SUMMARY

This study evaluated the accuracy of the latest, high-end commercial personal laser scanner (PLS) in estimating diameter at breast height (DBH) and tree height in an old pedunculate oak (*Quercus robur* L.) stand. The research was conducted in the state-owned management unit Šiljakovačka Dubrava (Forest Office Velika Gorica, Forest Administration Zagreb, Croatian Forests Ltd.) in Central Croatia, in a 145-year-old oak stand. Three circular sample plots (20 m in radius each) were established, including 40 oak trees in total (Figure 1). Reference data were collected by detailed field measurements and terrestrial laser scanning (TLS). DBH was measured using a diameter tape, while TLS (FARO Focus Premium 150) was used as the reference for tree height. TLS data were acquired using a multi-scan approach from five scan positions per plot (Figure 3a), whereas PLS data were collected using FARO Orbis according to a predefined walking scheme (Figure 3b). Both scanners, along with their technical specifications, are presented in Figure 2 and Table 1.

Before extracting individual tree attributes, a pre-processing of the collected TLS and PLS data was carried out. TLS data were pre-processed (registration, georeferencing) using FARO SCENE v2025.1.1, while PLS data were pre-processed using FARO Connect v2025.1 (Figure 4). Processing of TLS and PLS data (point clouds) was performed in the same manner using LiDAR360 v8.1. After normalising the point clouds, DBH of each tree was semi-automatically estimated; firstly, by approximate determination of diameter by the operator, which was secondly approximated by the fit-by-circle method, i.e., by the software algorithm that approximates DBH using the least squares method to fit a circle from the x-y coordinates of input points. Stems fitted by the circle method were used as seed points for individual tree segmentation (Point Cloud Segmentation from Seed Points algorithm; Figure 5). Within the segmentation process, the heights (H) were automatically estimated and then manually checked for any inconsistencies or errors (Figure 6). The measured and estimated DBH and tree height values for each tree, obtained from field measurements, as well as TLS and PLS data, are provided in the appendix (Table A1).

The accuracy assessment compared PLS-derived attributes against reference data using the correlation coefficient (r), mean difference (MD) and root mean square error (RMSE). Results for DBH (Table 2) showed a strong correlation with reference values (r = 0.995), with deviations ranging from –0.99 cm to 3.02 cm. The MD was 0.62 cm (1.28 %), and the RMSE was 1.04 cm (2.13%). Figure 7 illustrates the slight, systematic overestimation of PLS-derived DBH. Tree height estimates (Table 2) were even more accurate, with deviations between –0.13 m and 0.92 m. The correlation with TLS reference data was r = 0.995. MD was 0.22 m (0.69%), and RMSE was 0.30 m (0.95%). Figure 8 demonstrates the close agreement between PLS and TLS estimates, again with a slight overestimation trend.

The results confirm the high accuracy and reliability of PLS data for both DBH and height estimation in an old oak stand. Minor biases can be attributed to structural and morphological characteristics of trees, such as thick and furrowed bark in old oaks, which may cause an overestimation of DBH. Overall, the findings align with previous studies (e.g., Jurjević et al. 2020, Hyypä et al. 2020, Vandendaele et al. 2022, Kokeza et al. 2024, 2025), which report a slight overestimation but high accuracy of PLS-derived tree attributes.

In conclusion, when high-end instruments are used, the PLS technology provides highly accurate and efficient estimates of DBH and tree height, demonstrating strong potential for integration into operational forest inventory. Further research across different stand types and conditions is recommended to establish best-practice guidelines for PLS data acquisition and processing.

KEY WORDS: personal laser scanning (PLS), LiDAR, diameter at breast height, tree height, forest inventory