Editorial

Laser Scanning in Forests

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The introduction of Airborne Laser Scanning (ALS) to forests has been revolutionary during the last decade. This development was facilitated by combining earlier ranging lidar discoveries [1–5], with experience obtained from full-waveform ranging radar [6,7] to new airborne laser scanning systems which had components such as a GNSS receiver (Global Navigation Satellite System), IMU (Inertial Measurement Unit) and a scanning mechanism. Since the first commercial ALS in 1994, new ALS-based forest inventory approaches have been reported feasible for operational activities [8–12]. ALS is currently operationally applied for stand level forest inventories, for example, in Nordic countries. In Finland alone, the adoption of ALS for forest data collection has led to an annual savings of around 20 M€/year, and the work is mainly done by companies instead of governmental organizations. In spite of the long implementation times and there being a limited tradition of making changes in the forest sector, laser scanning was commercially and operationally applied after about only one decade of research. When analyzing high-ranked journal papers from ISI Web of Science, the topic of laser scanning of forests has been the driving force for the whole laser scanning research society over the last decade. Thus, the topic "laser scanning in forests" has provided a significant industrial, societal and scientific impact.

The number and variety of remote sensing methods and applications of all kinds of lasers and ranging measurements for forests continues to increase. The need for increased research having high potential for societal impact has led to this special issue, which invites authors to cover new methods in information extraction, new developments in individual-tree-based or area-based inventories, developments in the use of laser waveform for forest measurements, and new applications and concepts for using laser scanning

for forests. Additionally, coverage of topics such as techniques for the fusion of ALS and TLS data and accuracy and performance evaluations were requested.

Concerning area-based and individual-tree-based inventories several improvements were proposed. In [13], an improvement for individual tree detection was reported applicable for both area-based and individual-tree-based inventory. When trees overlap, the surface model between the trees corresponding to the first pulse stays high, whereas the corresponding model from the last pulse results in a drop in elevation; its better penetration between the trees and this drop in elevation can therefore be used for separating trees. In [14], the accuracy of the results achieved from regression models based on 0.5 m raster cells was approximately 2–5% lower than that achieved from the 3D point cloud, which points to the use of smaller raster cells in practical forest inventories for computational reasons. Paper [15] summarizes the findings of the ISPRS/EuroSDR Tree Extraction project after further analyzing the results obtained in different tree height classes. Several methods were reported to be superior to manual detection of the dominant, co-dominant and suppressed trees. In addition, new and point cloud-based clustering methods were recommended for suppressed tree detection. In paper [16] the decay rate obtained from waveforms showed the best correlation with average Leaf Area Density. In Vaughn *et al.* [17] discrete point data alone provided 79.2% overall accuracy for tree species discrimination (five species) whereas waveform information improved the overall accuracy to 85.4% for the five species. Shrestha and Wynne [18] reported that biophysical parameters, such as tree height, diameter breast height, crown diameter, and biomass, can be extracted for individual trees in an urban area based on point-based lidar distributional metrics.

Practical forest inventories further require delineation of stands, accurate elevations models, and cost-efficient ALS data; these topics were also covered in the special issue. The delineation of forested areas is a critical task, because the resulting maps are a fundamental input for a broad field of applications and users. In Eysn *et al.* [19] a new approach for the automatic delineation of forested areas is reported based on defining crown coverage as a relation between the sum of the crown areas of three neighboring trees and the area of their convex hull. The study by Treitz *et al.* [20] provided further evidence that low-density LiDAR-based predictions offer significant potential for integration into tactical forest resource inventories. Fricker *et al.* [21] developed a methodology to quantitatively correct sub-canopy elevation derived from large-footprint lidar data in dense tropical forests using small footprint discrete-return lidar measurements. Consequently, the correction reduced the average digital elevation model error and variance significantly, particularly over sloped terrain.

Close-range measurements might be used in sample based inventories, in reference data collection and in the studies leading to new concepts in airborne data collection. Wallace *et al.* [22] reported using a laboratory prototype of a multispectral lidar to measure NDVI relating to canopy biomass. Seielstad *et al.* [23] reported that TLS utilizing intensity data is capable of distinguishing fine fuels from branches with high accuracy. By using an intensity threshold to classify fine fuels and branchwood, it was also anticipated that fuel mass by size class could be predicted from laser density data.

In the future, space-borne lidar will contribute to accurate and efficient global biomass estimates. There is also a need to study synergy of SAR and lidar. Ballhorn *et al.* [24] demonstrated that ICESat/GLAS data can be used to measure peat topography and to collect large numbers of forest biomass samples in remote and highly inaccessible peatland forests based on an experiment in Central Kalimantan, Indonesia. Hilbert and Schmullius [25] demonstrated the potential of estimating terrain

elevation and tree height using ICESat/GLAS waveforms in the Thuringian Forest. Peduzzi *et al.* [26] showed that lidar and SAR data showed an important synergistic gain in the explanation of LAI variability.

We would like to thank the authors of the special issue for their contributions to our SilviLaser ("Laser Scanning in Forests") society and additionally thank the reviewers and the *Remote Sensing* Editorial Office for conducting a high-quality review process for all of the published papers. We hope that this special issue will further stimulate the scientific, societal and industrial impact on our society.

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