**Comparing the Accuracy of Airborne Laser Scanning (ALS)- and Terrestrial Laser Scanning (TLS)-based methods, and manual measurements for short period Individual Tree Growth Detection**

**Introduction:** Accurate forest change studies require advanced methods for change detection and accurate reference data for determining the level of accuracy of the used methods. In this study, both topics were assessed. Three change detection methods (TLS-based, ALS-based and manual measurements) at individual tree level were cross-compared. Also, the accuracy of each individual datum and method was mathematically estimated based on the cross-comparison metrics.

**Methods:** A boreal forest test site in Evo, Finland was manually measured and laser scanned in 2014 and 2021. From the point clouds, tree stem curves were automatically extracted using the algorithm developed by Hyyppä *et al*. (2020). The growth in diameter at breast height (DBH) and stem volume was then calculated by a) subtracting the stem curve proportions of 2014 from 2021 in the TLS-based method, b) obtaining the stem curve of 2021 from the respective point cloud and then scaling the stem curve proportions according to height growth in the ALS-based method, and c) subtracting the manual measurements of stem proportions.

Additionally, the accuracy of each individual growth measurement method was calculated based on the RMSE and bias metrics of cross-comparison. Using these metrics, it was possible to derive a bias estimate and a standard deviation estimate of each individual growth measurement method.

**Results:** The results showed that the ALS-based method worked the best when growth manual measurements were used as reference data (correlation 0.44 {0.66}, RMSE 9.8 mm {0.052 m3} in DBH {stem volume}). At short time periods, there is high correlation in the residual error of a scaled stem curve which was mostly cancelled when the scaled stem curve proportions were subtracted. This did not occur with the TLS-based method, in which the stem curve proportions were estimated individually for 2014 and 2021. However, because of under-canopy location and denser point clouds, the TLS-based single-time DBH and volume values correlated the best with the single-time manual measurements.

Because of two independent stem curve estimations, the TLS method produced the most outlying growth values (4 in DBH and 8 in stem volume). The ALS method produced 1 and 3 suspicious values of DBH and stem volume growth, respectively. The manual measurements produced only 1 suspicious value of DBH growth, but no suspicious stem volume growth values.

The standard deviation estimates of each individual method showed that the manual measurements are the most accurate (standard deviation 4 mm {0.03 m3} in DBH {stem volume}), but the ALS-based method is closely followed (standard deviation 8 mm {0.04 m3}).

**Conclusion:** The accuracy of laser-scanning based change detection methods is rapidly approaching the accuracy of the current, manually measured reference data. Therefore, in order to develop and benchmark even more advanced forest change detection methods, the accuracy of the underlying reference data should be considered.

 **References:**Eric Hyyppä, Antero Kukko, Risto Kaijaluoto, Joanne C. White, Michael A. Wulder, Jiri Pyörälä, Xinlian Liang, Xiaowei Yu, Yunsheng Wang, Harri Kaartinen, Juho-Pekka Virtanen and Juha Hyyppä. (2020) ‘Accurate derivation of stem curve and volume using backpack mobile laser scanning’, *ISPRS Journal of Photogrammetry and Remote Sensing*, Volume 161, pp. 246-262, <https://doi.org/10.1016/j.isprsjprs.2020.01.018>