Finding hidden trees in remote sensing of forests by using stochastic geometry, sequential spatial point processes and the HT-like estimator

Lauri Mehtätalo[1], Kasper Kansanen[2] and Adil Yazigi[2]

[1] *Natural resources institute Finland (LUKE), Joensuu, lauri.mehtatalo@luke.fi*
[2] *University of Eastern Finland, Joensuu*

Remote sensing is increasingly used in collecting data for forest inventories. Especially, aerial and terrestrial laser scanners are used to collect three-dimensional information about the forest. In aerial laser scanning, a laser scanner is installed to airplane or a drone and the device is used to collect information about the forest canopy below. Individual tree detection can further be done using the laser point cloud to extract individual tree crowns and estimate the tree heights and tree crown size and shape. In terrestrial laser scanning, a scanner is placed on a tripod and the surrounding forest is scanned for measurements of tree stems. Individual tree stems can be detected from the point cloud and used for estimation of tree DBH and other tree characteristics.

In both abovementioned cases, the detected trees can be ordered according to their shortest distance to the sensor. Because of this hierarchical ordering of trees, trees that are "earlier" in the hierarchy can cause "latter" trees to remain undetected because they are located in the hidden area or sector formed by the earlier trees. These undetected trees cause problems in inventories where the population totals per area-unit are of interest. We discuss a recently introduced Horvitz-Thompson-like estimator for the population totals in this setting, which is unbiased in certain conditions if the tree locations follow the complete spatial randomness [1, 2]. We also present approaches to take into account the spatial pattern of tree locations in the approach by using a ordered spatial point process model [3].

References

[1] Kansanen, K., P. Packalen, M. Maltamo, and L. Mehtätalo. (2021). Horvitz-Thompson-like estimation 521 with distance-based detection probabilities for circular plot sampling of forests. *Biometrics* early view. URL https://onlinelibrary.wiley.com/doi/abs/10.1111/biom.13312.

[2] Kansanen, K., J. Vauhkonen, T. Lähivaara, and L. Mehtätalo. (2016). Stand density estimators based on individual tree detection and stochastic geometry. *Canadian Journal of Forest Research* 46(11):13591366. URL http://dx.doi.org/10.1139/cjfr-2016-0181.

[3] Yazigi, A., A. Penttinen, A.K. Ylitalo, M. Maltamo, P. Packalen, and L. Mehtätalo. (2019). Sequential spatial point process models for spatio-temporal point processes: A self-interactive model with application to forest tree data. *arXiv preprint*