ABOUT MYSELF

Ning Ye

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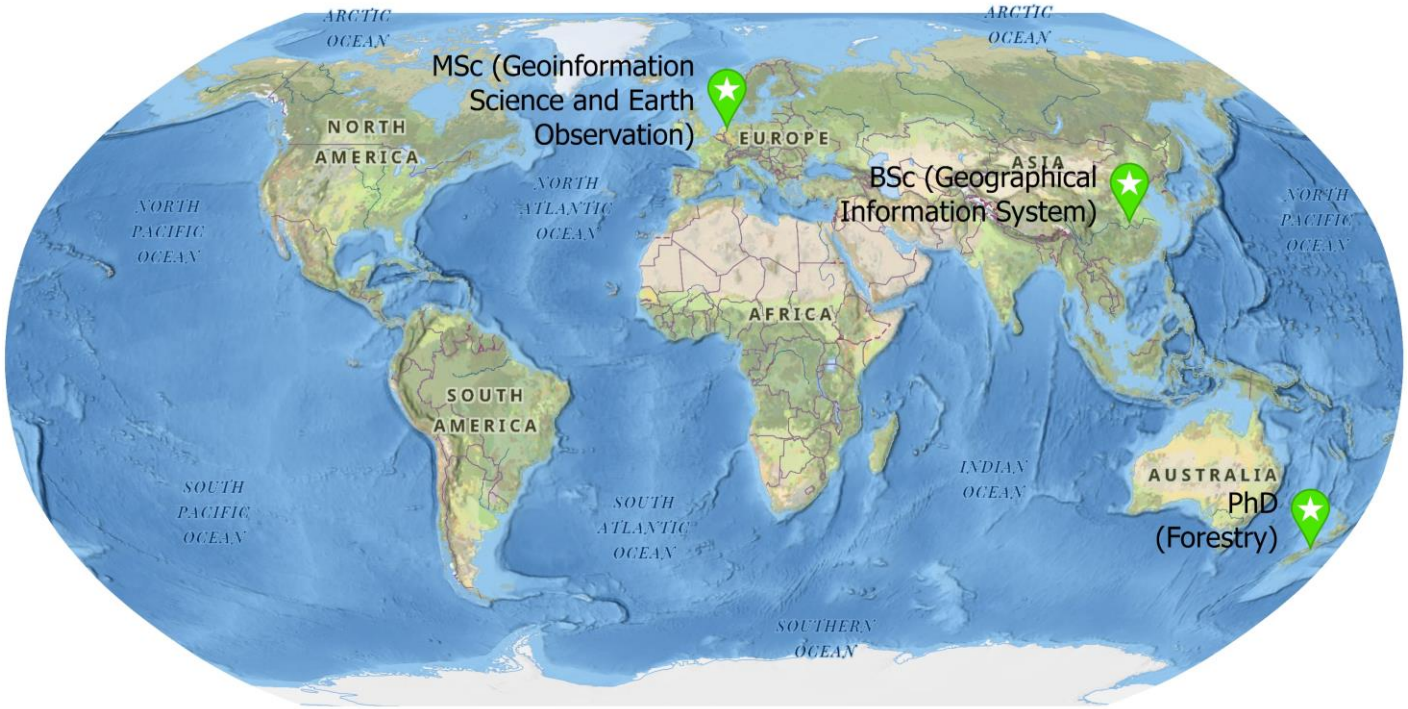

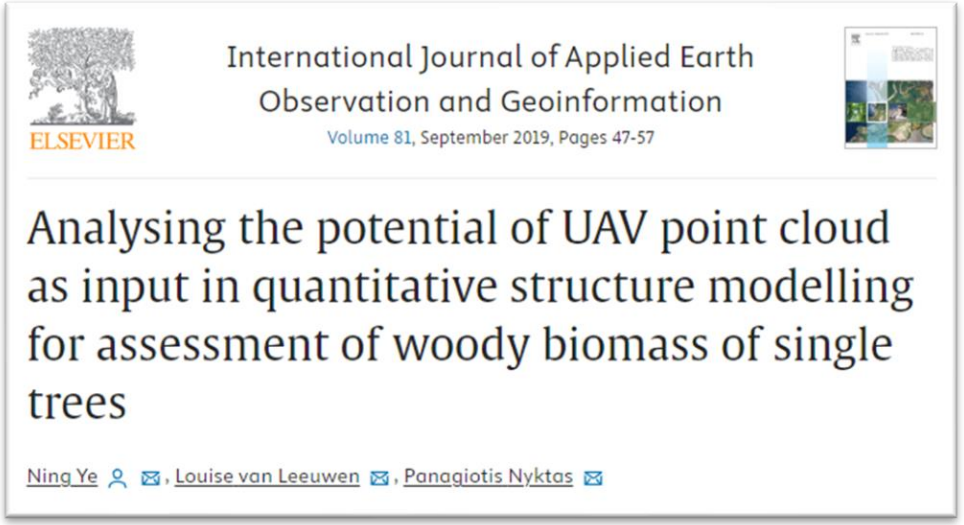

Role in this project:

Drone pilot, data analyst, report writer, mapper

MARLBOROUGH RESEARCH CENTRE
Te Rito Hiranga o Wairau

Funded by Agriculture & Investment Services
Ministry for Primary Industries
Manatū Ahu Matua

SLMACC PROJECT 406896

INDIVIDUAL TREE BIOMASS ESTIMATION OF DURABLE EUCALYPTUS USING UAV LIDAR

NZDFI SCIENCE TEAM SEMINAR
University of Canterbury

Tuesday 12th December 2023

Ning Ye, Euan Mason and Cong (Vega) Xu

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
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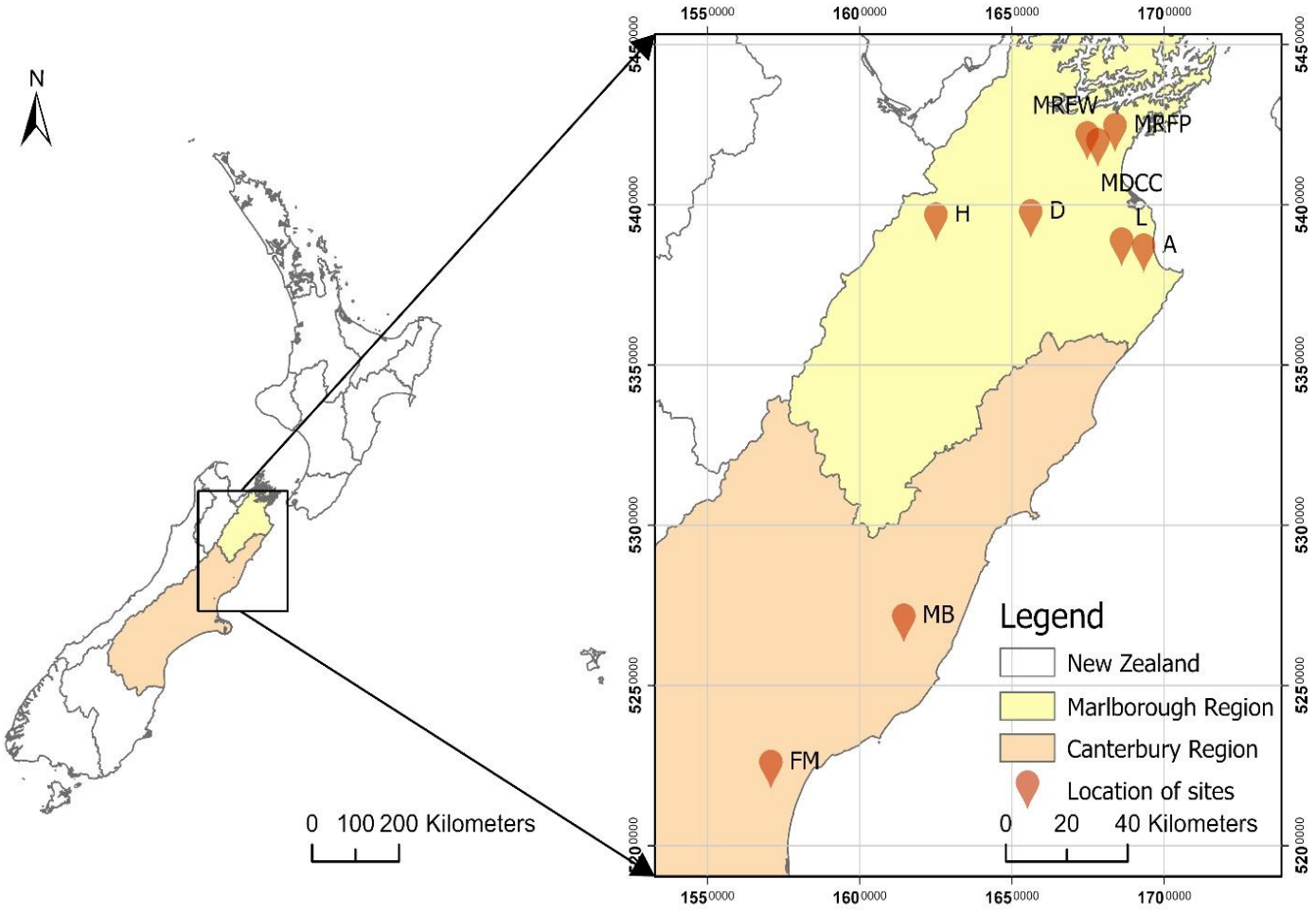
Objectives

- Estimate individual tree biomass from UAV-LiDAR metrics (*E. bosistoana* and *E. globoidea*)
- Compare different machines learning models with statistical model
- Evaluate which UAV-LiDAR metrics are useful for estimating of biomass

Study area and drone survey



UAV LiDAR collection details

Flight date (Day/Month/Year)	Flight ID	Flight plan			LiDAR data information		
		Flight height (m)	Side overlap (%)	Front overlap (%)	All returns' density (pts/m²)	All returns' point spacing (m)	LiDAR cover area (ha)
10/11/2022	FM_1	60	60	70	753.05	0.04	14.38
	FM_2	60	60	70	740.04	0.04	8.62
	FM_3	60	60	70	1083.19	0.03	17.48
25/11/2022	MRFP_1	100	75	80	824.49	0.03	13.03
	MRFP_2	60	60	70	903.13	0.03	5.46
02/12/2022	MB_1	120	80	90	736.85	0.04	11.73
04/01/2023	MRFW_1	60	60	70	1051.14	0.03	9.60
04/01/2023	MDCC_1	60	60	70	950.16	0.03	11.57
22/01/2023	H_1	60	60	70	752.28	0.04	13.80
22/01/2023	D_1	60	60	70	1055.64	0.03	12.88
22/01/2023	A_1	60	60	70	1005.70	0.03	14.41
22/01/2023	L_1	60	60	70	988.95	0.03	9.34

Ground truth data collection

- ~30 E. globoidea and ~70 E. bosistoana

Biomass

- Dry weight and green weight
- …

Taper & volume

- Canopy width in the two directions NW-SE and NE-SW
- Diameter measurements (Ground line diameter (5 cm above ground), DBH…)
- Height measurements (Tree height, height to the base of the green canopy…)
- …

GIS

- Position at the centre of the stump of each tree (GNSS)

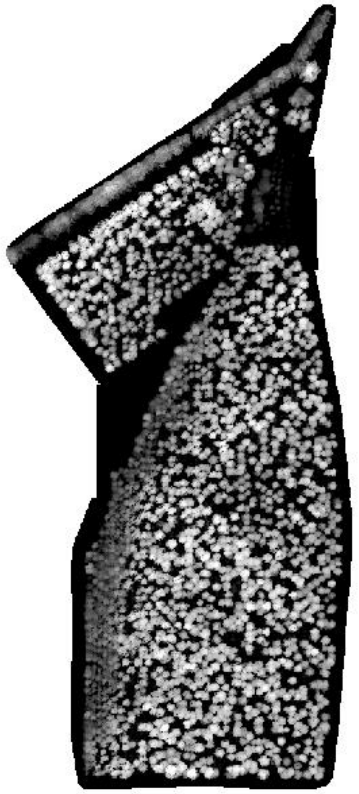
Point cloud

3D point cloud

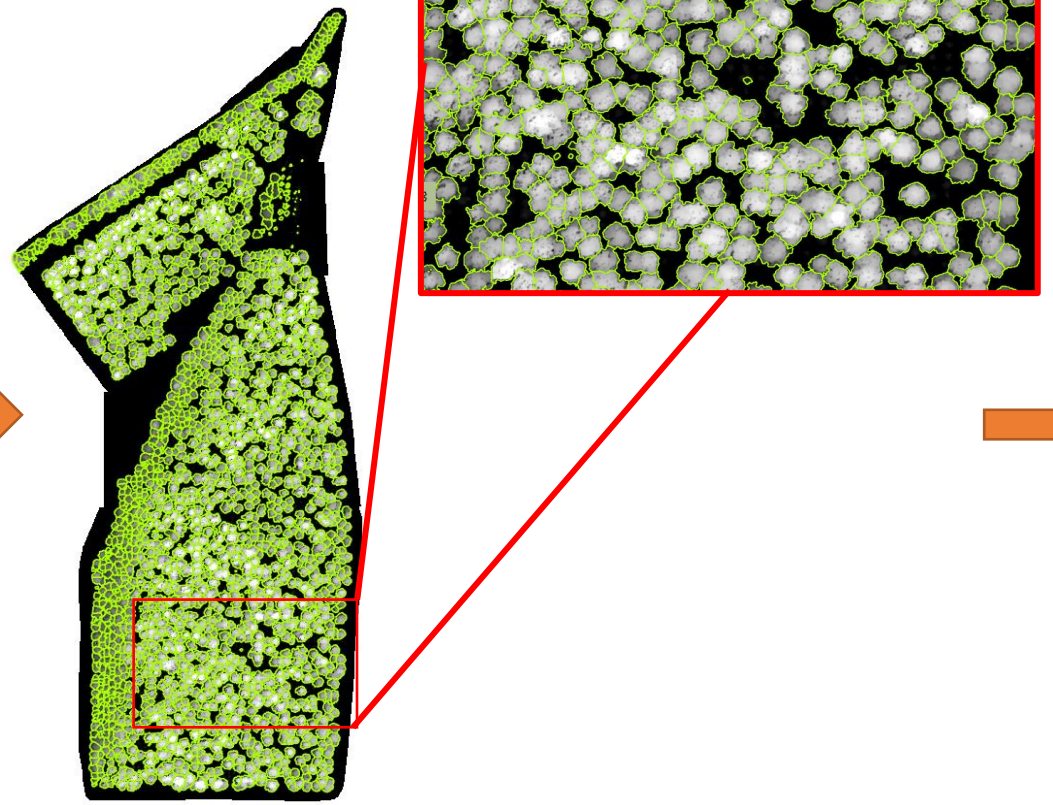
Individual tree segmentation

CHM

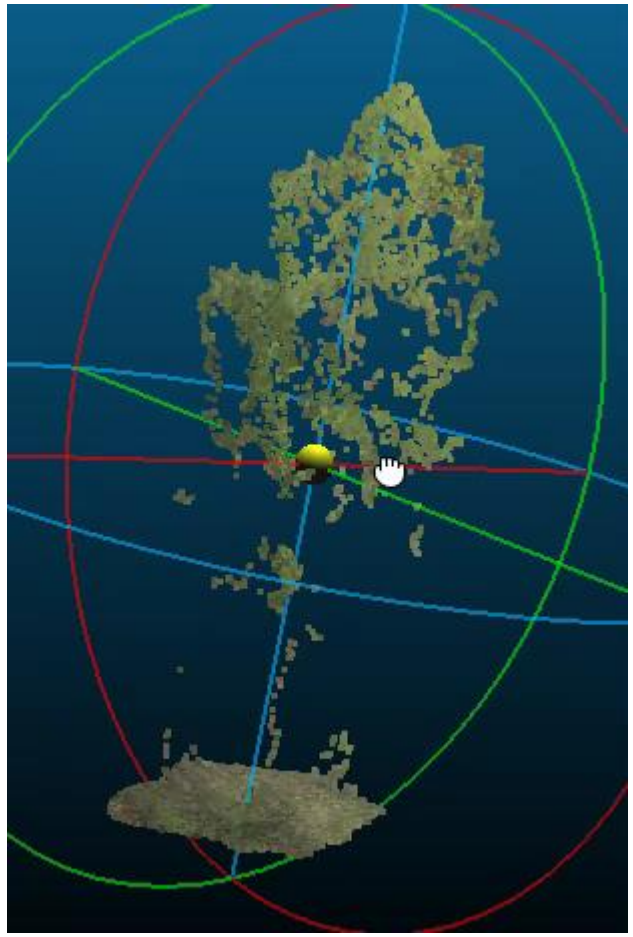
Canopy height model



Individual tree segments

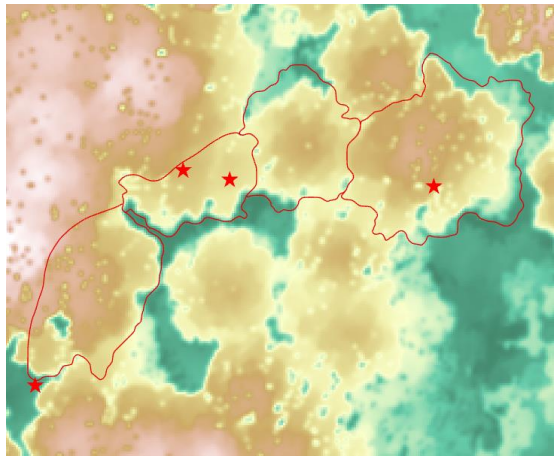


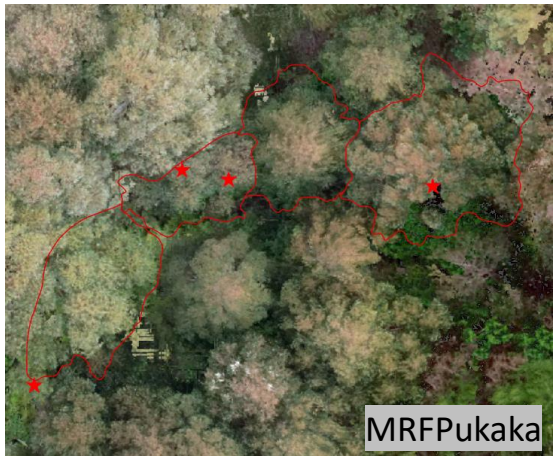
Individual tree point cloud



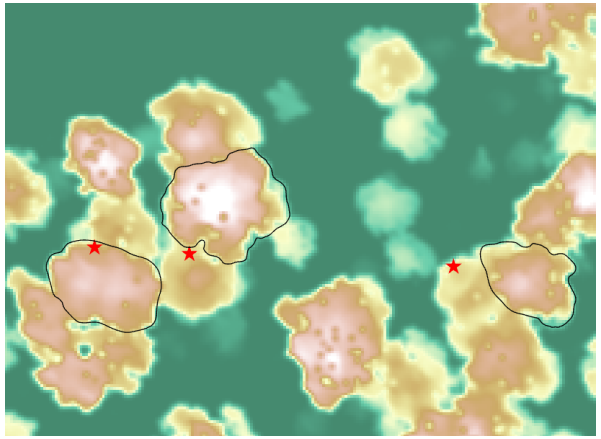
Challenges

- Crown overlap





- Co-registration error



Solution:

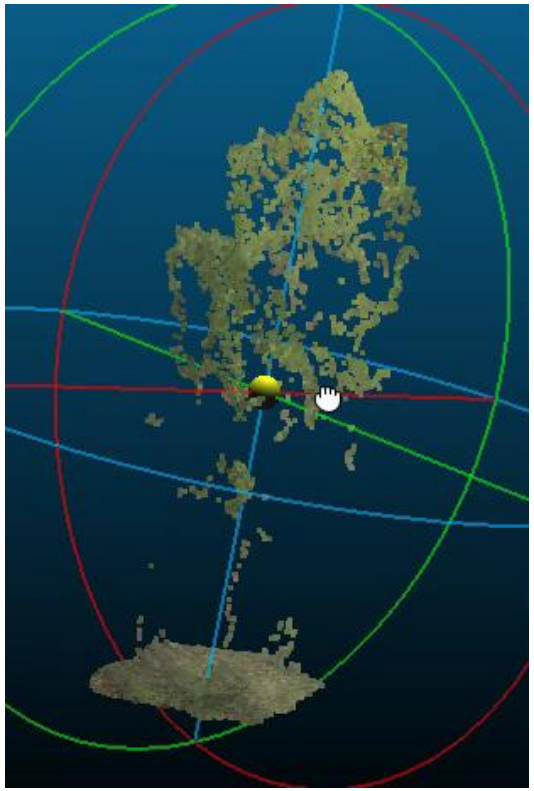
- Field crew verification
- Additional data: aerial photos, measured height, crown width and foliage weight

101 out of 106 trees left

LiDAR metrics

Summary of LiDAR metrics, grouped by function. Adapted from Tompalski and Goodbody (2023)

Function	Description and abbreviations	# Metrics
metrics_basic	total number of returns (n) elevation maximum, minimum, mean, standard deviation, coeficient of variation, skewness, and kurtosis (zmax, zmin, zmean, zsd, zcv, zskew, zkur)	8
metrics_percentiles	elevation percentiles (zq5, zq10, …, zq90, zq95, zq99)	21
metrics_percabove	percentage of returns above a threshold (pzabovemean, pzabove2, pzabove5)	3
metrics_dispersion	interquartile distance (ziqr) mean absolute deviation from the mean, and from the median (zMADmean, zMADmedian) canopy relief ratio (CRR) normalized Shanon diversity index, Vertical Complexity Index (zentropy, VCI)	6
metrics_canopydensity	elevation range is divided into equal intervals, and the cumulative proportion of returns in each interval is calculated (zpcum1, zpcum2, …, zpcum8, zpcum9)	9
metrics_Lmoments	L-moments, L-moment skewness and kurtosis, L-moment coeficient of variation (L1, L2, L3, L4, Lskew, Lkurt, Lcoefvar)	7
metrics_lad	metrics based on the leaf area density (lad_max, lad_mean, lad_cv, lad_min, lai)	5
metrics_interval	Interval metrics - proportion of returns between specified elevation intervals. Default intervals are: 0, 0.15, 2, 5, 10, 20, and 30. (pz_below_0, pz_0.0.15, pz_0.15.2, pz_2.5, pz_5.10, pz_10.20, pz_20.30, pz_above_30)	8
metrics_rumple	A wrapper function for the rumple metric (rumple)	1
metrics_voxels	total number of filled voxels (vn) FRall - a ratio between the number of filled voxels and all voxels located in the maximum extent of the point cloud. In case of FRcanopy empty voxels above the canopy are excluded in the calculations (vFRall, vFRcanopy) vertical rumple (vzrumple) voxel elevation standard deviation and coeficient of variation (vzsd, vzcv) canopy volume (OpenGapSpace, ClosedGapSpace, Euphotic, Oligophotic)	10
metrics_kde	kernel density estimation applied to the distribution of point cloud elevation (Z) (kde_peaks_count, kde_peaks_elev, kde_peaks_value)	12
metrics_echo	percentage of returns by echo types (First, Intermediate, Last; and Single, Multiple) (pFirst, pIntermediate, pLast, pSingle, pMultiple)	5
metrics_HOME	height of median energy (HOME)	1



96 metrics derived

Remove missing values

→86 valid metrics derived for each tree

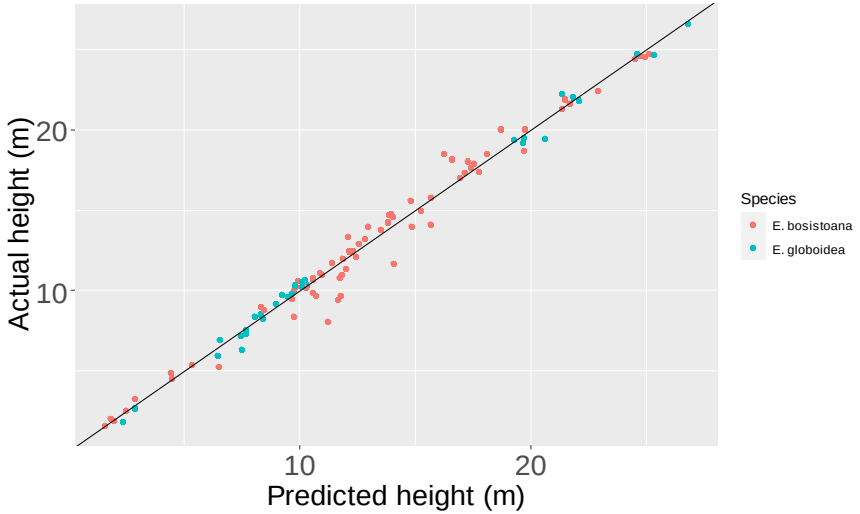
Modelling

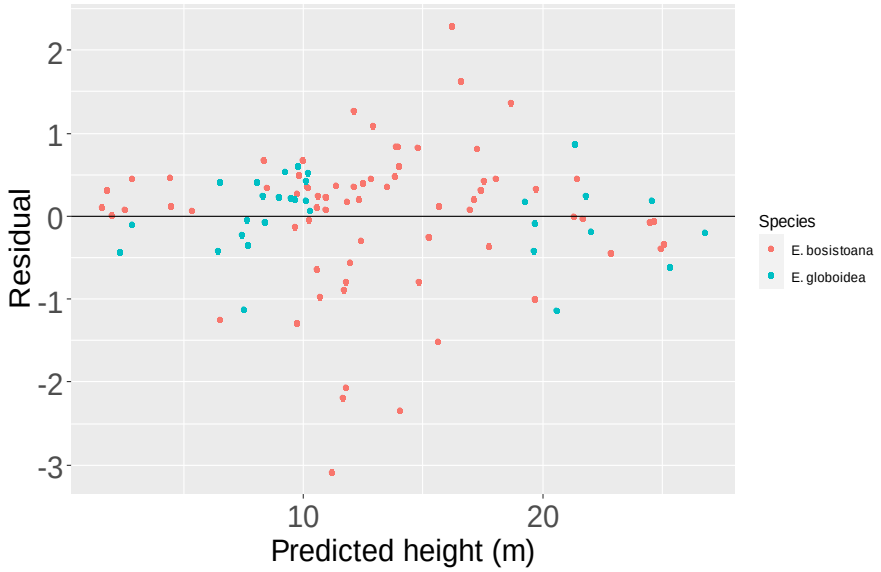
Models used:

- Statistical model- Multi-linear model
- Partial Least Squares Regression (PLSR)
- Random Forest (RF)
- eXtreme Gradient Boosting (XGBoost)

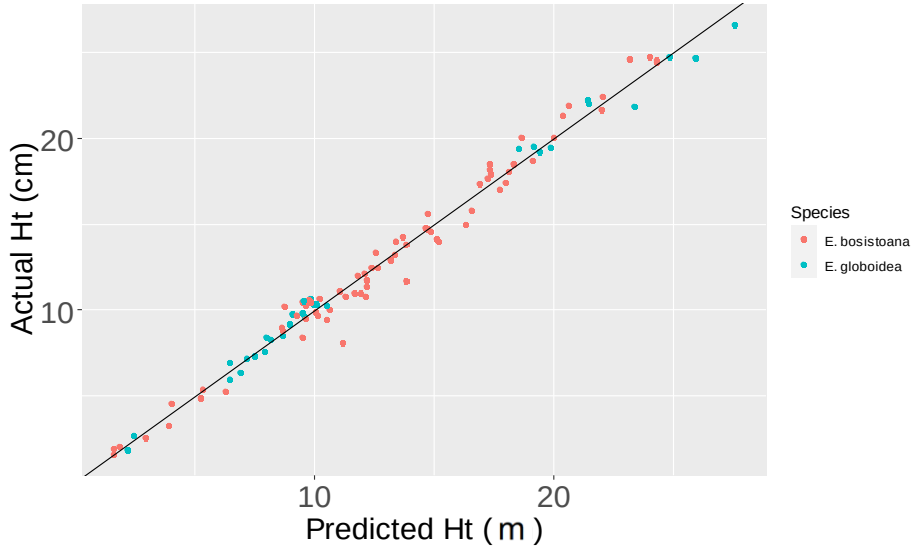
Results - Height

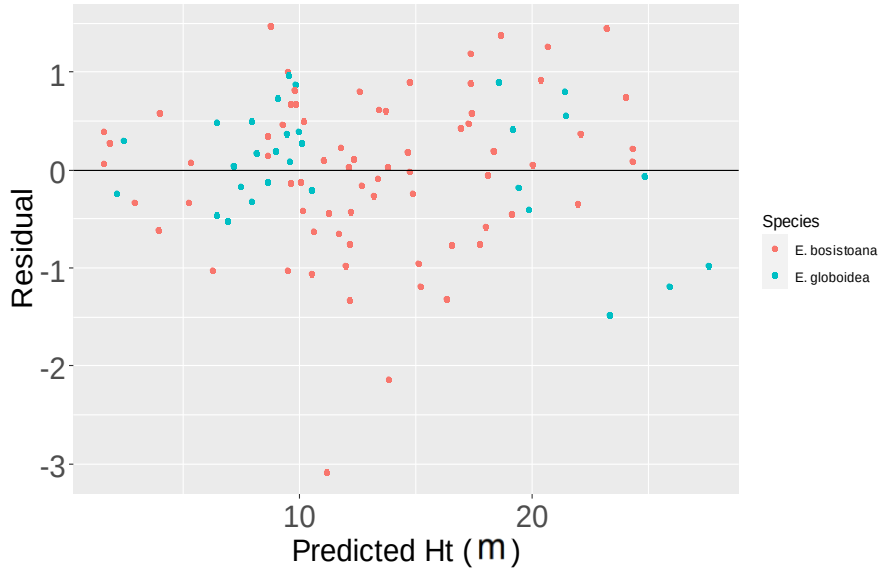
Multi-linear Model





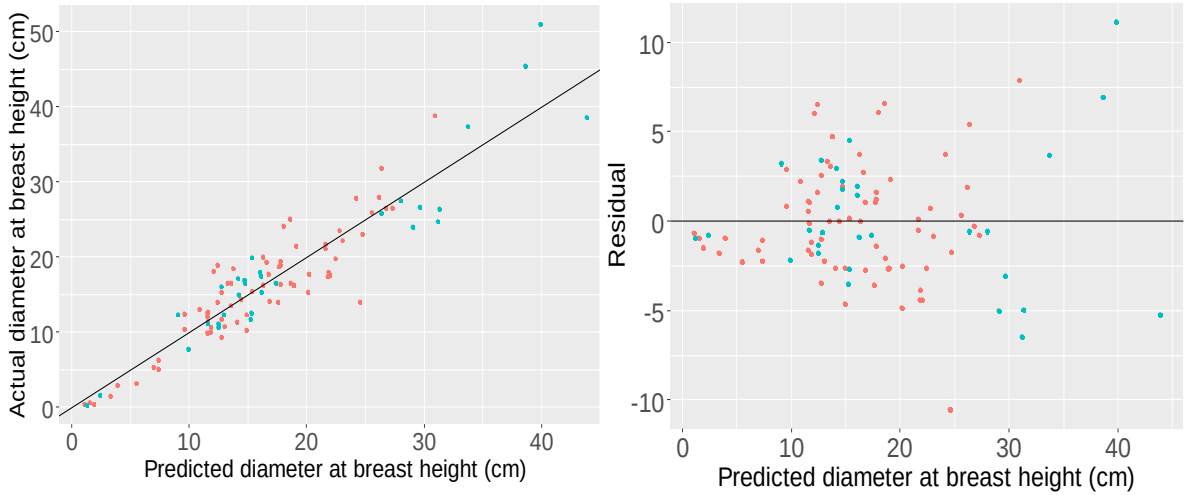
PLSR



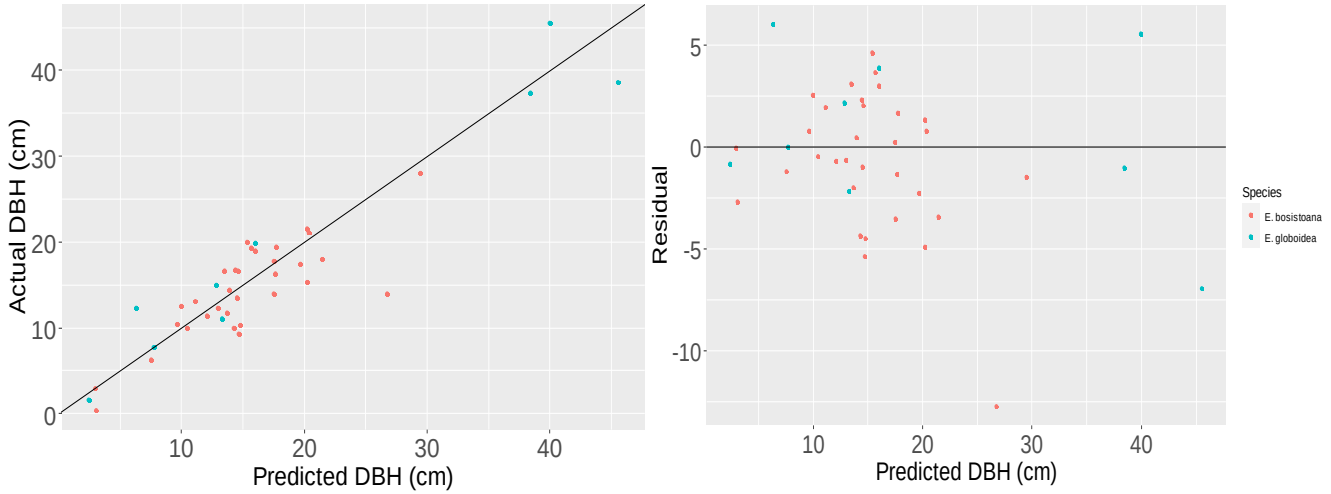


Results - DBH

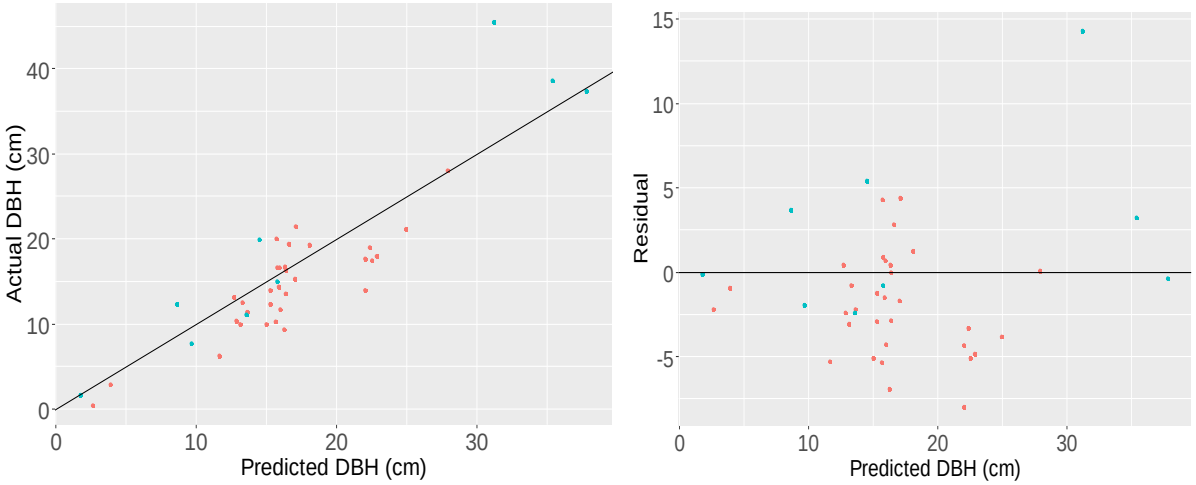
Multi-linear



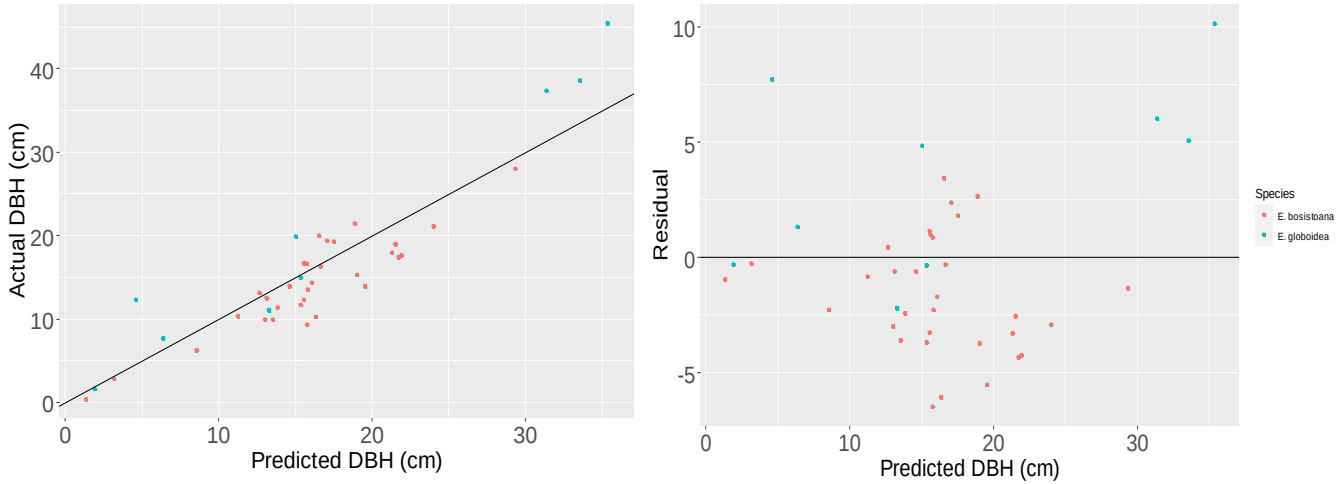
PLSR



Random Forest

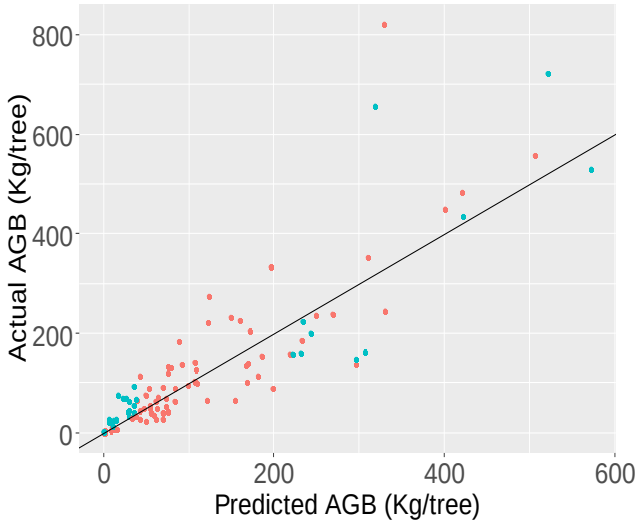


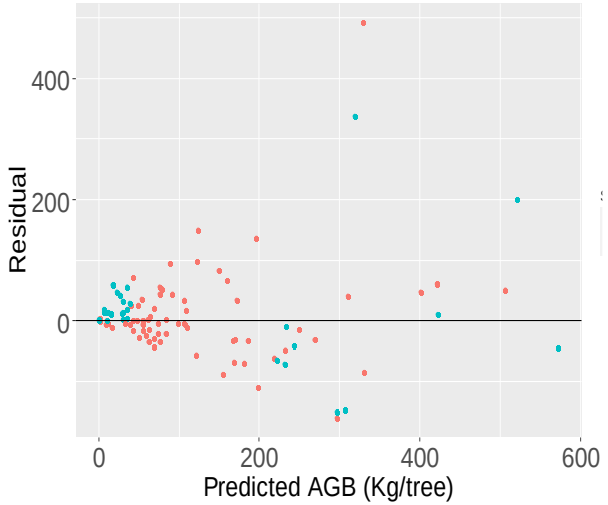
XGBoost



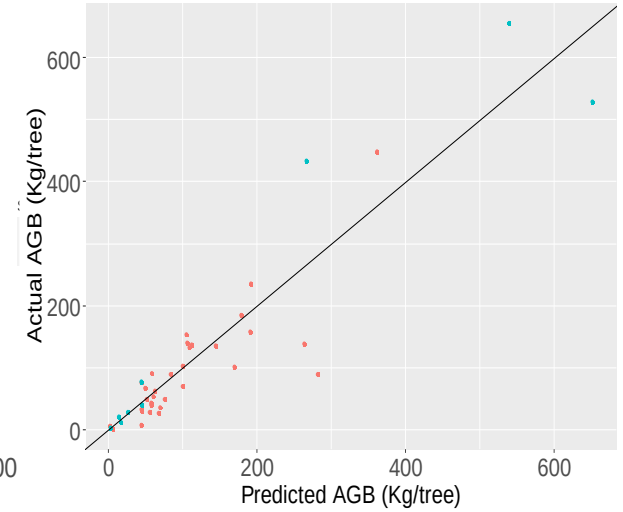
Results - Biomass

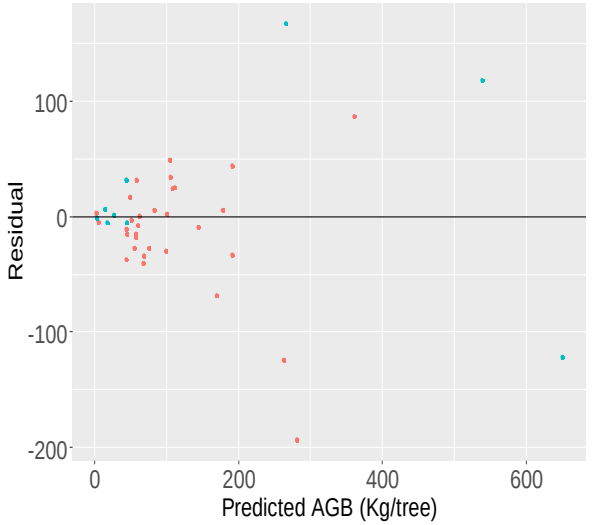
Multi-linear



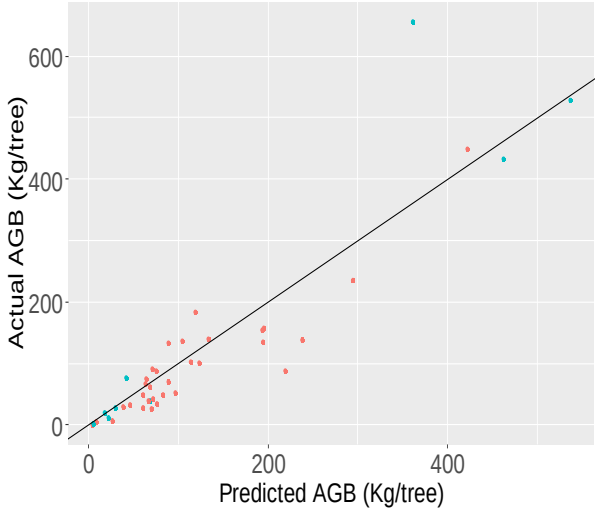


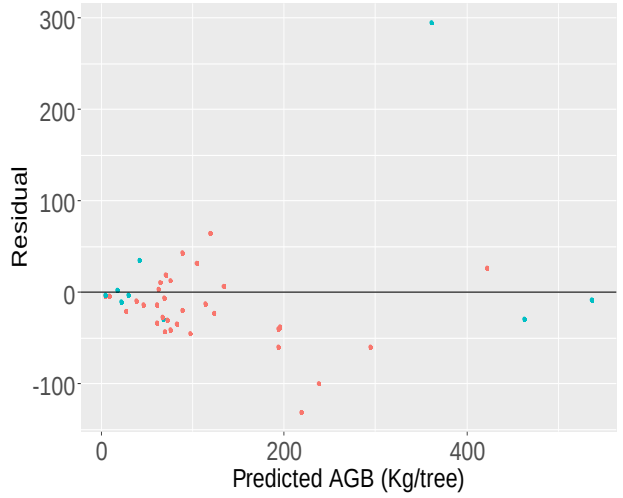
PLSR



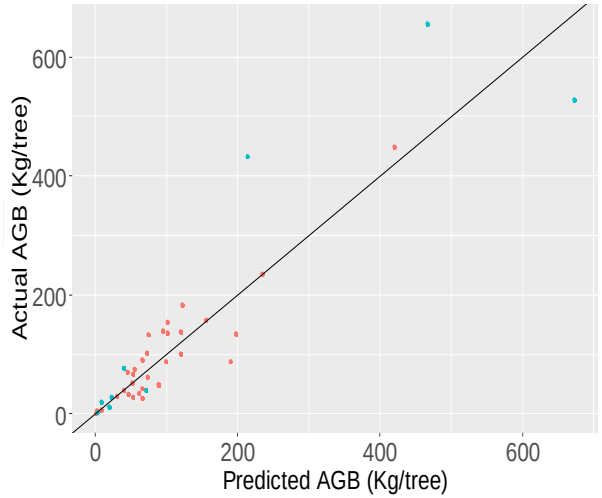


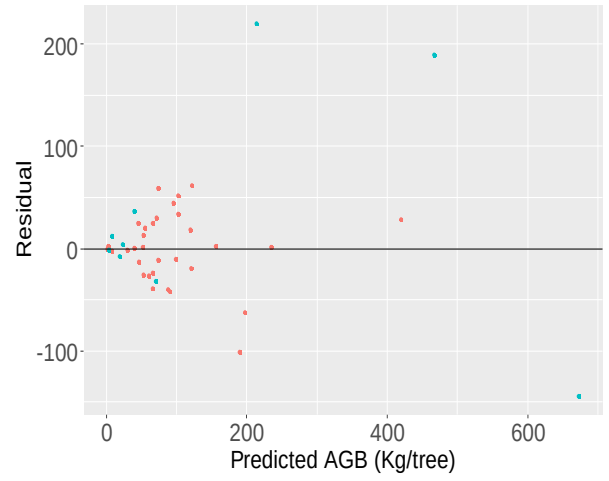
Random Forest





XGBoost



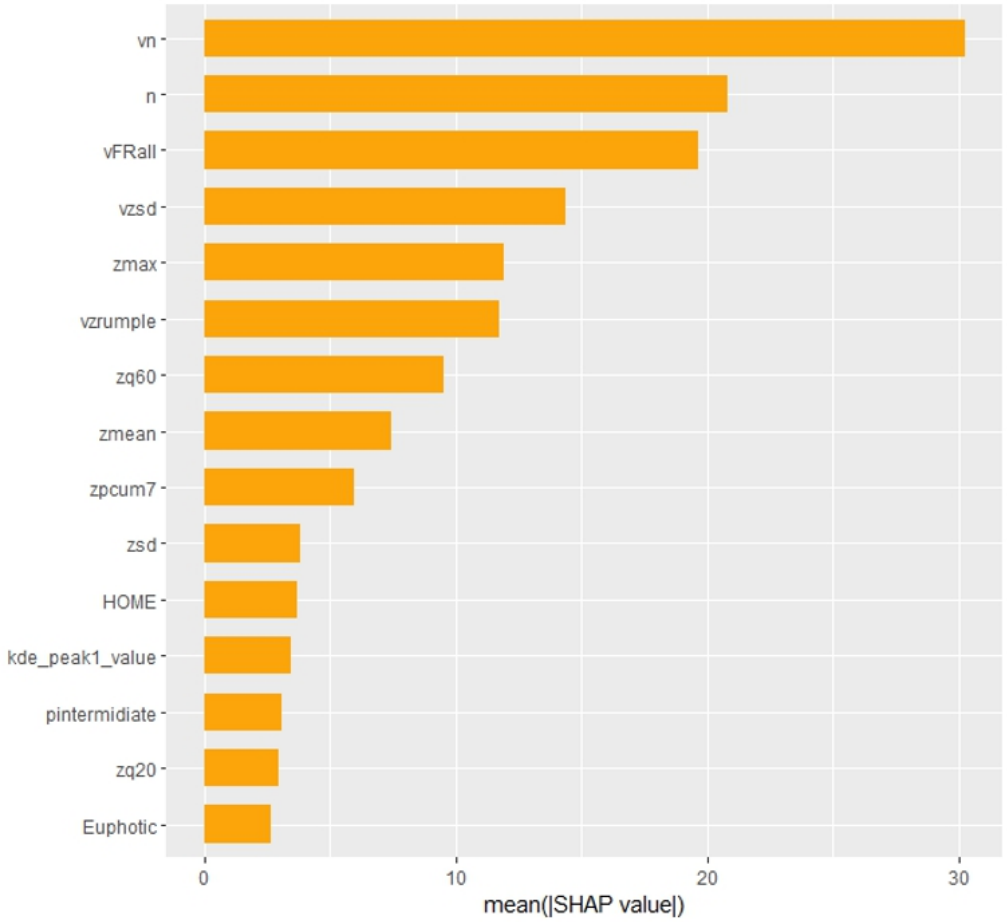


Results - Model Comparison

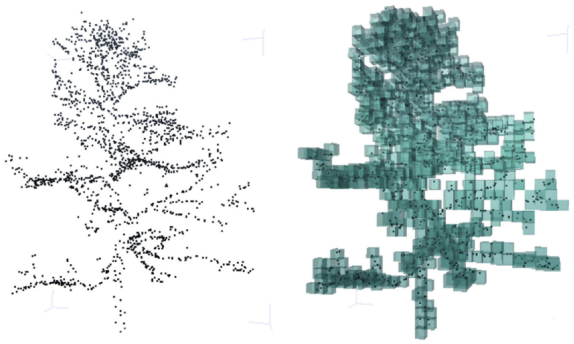
Method	Response variable	RMSE	R^2
Multi-linear	AGB	80 kg	0.74
PLSR	AGB	59 kg*	0.84
RF	AGB	59 kg*	0.83
XGBoost	AGB	59 kg*	0.83
Multi-linear	DBH	3.33 cm	0.86
PLSR	DBH	3.57 cm*	0.85
XGBoost	DBH	3.63 cm*	0.83
Multi-linear	Height	0.8 m	0.98
PLSR	Height	0.8 m	0.98
Direct measurement of zq95	Height	0.8 m	0.98
Vertex measurement	Height	0.71 m	0.99

* Results from separating fitting and testing sets

Useful LiDAR Metrics for Estimating Biomass

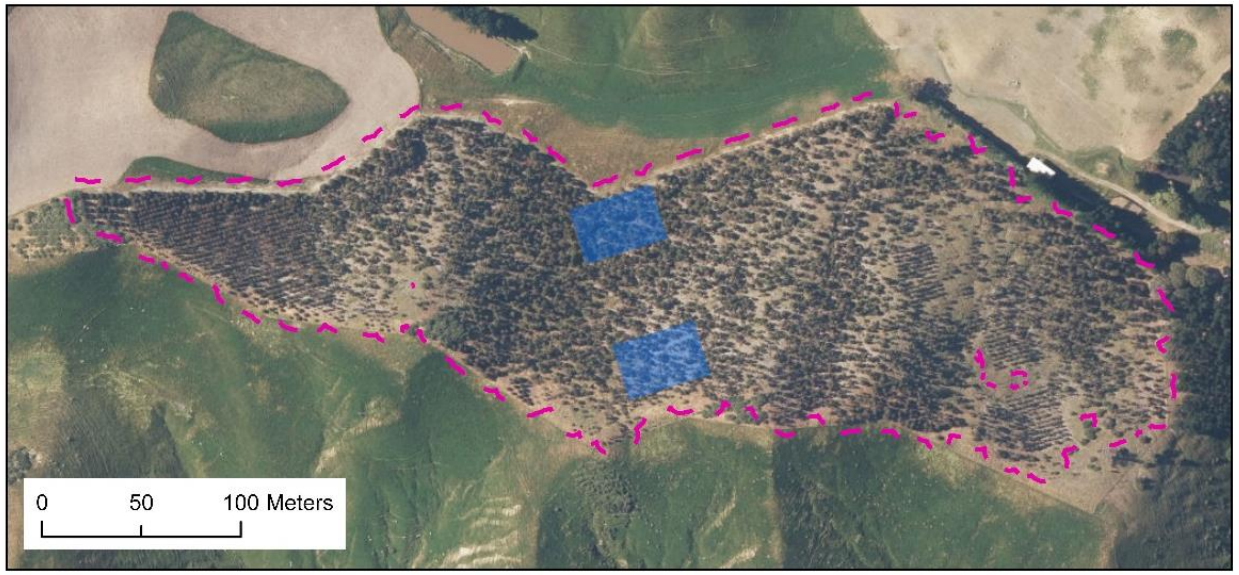


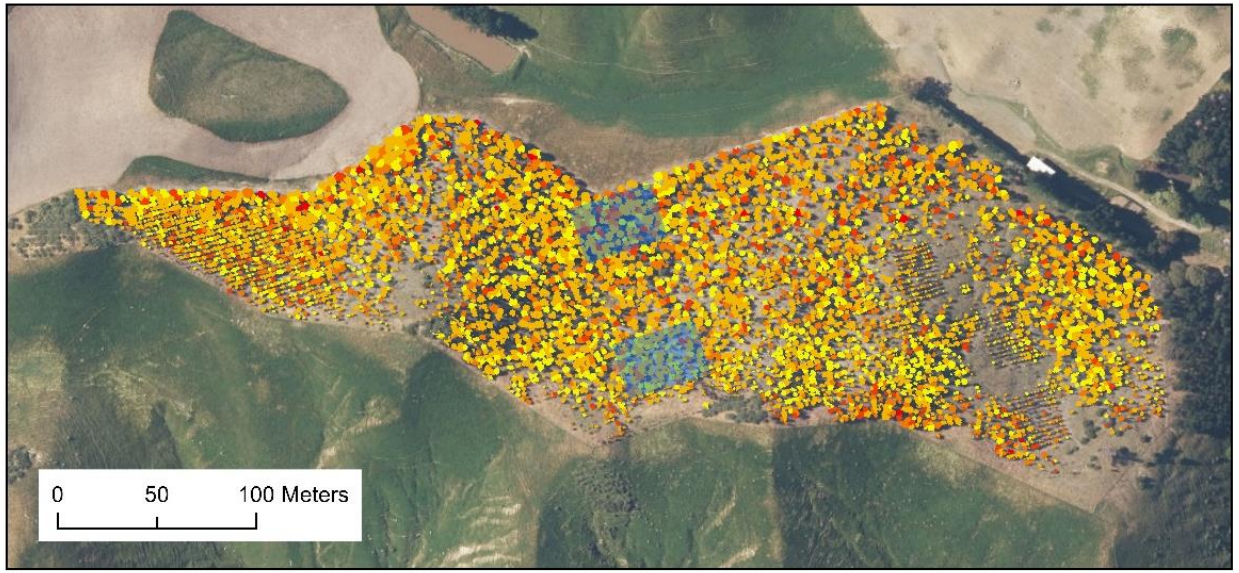
Metrics name	Description
vzrumple	vertical rumple
vn	total number of filled voxels
vFRall	vFRall - a ratio between the number of filled voxels and all voxels located in the maximum extent of the point cloud
HOME	height of median energy
zmax	maximum height

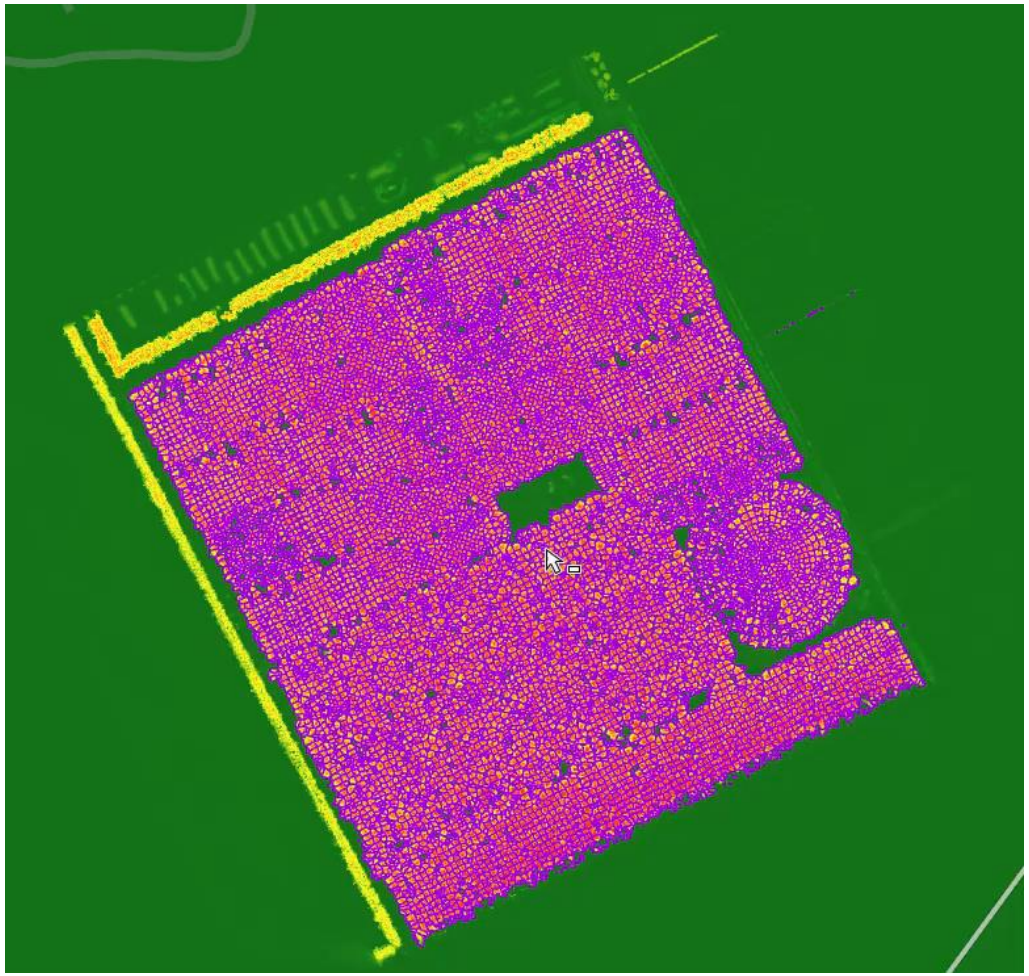


Zięba-Kulawik, Karolina & Skoczylas, Konrad & Wezyk, Piotr & Teller, Jacques & Mustafa, Ahmed & Omrani, Hichem. (2021). Monitoring of urban forests using 3D spatial indices based on LiDAR point clouds and voxel approach. Urban Forestry & Urban Greening. 65. 127324. 10.1016/j.ufug.2021.127324.

Potential Application and Challenges







Conclusion

- Biomass: **PLSR > XGBoost > RF** > Multi-linear
- The SHAP analysis revealed that height and voxel metrics were the most influential features for AGB estimation
- Potential application: stand biomass estimation at site level, transfer to other species and regions

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