Supplementary information

**Figure S1. Images of the 10 forest plots studied**

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| --- | --- |
| Plot 1: Coppice of hornbeam and birch | Plot 2: Even-aged coppice of Beech |
| J:\Co\T-lidar_gedinne\images\DSC_0138.JPG | J:\Co\T-lidar_gedinne\images\DSC_0018.JPG |
|  |  |
| Plot 3: Uneven-aged coppice of beech | Plot 4: Even-aged coppice of douglas fir |
| J:\Co\T-lidar_gedinne\images\DSC_0021.JPG | J:\Co\T-lidar_gedinne\images\DSC_0005.JPG |
|  |  |
| Plot 5: Even-aged coppice of spruce | Plot 6: Even-aged coppice of oak and pine |
| J:\Co\T-lidar_gedinne\images\DSC_0024.JPG | J:\Co\T-lidar_gedinne\images\DSC_0027.JPG |
|  |  |

|  |  |
| --- | --- |
| Plot 7: Uneven-aged coppice of beech | Plot 8: Even-aged coppice of spruce |
| J:\Co\T-lidar_gedinne\images\DSC_0009.JPG | J:\Co\T-lidar_gedinne\images\DSC_0015.JPG |
|  |  |
| Plot 9: Even-aged coppice of spruce | Plot 10: Uneven-aged coppice of beech |
| J:\Co\T-lidar_gedinne\images\DSC_0016.JPG | No image |

**Table S1. Summary of experimental design, scanner settings, and methodologies of previous studies on automatic stem detection and DBH extraction from TLS data for forest inventory. The number of trees in brackets in the column Tree is the number of trees used for DBH comparison (m=measured). The tree forest types are broadleaves (B), coniferous (C), and mixed (M). The shape of the plots is in bracket in the column Size (r: rectangle, s: square, and c: circle). NHA is the number of trees per hectare. Mode is the scanning method (MS: multiscan, SS: single scan, PLS: personal mobile laser scanning, and HMLS: hand-held mobile laser scanning). Occl. is the rate of trees detected without occlusion and Occl. + missed is the proportion of trees automatically detected.**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Plot (n)** | **Tree (n)** | **Forest type** | **Terrain** | **Size (ha)** | **NHA** | **Mode** | **Detection** | | | **DBH** | | |
| **Process** | **Occl.** | **Occl+ Missed** | **Process** | **Bias (cm)** | **RMSE**  **(cm)** |
| Simonse *et al*. 2003 | 1 | 28 | C | / | ~0.12 (r.) | ~233 | 4 MS | Filter+2D-SliceHough transform+ fitting circle | / | 93 | 1.3m circle fitting | 1.7 | / |
| Thies and Spiecker, 2004 | 1 | 50 (11m) | B (UEA) | Slope (41%) | ~0.09 (s) | 555.6 | SS | Simonse *et al*. [6] method | / | 22 | Circle fitting | -0.75 | 3.48 |
| 5 MS | / | 52 | 0.32 | 3.22 |
| Hopkinson *et al*., 2004 | 2 | 138 | C & B | / | 0.12 (s) | 465– 661 | 5 MS | 2D-Slice between 1 and 7 m + manual detection | 97.1 | / | Manual extraction and cylinder fitting (1.25 and 1.75 m) | / | / |
| Bienert *et al. 2006* | / | 65 | / | / |  | / | 2 MS | XY cluster at 1.3 m+ fitting circle | *97- 100* | / | *1.3m circle fitting* | *0.9* | *1.5* |
| Bienert *et al*. 2007 | 21 | 547 | M & B |  | 0.07 (c.) | / | SS | Similar to [48] + point density raster analysis | / | 97.4 | / | / | / |
| Maas *et a*l., 2008 | 4 | 82 | B (1 C) | hilly/ flat | 0.07 (c.) | 212– 410 | SS | Similar to [14] | / | 97.5 | *Similar to [48]* | -0.67 –1.58 | 1.8– 3.25 |
| 1 | slope | 3 MS |  |  | / | 1.5 |
| Murphy, 2008 | 9 | 220 | C (EA) | Flat | 0.04 (c.) | / | 2 MS | Similar to [14] | 93 | 93 | *Similar to [48]* | -0.6 |  |
| Strahler *et al.*, 2008 | 1 | 102 | C (EA) | / | 0.79 (c.) | 130 | SS | Based on the range and intensity signal return | / | 40.2 | / | / | / |
| Brolly and Kiraly, 2009 | 1 | 213 | M | / | 0.28 (c.) | 753 | SS | 2D-Slice clustering+single circle fitting | 81 | 72.3 | Single circle fitting | -0.8 | 4.2 |
| 81 | 72.3 | *Multi circle fitting* | -1.6 | 3.4 |
| 81 | 62.9 | Cylinder fitting | 0.5 | 7 |
| Tansey *et al*., 2009 | 1 | 8 m | C | Flat | 0.05 (r.) | 1131 | 4 MS | XY cluster at 1.3 m+ Hough transform detection | / | / | Hough transform | -1.6 | 2.3 |
| / | / | Cylinder least square fitting | -3.4 | 3.6 |
| / | / | Circle least square fitting | -1.7 | 1.9 |
| Murphy e*t al.*, 2010 | 18 | 958 (~340 m) | C (EA) | Flat | 0.1 (r.) | 207– 570 | SS | Similar to 14 | 68 | 59 | 1.3m circle fitting or diameter profile | -0.3 – -1.9 | / |
| 5 MS | 100 | 99 |  |
| 15 | C (EA) | Flat | 0.03- 0.13 (c.) | 153– 326 | SS | Similar to 14 | *86* | 82 |  |
| 2 MS | 99 | 98 |  |
| Antonarakis, 2010 | 2 | 261 | B p (1 Co) | / | 0.49 (s) | 255– 2340 | 5 MS | Similar to Hopkinson | 80 (100&60) | / | Cylinder fitting (similar to [10]) | 0.3 – 0.4 | / |
| Othmani *et al*., 2011 | 17 | / | Co & EA | / | 0.07 (c.) | 56– 3600 | SS | Clustering+filtering+fitting circle |  | 90.6 | 1.3 Circle fitting +cor. with local linear diam. profile | 80%  < 5 cm | / |
| Lovell *et al*., 2011 | 2 | 157 | C | Flat | 0.13 & 0.79 (c.) | 124/ 477 | SS | intensity thresholds+maximum intensity value | / | 54/68 |  | / | / |
| Liang *et al*., 2012 | 9 | / |  |  | 0.03 (c.) | 509– 1432 | SS | local 3D point density+flatness (eigenvalue)+vertical distribution | / | 73 |  | / | / |
| Liang *et al.*, 2013 | 5 | 128 | C or M | / | 0.03 (c.) | 605– 1210 | SS | Similar to [53] | / | 73.4 | Cylinder fitting | 0.35 | 0.74– 2.41 |
| 4 MSS | Similar to [53] + new registration method | / | 95.3 | Cylinder fitting | 0.47 | 0.9– 1.9 |
| Pueschel e*t al*., 2013 | 2 | 149 | B &C | Slight slope (6&11%) | ~0.5 (s) | 579– 1032 | SS | Similar to Forsman and Alme, 2005 (neighboring difference in range image) | / | 84-85 | Circle fitting (+cor. with local linear diam. profile) | -0.07– 0.51 | 1.39– 2.43 |
| 6 MS | / | / | 0 – -0.32 | 0.64– 1.15 |
| Trochta *et al*., 2013 | 8 | / | / | / | 0.03 - 0.07 (p) | / | SS | Manual | 88 | / | / | / | / |
| 4 MS | 94 | / | / | / | / |
| Schilling *et al*., 2014 | 18 | 995 | B p | / | 0.07 (c.) | 452– 1160 | >3 MS | Hough transform with disc+ clustering+ row filtering |  | / | / | / | / |
| Mengesha *et a*l., 2014 | 7 | 268 | C | Slope (15-25%) | 0.07 (c.) | 538– 707 | 3 MS | Similar to [14] | / | 80.7 | / | / | / |
| 9 | 388 | 468– 637 | 3 MS | / | 86.2 | / | / |
| Liang *et al.*, 2014 | 1 | 46 | C | Slope (15%) | 0.2 (r.) | 250 | *PLS* | Similar to [54] for MSS | *96* | *82.6* | Cylinder fitting | *1.1* | *5.06* |
| Ryding *et al.*, 2015 | 3 | 171 | B | / | 0.01 (s) | (2700– 7900) | 3 MS | Manual | / | / | Cylinder fitting | 0.5 | 1.5 |
| *HMLS* | / | / |  |  |  |
| This study | 10 | 331  (202m) | B & C (Co, EA and UEA) | Flat & slope | 0.07 (c.) | 113– 1344 | SS | Similar to [19] | 83 | 75 | Similar to [19] | -1.16 | 3.26 |
| 5 MS | 99.5 | 92.8 | -0.17 | 1.16 |
| *HMLS* | *99.5* | *89* | *-0.05* | *1.07* |