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| **Assessing forest structural complexity: insights from alternative laser scanning approaches** |
| Forest structural complexity describes the size, shape and spatial arrangement of vegetation, being valuable information for forest management and conservation. Structural complexity can be estimated with conventional measurements, but to increase the level of detail, estimation accuracy and scalability, numerous remote sensing techniques have been developed. In this study we utilized close-range airborne and terrestrial laser scanning (ALS, TLS) to understand how well these technologies capture vertical, horizontal and volumetric complexity of the forest. Our goal was to generate new insights for forest structural complexity assessment to address whether additional value is obtained from TLS measurements conducted on-site, or if assessments from ALS point clouds suffice. Additionally, we investigated whether structural complexity should be assessed directly as the variability in the sampled observations (grid-level approach) or through the variability of the dimensions of individual trees (object-based approach).  Research was conducted in boreal forests in Southern Finland. TLS and ALS data were collected in May 2021 from 99 circular plots with a radius of 20 m. ALS data was collected from a helicopter at an altitude of 80 m, resulting in point cloud density of 1 800 pts/m2. TLS point clouds were acquired using one center scan and eight auxiliary scans from plot borders, with one scan featuring 3 mm point spacing at 10 m distance. Using the ALS and TLS point clouds, we computed metrics characterizing vertical, horizontal, and volumetric forest structural complexity using both grid and object level approaches. At the grid level, estimations included canopy height model variability and canopy cover variability within 6 x 60° sectors, as well as the proportion of voxels filled by vegetation, measuring vertical, horizontal, and volumetric complexity, respectively. Object level estimations were based on individual tree detection and characterization of the variability in tree height (vertical), crown area (horizontal), and box-dimensions (volumetric complexity). To assess which method could capture the largest variability in complexity, we applied F-test to compare ranges of the complexity measures between ALS and TLS. Agreement between ALS and TLS-based structural complexity estimates were assessed using coefficient of determination (R2) and Spearman’s rank correlation coefficient.  ALS captured a wider range of vertical complexity through the object-level approach, but TLS demonstrated greater capability in characterizing the range of horizontal complexity. TLS was also capable of capturing a significantly wider range of volumetric structural complexity estimations compared to ALS (*p* < 0.05). In general, object-level estimations had a broader range in both horizontal and vertical complexity (*p* < 0.05), whereas grid-level estimations obtained a significantly larger range in volumetric complexity. The highest agreement between the ALS and TLS was recorded for tree crown height (R2 = 0.66, Spearman rank = 0.76), whereas the lowest agreement was found for box-dimension (R2 = 0.03, Spearman rank = 0.25).  The results of this study highlight that object level estimations can capture a broader range in variation, and therefore these approaches should be prioritized in structural complexity assessments. However, grid-level estimation with TLS provided better characterization of the range for volumetric structural complexity. |