Quantification of the relationship between LiDAR derived canopy gaps and field measured expanded gaps in the boreal forest

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Introduction

The use of forest growth models to estimate future harvest volumes is important in sustainable forest management planning. However, the use of these models can result in an overestimation of volume compared to actual harvest volumes. One reason is the presence of natural and anthropogenic forest gaps that are not explicitly accounting for during modeling.

Tansaniu (2007) attempted to quantify these volume losses using temporary sample plots, however his results suggested complete enumeration of gaps would be required. Airborne LiDAR can identify these gaps using a LiDAR derived canopy height model. By relating the LiDAR gap areas identified (crown opening) to actual expanded gap areas (stem to stem) measured in the field, we estimated how many single trees, using their average occupancy area (stem to stem) were needed to fill in the gaps. Using species, size (height, diameter) and density, the total volume lost was estimated.

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Methods

Study Area: Weyerhaeuser Forest Management Area (FMA), Grande Prairie

Study Stand Type: Pure trembling aspen (Populus tremuloides) polygons
- 80% trembling aspen by canopy cover
- 50 - 70% total canopy cover
- 19 - 23 meters in height
- >10 in size

Sampling and Analysis:

LiDAR data was acquired from Alberta Environment and Sustainable Resource Development. In these data the point cloud averaged 1.6 hits/m² across the landscape. The point cloud was converted to a 2 m/m² (chm) raster using FUSION (Figure 1). Gaps were discerned from canopy using a 14.95 meter height merchantability threshold, 1.5 cm stump and 7 cm top (Figure 2).

In the field, the expanded gaps (stem to stem) were measured from a random sample of LiDAR gaps. These expanded gap areas were related to the LiDAR gaps using regression (Figures 3, 4 and 5).

Within the block a transect was established to systematically select trees to determine the average occupancy area (stem to stem) of mature trees with complete crown enclosure (Figure 6). The average occupancy by dbh was modeled (Figure 7). Using the estimate of the total expanded gap area within each polygon and the average mature tree occupancy area, the number of trees needed to fill in the gaps was estimated. Using the number of trees and the average volume/mature tree, the total volume lost due to gaps within a polygon was estimated.

The volume lost due to gaps was compared to results from an intensive temporary sample survey program used to estimate average polygon volume.

Figure 1: Polygon 289 Canopy Height Model (CHM)

Figure 2: Polygon 289 CHM reclassified using merchantability threshold

Figure 3: Example of LiDAR gaps and field validated expanded gaps

Figure 4: Schematic of relationship between LiDAR gaps and Expanded Gaps

Figure 5: Polynomial models relating LiDAR Gaps to Expanded Gaps

Figure 6: Schematic of relationship between mature trees and occupancy measurements

Figure 7: Relationship between tree dbh and occupancy area of mature trees in Polygon 289

Results: Polygon 289

- Total polygon area = 27.5 ha
- Calculated merchantable LiDAR gap area = 4.9 ha (17.8% of total area)
- Predicted expanded gap area of merchantable gaps (> 29 m²)
  = 10.2 ha (37.0% of total area)
- Average Occupancy Area = 29.55 m²
- Estimated volume for an average mature tree (DBH = 26.3 cm) = 0.477 m³

Volume Reconciliation: Polygon 289

- Step 1: The estimated volume lost based on modelled expanded gaps is:
  27.55 m² occupied occupancy/ha
  0.477 m³ mature tree vol. = 13725 m³/stand lost vol.
- Step 2: The estimated lost volume per hectare is:
  1725 m³/ha
- Step 3: The estimated potential full stacked volume per hectare is:
  371 m³/ha avg. polygon vol. (from TSPs) + 0.477 m³/ha lost vol. = 417 m³/ha potential vol.

Reconciliation

- Average volume from areas with canopy cover = 70% = 440 m³/ha
- Estimated volume lost as a percent
  63 m³/ha lost vol.
  440 m³/ha est. vol. from TSPs with CC > 70%

Conclusions:

- LiDAR can be used to estimate the unproductive areas within a forest stand
- LiDAR gap area is strongly related to expanded gap area measured in the field. This relationship varies from stand to stand.
- The area that a single mature tree occupies (occupancy area) when measured in a similar manner as the expanded gap, can be used to determine the number of trees that are required to “fill in” the gaps with trees.
- Using the average size (height and dbh) of the merchantable trees in a stand an average volume per tree can be estimated and used together with density to estimate the volume lost due to gaps.
- The volume reconciliation shows that we can obtain reasonable estimates of volume loss.
- LiDAR derived canopy height models can be a useful in estimating the volume lost in a stand to gaps.

Acknowledgements:

Alberta Environment and Sustainable Resource Development
Department of Renewable Resources, University of Alberta
Weyerhaeuser Grande Prairie
Western Boreal Growth and Yield Association

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