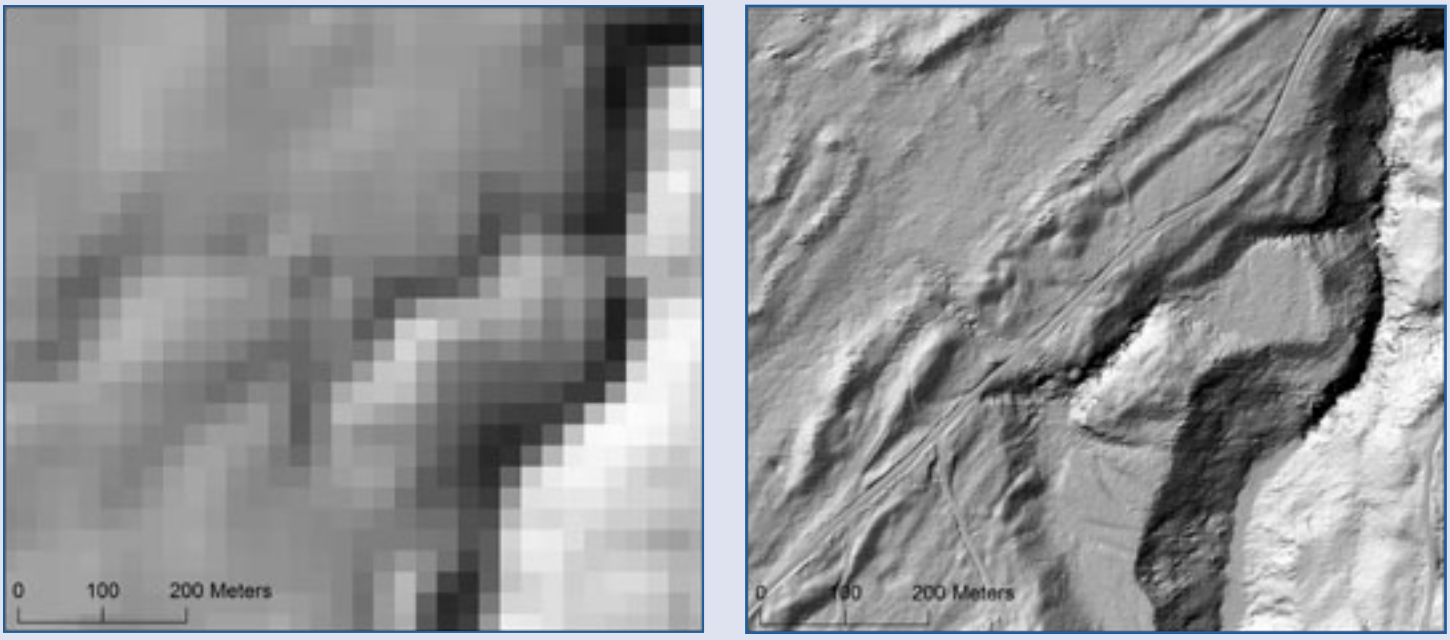


Figure 1. A comparison between a TRIM gridded digital elevation model (DEM) (25 m spatial resolution) (left) and a DEM generated from ALS data (1 m spatial resolution) for a 800 x 800 m area of BCGS mapsheet 092F.084 (near Campbell River, BC).

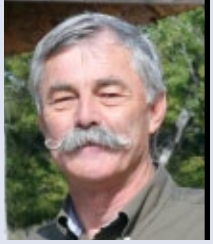
A Best Practices Guide for Generating Forest Inventory Attributes from Airborne Laser Scanning Data Using an Area-Based Approach

Airborne laser scanning (ALS; also referred to as Light Detection and Ranging or LiDAR) can map terrain and forest canopy structure at higher accuracy and finer resolution than air photo interpretation (Figure 1). Many forest companies have realized cost reductions by using ALS data in operational planning and there is growing interest in using ALS data to produce enhanced forest inventories (EFI). For more information on EFI, readers can refer to the January – February 2013 issue of **BC Forest Professional** (*Operational Implementation of LiDAR for Forest Inventory Purposes in Ontario*, p. 14). Recently, Western Forest Products and BC Timber Sales shared the cost of acquiring ALS data for more than 100,000 hectares of forest land on northern Vancouver Island, and are partnered with the Forest Analysis and Inventory Branch to ensure the EFI will meet vegetation resources inventory (VRI) standards.

As the use of new technologies in forest inventory can often necessitate alterations to existing standards, it is important to ensure consistency and transparency in the application of technology and related outputs. The Canadian Forest Service (CFS), Natural Resources Canada, has recently produced a best practices guide for the use of ALS data in forest inventory applications. The guide is available for download from the CFS bookstore (http://cfs.nrcan.gc.ca/publications?id=34887) and brings together state-of-the-art approaches, methods and data to enable readers interested in using ALS data to characterize large forest areas. The best practices recommended are based on more than 25 years of scientific research on the application of ALS data to forest inventory. The entire process required to generate forest inventory attributes from ALS data is described — from ground sampling through to metric generation and model development — with best practices recommended for each step. Since the collection of ground plot data for model calibration and validation is a critical component of the recommended approach, it is described in detail in the guide. Appendices provide additional details on ALS data acquisition and metric generation. The guide is not intended to be prescriptive, but rather to provide a science-based foundation upon which those interested in using ALS data to produce EFIs can make informed decisions appropriate for their specific forest and management environments.

An area-based approach is a method for predicting forest inventory attributes such as volume or basal area, at high spatial resolution across an entire management area. Using ALS data and ground plot measurements, the area-based approach is accomplished in two steps (Figure 2). In the first step, tree-level attributes (e.g. height, basal area) from a sample of ground plots are measured and summarized to the ground plot level. ALS data are acquired for the entire area of interest (wall-to-wall coverage) and canopy metrics (e.g. descriptive statistics) are calculated for each grid cell, the size of which relates to the size of the measured ground plots. Canopy metrics are also calculated for a subset of the ALS data that are clipped to correspond to the area (shape and size) of the measured ground plots. These co-located ALS data and ground measurements are then used to develop predictive models for forest inventory attributes of interest. To ensure the development of robust models, it is necessary for the ground plots to represent the full range of variability





Viewpoints

By Joanne White, Mike Wulder and Roger Whitehead

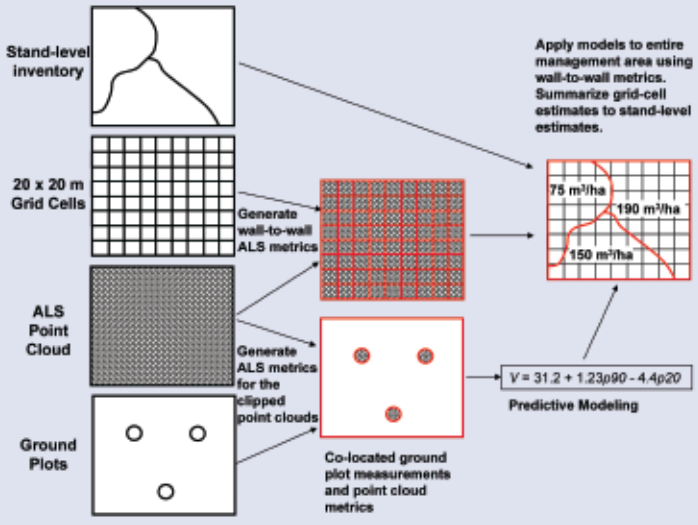


Figure 2. Schematic of the area-based approach using ALS data to generate forest inventory attributes.

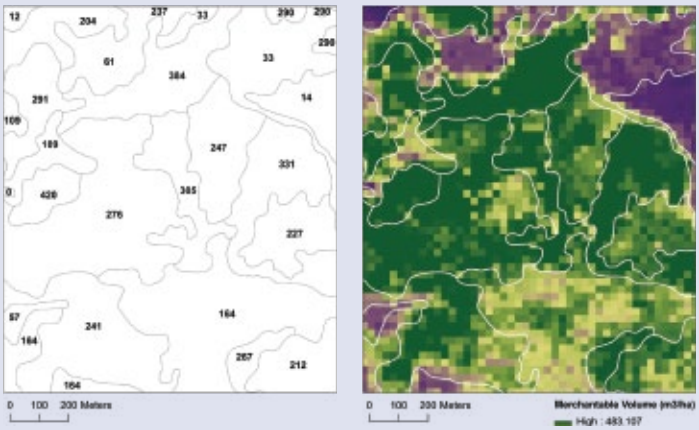


Figure 3. A conventional forest inventory provides a single stand-level estimate of merchantable volume (m³/ha) (left), whereas an EFI provides a grid-cell level estimate (right), enabling within stand variability to be characterized.

in forest conditions in the area of interest. To this end, it is recommended that the ALS data be acquired first and that select metrics be used to stratify the area of interest and guide the acquisition of ground plots. In the second step of the area-based approach, these predictive models are applied to every grid cell in the area of interest to generate wall-to-wall estimates and maps of specific forest inventory attributes. The outputs are raster layers that can be stored and analyzed within a GIS.

The foremost advantages of the area-based approach are:

- Having complete (e.g. wall-to-wall) spatially explicit measures of canopy height, associated ALS metrics and all modelled attributes (e.g. basal area, volume) for an area of interest.
- Scalability of the resulting information.

Conventional forest inventories provide a single stand-level estimate for a given attribute of interest, whereas the area-based approach using ALS data provides within-stand estimates of attributes of interest that can then be rolled up to the stand level (Figure 3). The ability to scale wall-to-wall ALS-based estimates allows them to be seamlessly integrated into existing conventional stand-level strategic, tactical and operational forest inventories. This enables within-stand variability to be characterized while at the same time not precluding the implementation of standard or mandated inventory practices. Moreover, the scalability of ALS-based estimates can greatly improve synergies between strategic and operational information for management and planning. Lastly, it should be noted that estimates of forest inventory attributes derived from ALS data using the area-based approach often meet or exceed operational accuracy requirements.

Citation:
White, J.C., Wulder, M.A., Varhola, A., Vastaranta, M., Coops, N.C., Cook, B.D., Pitt, D, Woods, M. 2013. A best practices guide for generating forest inventory attributes from airborne laser scanning data using the area-based approach. Information Report FI-X-10. Natural Resources Canada, Canadian Forest Service, Canadian Wood Fibre Centre, Pacific Forestry Centre, Victoria, BC. 50 p.

For more information contact:
Joanne White is a research scientist with the Canadian Forest Service (Pacific Forestry Centre, Victoria, BC). Specializing in remote sensing applications in forestry, Joanne has co-authored more than 70 peer-reviewed science articles. Contact her at: joanne.white@nrcan.gc.ca

Mike Wulder is a senior research scientist with the Canadian Forest Service (Pacific Forestry Centre, Victoria, BC). Recognized as an international expert in the application of LiDAR for forest applications, Mike has co-authored more than 200 peer-reviewed science articles. Contact him at: mike.wulder@nrcan.gc.ca

Roger Whitehead is a regional coordinator of the Canadian Wood Fibre Centre (CWFC) in Victoria, BC. The CWFC is a virtual research centre of the Canadian Forest Service, with employees distributed across the country. As part of its mandate to increase competitiveness of Canada's forest industry and benefit forest-based communities across the country, CWFC delivers the Resource Assessment Program of FPInnovations, which is focused on resource characterization, production and optimization. Contact Roger at: roger.whitehead@nrcan.gc.ca