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| **Remote Sensing-based Two-Phase Forest Inventory using High-resolution Laser Scanning** |
| **Introduction/Aim:**  Remote sensing (RS) has been extensively used within various statistical inference frameworks for estimating forest variables. This study presents an entirely RS-based forest inventory approach using terrestrial laser scanning (TLS) data and samples of very high resolution (VHR) airborne laser scanning (ALS) data within a hybrid-inference framework for estimating the total stem volume of a test site. The variance of the design-phase dominated the total uncertainty and two methods were tested for estimating the design-phase variance: A) Increasing the sample variance of the ALS strips by splitting them into smaller grid cells at various regular spatial intervals, and B) using the established Matérn variance estimator based on splitting the strips into square cells of equal dimensions.  **Methods:**  The test-site is located in mid-Sweden covering 5km2. The VHR ALS data with an average point density of 593 points/m2 was acquired in 4 systematic strips of 11km length and 0.1km width (design-phase). Thirty-two points were distributed randomly within the 4 ALS strips, where TLS scans were done using a single-scan mode to provide diameter estimates of trees. An individual tree crown (ITC) segmentation algorithm was implemented for detecting trees in the laser data. ALS metrics were derived for each ITC segment. The segmented TLS and ALS ITCs were linked based on diameter estimates, transformed geolocations, and proximal tree top distances within 10m search radius. The stem volume of TLS trees (VOLTLS) were estimated using allometric functions. A model for VOLTLS as a function of ALS metrics was developed, VOLTLS=*β0+β1X1+…+βpXp*, where [*β0,βp*] are the model coefficients for *p* ALS metrics selected as explanatory variables (model-phase). Hence, the tree-level stem volume could be estimated for all ALS ITCs, which were then used in a ratio-estimator to predict the stem volume for the entire test-site based on the 4 ALS strips. The variance of the design-phase with method ‘A’ was estimated by splitting the strips into grid cells at equal intervals and implementing a random sampling variance estimator for systematic subset of the grid cells. The theoretical derivation of this approach remains to be developed, whereas, for method ‘B’, the strips were divided into square cells of equal dimensions and further split into equal halves horizontally and vertically followed by implementing the Matérn cross-variance estimator.  **Results:**  The total stem volume per hectare (ha) was estimated as 123.3m3ha-1 for the test-site. The variance of the model-phase for hybrid inference contributed less than 1%, while the variance from the design-phase contributed around 99% of the total variance. The standard errors () from the two methods were: (A) 6.33m3ha-1 (5.1%) and (B) 4.35m3ha-1 (3.5%).  **Conclusion:**  This study proposes that an entirely RS-based forest inventory can be conducted using VHR laser data using hybrid inference. Alongside, this study compared two methods for estimating the design-phase variance, where the Matérn estimator (method ‘B’) indicated the lower variance. The total uncertainty appeared relatively low compared to model based wall-to-wall approaches and the sample based design phase is cost efficient and allows the inventory to be repeated more frequently than wall-to-wall inventories. |

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