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| **Comparison and validation of multiple QSM algorithms against destructively sampled biomass measurements** |
| **Introduction/Aim:** Terrestrial laser scanning (TLS, also terrestrial LiDAR) has proven its ability to capture in-situ forest structure with sufficient detail to estimate individual tree biomass and topology. Therefore, TLS currently plays an important role in validation and calibration of both site-specific and global aboveground biomass and forest structure studies. Quantitative structure models (QSMs) that convert point clouds into volumetric 3D models have been instrumental in the process of deriving tree structure and biomass estimates from tree point clouds. Despite the availability of multiple QSM algorithms, there is no standardized benchmarking procedure present and there is an apparent scarcity of open-source validation data. The objectives of this work are to validate existing and previous research utilizing these algorithms, to propose avenues for the future development of QSMs, and to establish a framework for future validation efforts. **Methods:** Here, we utilized a combined dataset from four previous studies of co-incident TLS scans and destructively measured AGB to compare and contrast multiple different QSM reconstruction methods, including *TreeQSM v2.0, TreeQSM v2.4.1,* and *AdTree*. An additional QSM reconstruction method, *RayCloudTools,* will also be added to the comparison in the future. The combined dataset consists of 144 trees from Australia, Belgium, Guyana, and Brazil, and includes both conifer and hardwood point clouds across 14 different species. Point clouds that were obtained in “leaf-on” conditions were leaf-wood separated using the PointTransformer deep learning architecture that was trained on a dataset of manually segmented tree point clouds (Van den Broeck et al., 2024; in preparation). QSM based volumes were obtained using each algorithm and compared to the destructive sampling values. Additional analysis focused on understanding the allocation of volume within generated QSMs, and the effect of point cloud quality on the biomass estimates. **Results:**Results show significant variation in the overall ability for different QSM algorithms to estimate total tree biomass. *TreeQSM v2.4.1* demonstrated a large amount of variability of biomass estimated, as well as a large biomass overestimation (an average of 3.8 times the destructive values; CCC = 0.62), while *AdTree* performed better (CCC = 0.82), and *TreeQSM v2.0* was the most accurate (CCC = 0.98). The analysis for *RayCloudTools* estimates are currently being processed. Additionally, there is a variable effect of point cloud quality in the generated tree volumes from different models. Furthermore, the stability, ease of use, and accessibility varied greatly between tested algorithms, which is important to weigh against quantitative results. **Conclusion:** Validation and benchmarking of QSM algorithms against each other will lead to increased data-interoperability of LiDAR-based biomass and structure estimates. Additionally, the importance of cultivating pipelines to easily acquire high-quality LiDAR data is once again underlined, as there is a clear improvement in QSM model quality alongside point cloud quality. We hope to make full use of the open-source validation data that is available, and to further explore potential validation and benchmarking procedures. |