Evolution of TLS as a viable forest inventory and plot monitoring tool

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Technologies
Perspectives
Plot origins
The frontier
Next steps

TLS Forest Research Trend (2010-2019)

- Web of Science Database
- Topics: terrestrial, tree, lidar
- Search year: 2010-2019
- Results: 530 publication records

Topic of TLS becomes increasingly popular over the decade

Hopkinson & Xi, CIF, 2019
Consumer-based Flash LiDAR
Xbox Kinect

More typical commercial TLS sensor types

Configurations
- Static frame = HV dual axis scanner
- Rotating head = single vertical line scan
- Combo = frame with pan / tilt mount
- Precision / resolution = mm to cm
- Range = metres to kilometres
- Most combine GPS & image capture
- Some apply motion compensation with IMU

Optech ILRIS
Riegl
Teledyne Polaris

Echidna
Trimble
Z+F
Leica
Faro

Hopkinson & Xi, 2019
Mobile solutions

LiBackpack

Zeb 1

CSIRO Team:
Zlot, Böse, Wark, Flick, Dell

Frame scan configuration

Hopkinson & Xi, 2019

Hopkinson & Xi, 2019
**PSP sampling configurations:  Frame scan**

At least 3 scans for uniform sampling  
Complex set up requires tree height  
Occlusion into plot centre

![Frame scan configuration](image_url)

*Hopkinson & Xi, 2019*

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**PSP sampling configurations:  Hemisphere scan**

Frame scanner with pan/tilt mount  
OR: rotating line scanner; e.g. Echidna  
Occlusions heading out of plot

![Hemisphere scan configuration](image_url)

*Hopkinson & Xi, 2019*
PSP sampling configurations: Mobile scan

https://greenvalleyintl.com/applications/finding-dbh-values-handheld-mobile-lidar/

Point cloud attributes: Density & Occlusions
Assessing forest metrics with a ground-based scanning lidar

Hopkinson, Chasmer, Pow, Treitz. 2004
Tree stem identification & extraction

- Neighbourhood around stem centroid at max crown size
- Point data extracted written to “tree” file
- Tree files “cleaned”

Crown diameter

- Manually assessed with virtual calipers
**Tree Height**

Vector connecting max & min pt within file

Vector length – tree ht

**Stem DBH**

Tree stem data from 1.25 – 1.75 m selected

Cylinder “primitive” fitted

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**Automated allometric biomass estimation**

**Workflow**

Plot scans →

Align →

DEM →

Tree isolation →

Stem extraction →

DBH, height, stem taper/volume →

Allometric equations applied

Quantitative Structural Modelling (QSM)

Workflow
Decompose point cloud into classes
• Stem
• Branch
• Other
Apply biomass factor to each class

<table>
<thead>
<tr>
<th>Component</th>
<th>Maple</th>
<th>Aspen</th>
<th>Pine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem</td>
<td>92.3%</td>
<td>81.2%</td>
<td>91.5%</td>
</tr>
<tr>
<td>Branch</td>
<td>6.5%</td>
<td>17.6%</td>
<td>8.4%</td>
</tr>
<tr>
<td>Isolated wood</td>
<td>0.3%</td>
<td>0.05%</td>
<td>0.03%</td>
</tr>
<tr>
<td>Understory</td>
<td>0.9%</td>
<td>1.2%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>


Artificial intelligence species classification

Workflow:
7 TLS plots/582 stems → Machine learning segmentation → Deep learning classification → 92% accuracy

Ongoing Research

Hardware
• Multispectral lidar
• Low-powered real-time LED/RGB monitoring
• Data fusion & scaling (TLS for cal/val)

Software
• Machine learning, artificial intelligence & deep learning
• New allometric approaches

Applications
• Shrub & juvenile biomass assessment
• Change detection (growth, stress, mortality, seasonal)

Ecosystem Diagnostic Imaging Facility
• Western Economic Diversification Project
• Airborne Multispectral Lidar, TLS, UAV
• Environment & Resource Monitoring
• Risk Assessment & Mitigation
• Disaster Response