EU – Forest Observations for Carbon Market Integrity using Sentinels

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EO4CarbonMarkets | Tree Planting | 9 October 2025

National Physical Laboratory

- UK's National Metrology Institute founded in 1900
- A public corporation owned by the Department for Science, Innovation and Technology (DSIT)
- Based in sunny SW London

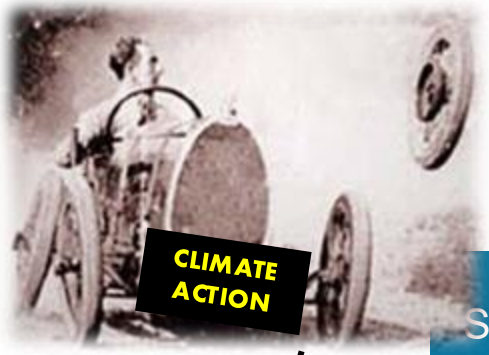
- Climate & Earth Observation Group
- Embedding "metrology in EO"
- Led development of the CEOS "Quality Assurance Framework for Earth Observation" (QA4EO)
- Working towards the generation of interoperable, quality assured, **fit for purpose** EO data and derived products that encompass in-situ, airborne, satellite and model outputs.

EU-FOCIS

ESA EO4Society
High Priority application area: G) Forest Management
KO: November 2024; **Duration:** 24 months

Develop and demonstrate a (above ground) carbon information product for Europe, using ESA open-source satellites, to support voluntary (and compliance) market investment in forest carbon initiatives

Responsible European corporates are actively seeking high-quality projects close to home!



Net Zero Pathways

Paris Agreement; EUGD; CCRF

Monitor & Adjust

Standards, Regulation, MRV
Consistent, Quantifiable mitigation outcomes

GGR & NbS

Finance needed for scale

VCM & Alternative approaches

Various implementation avenues

Greenwashing / Phantom Credits

Undermine ambition / Worsen climate change

UK's Woodland Carbon Code

Woodland Carbon CO_2de®

Delivered by Scottish Forestry on behalf of Forestry Commission, Welsh Government and Northern Ireland Forest Service.

- Quality Assurance standard for UK woodland creation projects.
- Allows landowners to register and sell woodland carbon units to companies and individuals who want to offset their emissions.

Key requirements and Challenges:

Accessible

- **Cost** must be low / financial incentive
- **Methodology** must be simple … ucible, scalable
- **Time bur…**
- **Human re…** … on
- **H&S** must …

+

Integrity

- **Methodology** must be scientifically sound
- **WCUs** must be quantified following standardised good practices

Applicable to CRCF – Tree Planting Methodology

Can we use satellites operationally?

Are the numbers, right?…..

Satellite derived AGB

Orange = known issues

- Relationships between spectral response (or index) and field inventory data using linear and multiple regression models;
- **VI's** - saturate with increasing biomass
- **ML methods** (RF, SVM, ANN)
- **SAR** – saturation, canopy / surface water, geometric effects
- **GPP** – VI, LUE, process-based models

Dedicated Missions

- **ESA CCI Biomass**
  - Sentinel-1, ASAR, ALOS
  - 100m
  - 2010, 2017, 2018, 2019, 2020
- **NASA GEDI**
  - 25m footprint
  - ISS: 51.6°N,S
- **JAXA MOLI**
  - ISS
- **ESA BIOMASS**
  - 200m
  - SOTR EU coverage restriction

Commercial Products $$$

- **Chloris Geospatial**
  - S1, S2, Landsat, GEDI
  - 30m
  - 2013 onwards
- **PLANET Biomass Proxy**
  - Microwave/optical fusion
  - NDVI
  - Crop biomass

Forest carbon projects - ‘a couple’ to ‘thousands’ of hectares

Spatial scale	Ground (plot – ha)		Drone (ha's)			Airborne (region, country)			Commerical Satellite (metres)		Open Access Satellite (20m–100's m)		
Key Issues	Inventory	TLS	Optical	Radar	Lidar	Optical	Radar	Lidar	Optical	Radar	Optical	Radar	Lidar
Sporadic / limited data collection													
Skilled forester / instrument operator													
Field resource intensive / acquisition restrictions													
Weather dependent													
Cloud / Aerosol effects													
Acquitistion cost prohibitive													
Limited spatial coverage													
Large data volumes													
Technical expertise, immature workflows													
Restricted EU coverage												SOTR	ISS

EU-FOCIS Approach

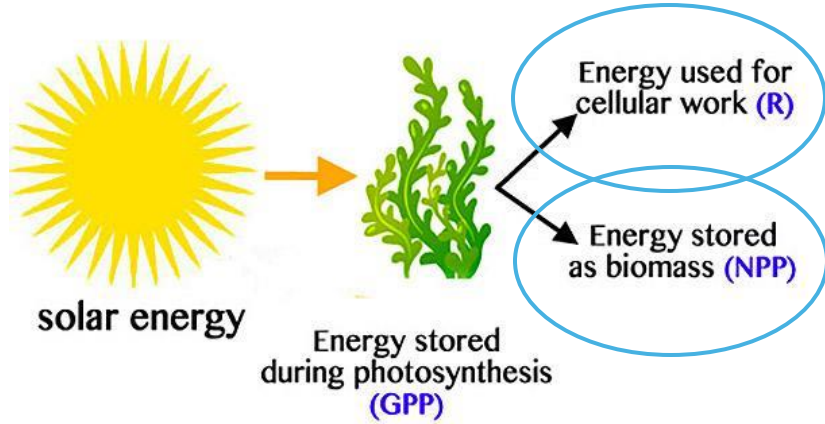
EU-calibrated **F**orest **A**GB/**C**arbon **S**equestration information product

EU-FACS

1. Spatially and temporally explicit estimates of terrestrial vegetation **GPP** (carbon sequestration potential) derived from ESA Copernicus **Sentinel-2 MSI**, and future **CHIME** and **LSTM** expansion satellite missions; and

2. A ground reference database of AGB stock / change measurements derived from **TLS** calibrated allometric scaling models for broad vegetation composition classes across Europe

Why GPP?



- Rate at which plants capture carbon and store it as carbohydrate over a given time per unit area
- In healthy vegetation its directly related to absorbed solar radiation in the PAR range (400-700 nm) and light use efficiency (LUE) (Monteith, 1972).

$$NPP = GPP - R$$

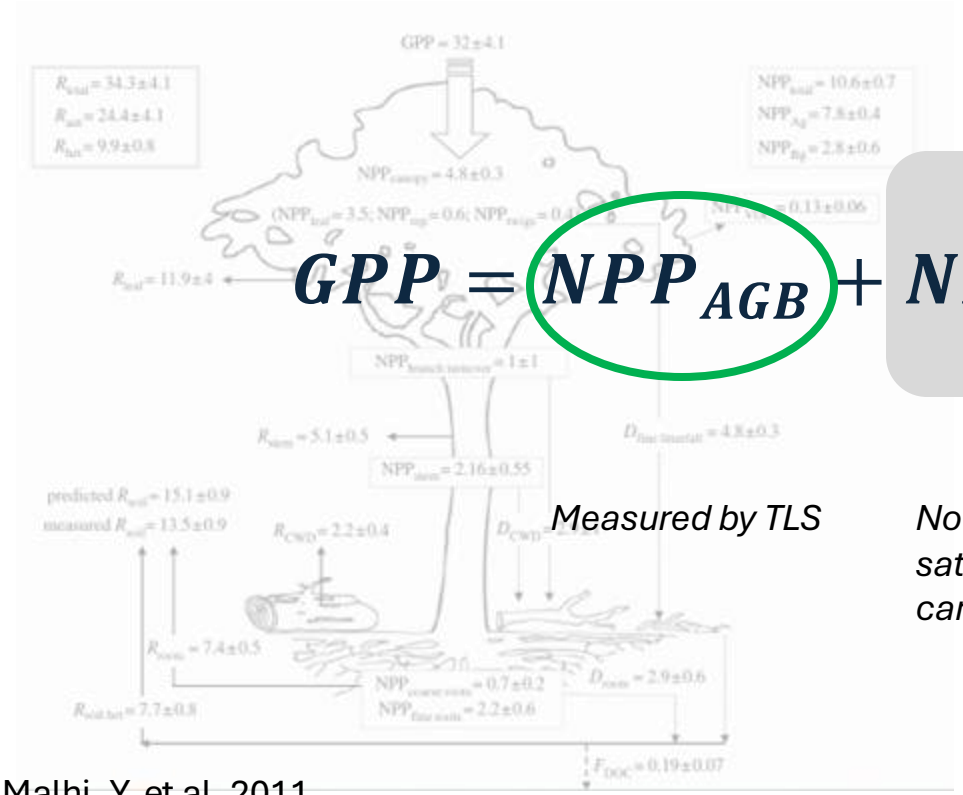
net primary productivity | gross primary productivity | respiration

GPP = PAR * FAPAR*LUE(εmax)*Scalars

- GPP is the potential carbon sequestration based on **water**, **temperature** and **light** availability….
- Can make some inference on the impact of climate on AGB allocation i.e.
  - A wetter warmer year may lead to faster growth than a drought year.

EU-FACS Development

- To quantify spatially representative information on AGB/carbon stock and accumulation year on year (or portion of GPP that is locked away in the long-term)
  1. The allocation of Net Primary Production (NPP) to woody AGB using GPP data; and
  2. Highly accurate AGB estimation, from TLS measurements of representative forestry for a minimum of 2 points in time that are at least several years apart



Seen by satellite *Accounted for in LUE model*

$$GPP = NPP_{AGB} + NPP_{BGB} + NPP_{Foliage} + NPP_{Respiration}$$

Measured by TLS

Not seen by satellite nor TLS = can't measure it

Short cycle processes don't contribute significantly to long term carbon accumulation

Malhi, Y. et al. 2011

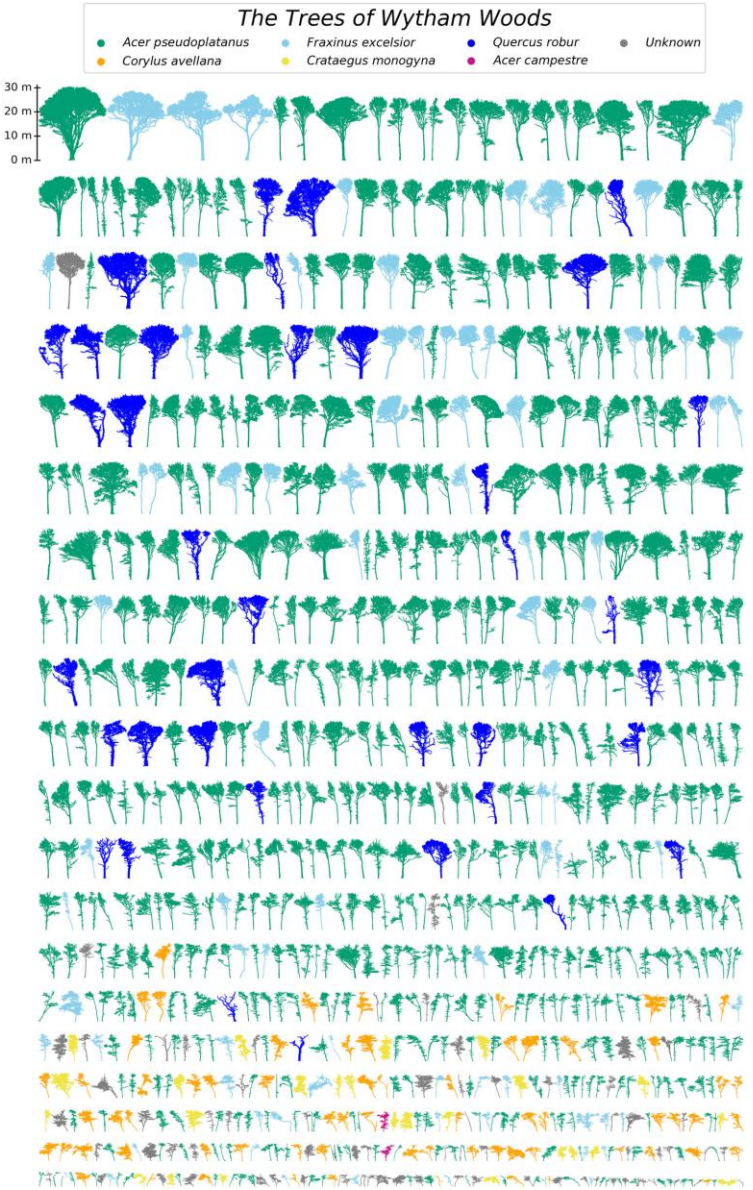
Why TLS? Current best estimate of AGB

- Traditional allometry assumes AGB ∝ $c\rho D^2 H$ (scaler c, density ρ, diameter D, height H)

- Various published studies show these models are biased & underestimate, particularly for large trees - UK Wytham Woods

- Considered the "gold standard" for forest AGB
  - Highly comparable to destructive measurements
  - Non-destructive!
  - Captures detailed 3D information, which allows for precise measurements of tree size (diameter, height, crown area), structure, and volume.

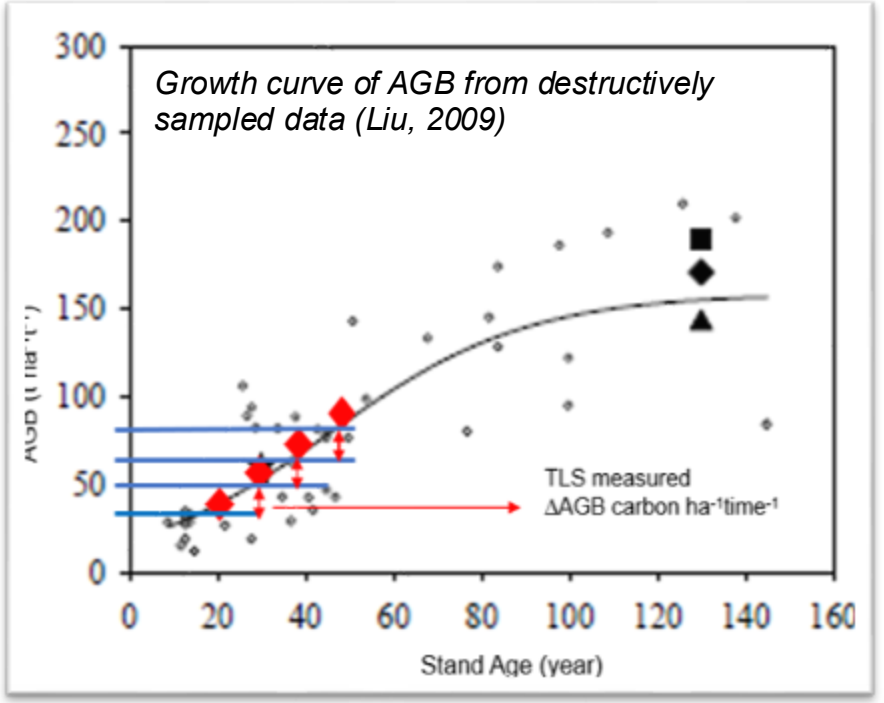
*A typical mixed deciduous UK woodland contains almost **twice as much** AGB than is estimated with traditional methods*



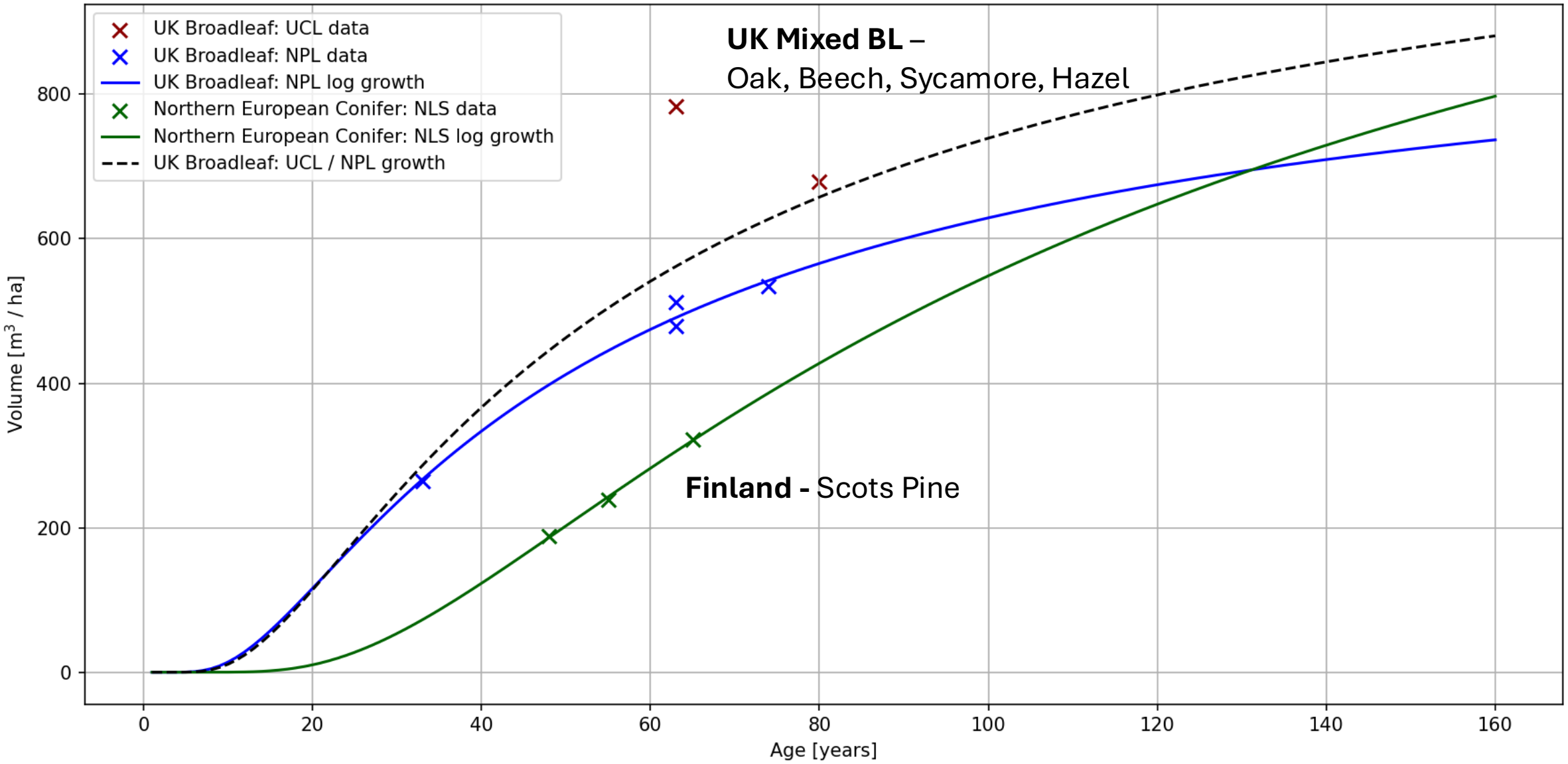
https://doi.org/10.1002/2688-8319.12197

Measure volume change

- Representative species compositions: **Conifer; Mixed Broadleaf Mix**
- >20 years old through to “ancient” 150+
- ~10-year increments
- UK (south); Finland, Portugal
- Known planting and management regime
- RIEGL vz-400i; vz600i
- 4 Scanning teams
- Different data processing tools



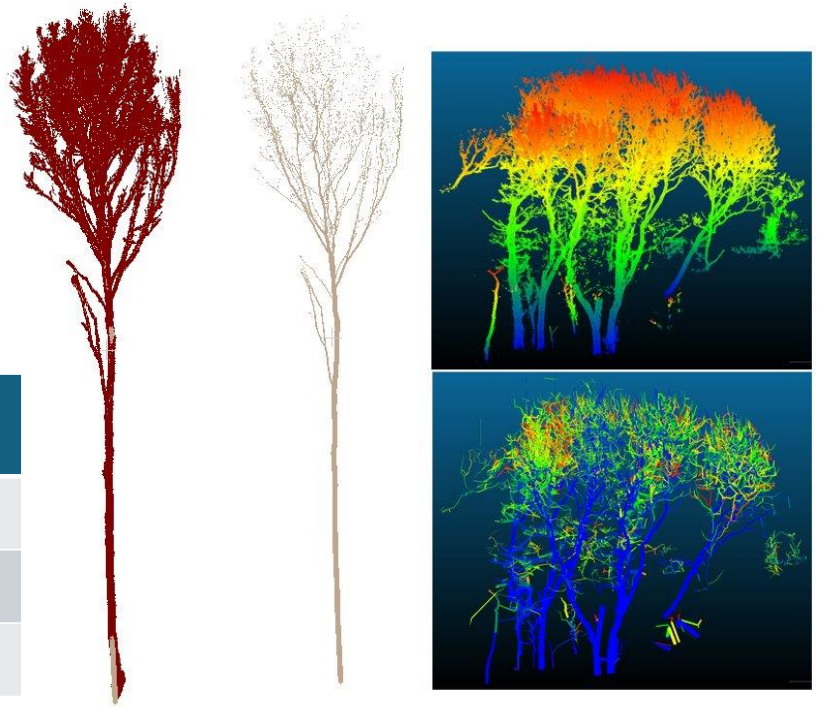
Initial TLS Results



Initial TLS Results (UK)

- Following same sampling protocols (Wilkes, 2017)
- Point cloud processing with RayCloudTools (RCT) and TLS2trees
- Manual decisions made on “cleaning” of segmented point cloud
- Can lead to significant differences in tree counts, tree volumes and area volume estimates
- **Further research is needed to explore these differences**
- **Similarly to inventory data, uncertainty in scaling to plot/project area needs to be evaluated**

Monks Wood, Huntingdon UK. 63 Years Old. Mixed BL Woodland



Plot Name	Age	Number of trees	Area [ha]	Trees per ha	Volume [m3]	Volume per tree [m3]	Volume/ha [m3/ha]
Monkswood 1	63	154	0.314	490.45	160.75	1.04	**511.94**
Monkswood 2	63	124	0.240	516.67	114.96	0.93	**479.02**
Monkswood 3 - 4	63	367	0.63	321.43	493.60	2.44	**783.49**

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