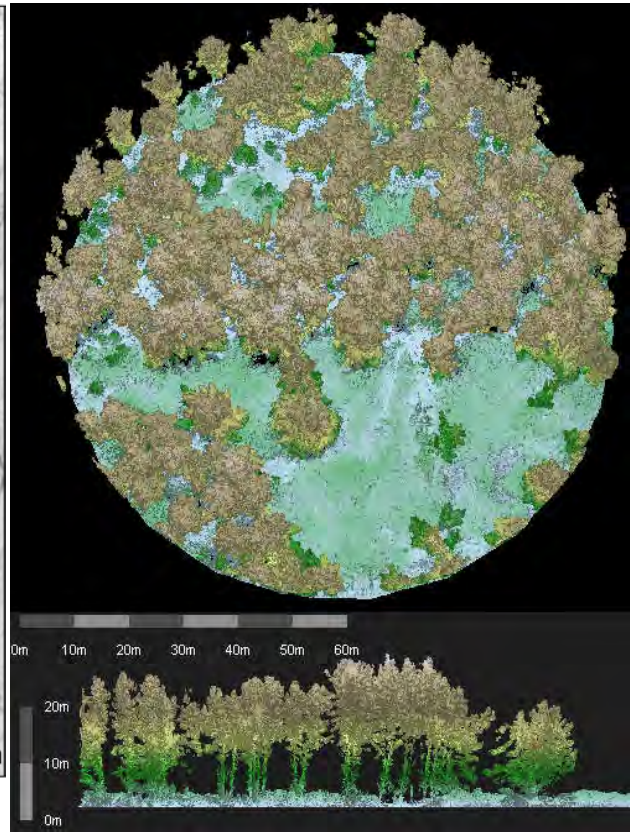
Application of voxelised metrics

- Widely used in TLS
- Now in use with ALS: higher density
- Improve information content of metrics
- Applications include:
  - Crown properties (Popescu & Zhao, 2008)
  - Succession and species composition (Van Ewijk, 2015)
  - Canopy base height (Maguya et al., 2015)
  - Above ground biomass (Kim et al., 2016)
- Forest inventory?

Voxelised metrics for forest inventory

- FWPA funded project
- 73 *P. radiata* plots – Tumut, NSW
- Riegl VUX-1UAV (helicopter)
- 280 pulses m^{-2}





Tumut study: methods

- Primary objective: Benefit of voxelised metrics
- Secondary objective: Impact of pulse density
  - Thinned from: 280, 260, 240, 220, …20, 15, 10, 5, and 1 pulse m^{-2}
- Metrics
  - Voxelised – literature review, Standard, Combined
- Random forests with cross-validation
  - Stand density
  - Volume
  - Top Height
  - Basal Area

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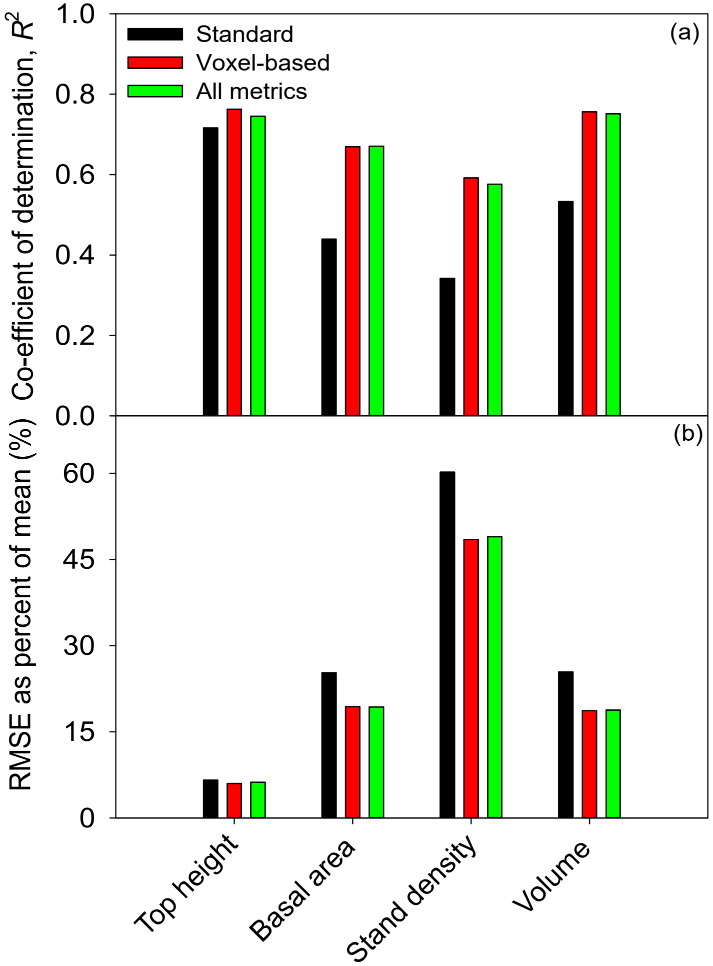
Tumut study: results



R^2 Results	Standard	Voxel-based
Top height	0.71	0.76
Basal area	0.44	0.67
Stand density	0.34	0.58
Volume	0.53	0.75
nRMSE Results	**Standard**	**Voxel-based**
Top height	6.6%	6.1%
Basal area	25.2%	19.6%
Stand density	60.1%	48.6%
Volume	25.5%	18.7%

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Tumut study: metric importance

- Voxel-based vs. standard metrics?
- Ranked importance – top metrics:
  - Top height: 73% voxel-based
  - Basal area: 97% voxel-based
  - Stand density: 94% voxel-based
  - Volume: 98% voxel-based
- Similar pattern across pulse densities
  - Majority of top metrics were voxel-based

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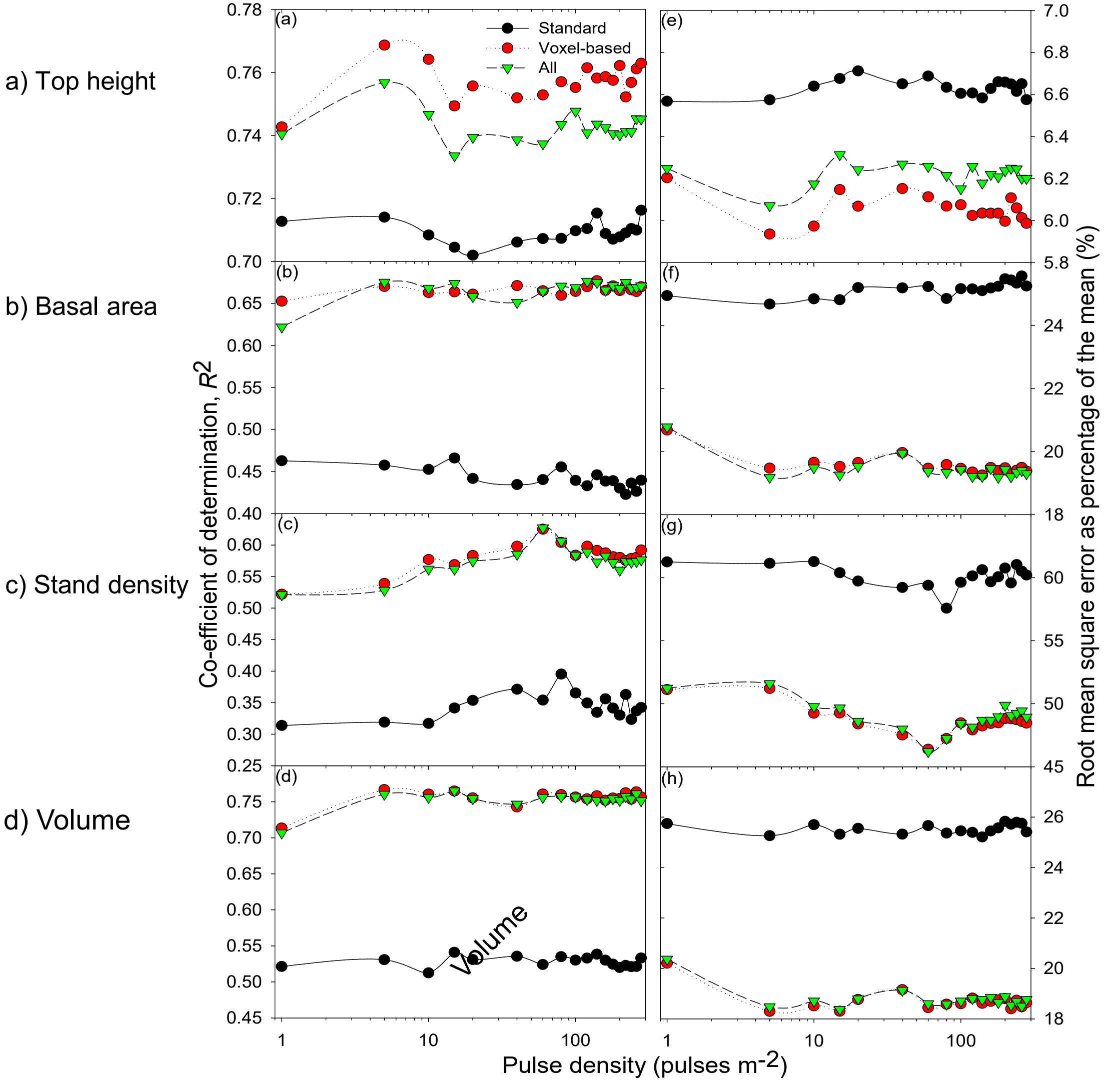
Tumut study: pulse density



- Thinned data and repeated modelling
- Pulse density had limited impact on results down to 1 pulse m^{-2}
- Lowest precision at 1 pulse m^{-2}
- Trends remained the same: voxel-based and combined outperformed standard

Tumut study: conclusions

- Clear benefit from voxel-based metrics for forest inventory
- Substantial gains in prediction accuracy for most attributes
- Relatively insensitive to pulse density
  - Useful at current ALS densities
- Model prediction was low cf. literature
  - Combination of variable stands, limited sample size, and conservative modelling approach

Voxel-based metrics: final comments

- Low impact of pulse density – further work
- Voxel-based metrics are a stand in for tree level analysis
- Validation on secondary data

How to implement?

- Lasvoxel: LASTools
  - Fast, sparse voxelisation
  - Comparable results
  - Integrates into other LAStools

Acknowledgements

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- Christine Stone and Gabriele Caccamo – NSW DPI

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FORESTS ▪ PRODUCTS ▪ INNOVATION

Prosperity from trees *Mai i te ngahere oranga*

References

- Pope, G., & Treitz, P. (2013). Leaf Area Index (LAI) Estimation in Boreal Mixedwood Forest of Ontario, Canada Using Light Detection and Ranging (LiDAR) and WorldView-2 Imagery. *Remote Sensing, 5*(10), 5040.

- Popescu, S. C., & Zhao, K. (2008). A voxel-based lidar method for estimating crown base height for deciduous and pine trees. *Remote sensing of environment, 112*(3), 767-781.

- Van Ewijk, K. (2015). *Estimating Forest Structure from LiDAR and High Spatial Resolution Imagery for the Prediction of Succession and Species Composition.* Queen's University, Google Scholar database.

- Maguya, A. S., Tegel, K., Junttila, V., Kauranne, T., Korhonen, M., Burns, J., . . . Sanz, B. (2015). Moving Voxel Method for Estimating Canopy Base Height from Airborne Laser Scanner Data. *Remote Sensing, 7*(7), 8950-8972.

- Kim, E., Lee, W.-K., Yoon, M., Lee, J.-Y., Son, Y., & Abu Salim, K. (2016). Estimation of Voxel-Based Above-Ground Biomass Using Airborne LiDAR Data in an Intact Tropical Rain Forest, Brunei. *Forests, 7*(11), 259.