Unmanned aerial systems for characterizing forest structure and enhancing forest inventories

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UBC FACULTY OF FORESTRY - INTEGRATED REMOTE SENSING STUDIO

forestry
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Enhancing forest inventories

Evolving Needs

- Timber & non-timber values
- Monitor forest dynamics
- Reduce cost & improve value
- Climate change
- Inform proactive legislation

Data Driven Shifts

1. Airborne laser scanning (ALS)
2. Characterize forest structure
3. Spatial attribute modelling

DAP (blue) and ALS (green) pointcloud cross-section
Digital aerial photogrammetry

PROVIDES

- Cost-effective alternative to lidar
- Vegetation structure data
- High density point cloud products
- Spectral information
- Propensity for inexpensive and routine acquisitions
- EFI update potential

PROCESSING

1. Align imagery data set
2. Generate tie-points between images
3. Create dense point cloud and ortho-imagery

Rudimentary overview of DAP point cloud generation
Unmanned aerial systems

**PROS**

- Rapid commercial growth
- Diversity in platform types
- Rapid operationalization
- High spatial / temporal resolution
- Low relative cost
- Realized interdisciplinary potential
- Niche imaging tool

**CONS**

- Propulsion longevity - platforms
- Limited area coverages
- Regulatory restrictions - LoS

3 cm RGB imagery taken near Nakusp, BC
PhD research objectives

1. Review, examine, and report on DAP’s successes and limitations for characterizing forests of varying structures.

2. Determine the role of DAP in generating, extrapolating, and updating EFI data.

3. Assess DAP-derived inventory products and datasets for their potential to monitor, update, and expand inventory knowledge, as well as inform multi-level forest management initiatives.
Dissertation organization

Assessing the role of digital aerial photogrammetry for characterizing forest structure and enhancing forest inventories

Chapter 2
DAP role in area-based inventories

Chapter 3
UAS as a DAP acquisition platform

Chapter 4
DAP terrain models in young sparsely forested sites

Chapter 5
Characterizing forest regeneration using DAP

Chapter 6
DAP for delineating biotic disturbances in maturing stands

Chapters 7 & 8
DAP for creating, updating, and monitoring EFIs in mature stands
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DAP for creating, updating, and monitoring EFIs in mature stands
Characterizing terrain

Does seasonal timing of DAP acquisitions influence accurate terrain information in sparsely forested openings?

What is driving terrain error? When are the optimal times to acquire data?

Characterizing terrain

**Methods**

1. Acquire 20 UAS imagery sets & process into DAP data

2. Generate DTMs for each acquisition & compare with reference ALS data

3. Outline DTM error relative to ALS

4. Compare acquisition timing and vegetation cover to DTM error
Characterizing terrain

Findings
1. DTM error least in early spring, late fall & early winter

2. Significant trends between:
   • Veg cover & flight date
   • DTM error & flight date

Innovations
1. Seasonal veg differences (cover) influenced DTM error

2. Insight into optimal seasons to acquire DTM data

3. Facilitate multi-temporal monitoring?
Assessing regeneration

Can temporal and spatial knowledge of forest regeneration be improved using DAP?

Surveys are abundant and costly. DAP to enhance silvicultural management approaches?

Assessing regeneration

Methods

1. Field measurement & imagery acquisition

2. Generate DAP & process imagery

3. Segment using spec & struc data

4. Classify into conifer, deciduous, ground

5. Analyze struc, spec, spatial statistics
Assessing regeneration

Findings
1. Accurate land cover classifications > 86%
2. Improved spatial delineation of regen
3. Dual benefit of spec & struc data in DAP
4. Textural metrics important for distinguishing land cover

Innovations
1. Wall-to-wall spatial data to inform treatments
2. Monitor progress towards free-to-grow; height growth
3. Establish framework for generating early stage growth and yield data
4. Products to provide spatial data to prove compliance - auditing / reporting
Updating inventory baselines

What is DAPs capacity to create, update, and monitor EFIs in maturing stands using DAP?

Detect and predict residual harvest volume? Can DAP update ALS?

2013 ALS CHM

2015 DAP CHM

CHM diff


Updating inventory baselines

Ch 7: AREA-BASED
- Determine DAP potential to predict residual volume
- Explore prediction synergies of ALS and DAP

Ch 8: TREE-BASED
- Compare tree level predictions for ALS and DAP
- Update ALS attributes with DAP derivatives
Area based approach

Findings
1. DAP effective at updating residual timber estimates
2. More accurate to model ALS and DAP volume separately & take difference - indirect method
3. DAP and ALS structure characterization fundamentally different

Innovations
1. Fine scale management monitoring & updating
2. UAS effective as an operational management & inventory tool
Individual tree approach

Findings
1. ~70% agreement in detection of dominant stems for ALS and DAP
2. Potential to use multiple height metrics to measure growth + volume
3. Volume increment and growth estimates agreed with independent data

Innovations
1. Multi-sensor approach to tree-based inventory updates
2. DAP capable of detecting growth & volume increments
3. Potential for plantation / highly productive stands.
Results summary

**UAS capable & effective as acquisition platforms**: characterize structure - enhance inventories

**Terrain**: DAP timing can influence DTM accuracies - veg cover

**Regeneration**: Spatial, structural, spectral characterization of regen

**Area-based inventory**: Predicting residual volumes - ALS & DAP synergy

**Tree-based inventory**: Individual tree attributes - monitor growth
Future direction

**Acquisition parameters**
- Standardization and benchmarking for:
  - Flight altitude & GSD
  - Image overlap
  - Sensor types
  - Illumination conditions
- Further explore UAS as platforms for cost-effective parameter benchmarking
- Investigate capacity of new forms of ALS technology for characterizing terrain surfaces under forest canopy

**Data processing**
- Optimize parameterization of image-matching software for varying forest environments
- Establish standardized photogrammetric and point cloud processing workflows and tools

**Inventory update and model development**
- Systematic testing of spectral metrics for estimating species-specific forest variables
- Assessing the robustness of DAP for segmenting forest strata relative to ALS
- Calibration of DAP canopy closure estimates to reliably detect change
- Assess potential for ALS area-based model transferability to DAP acquisitions
- Investigate how prediction accuracies vary across differing forest conditions, especially in larger and more complex stands

**Forest change and growth**
- Potential to use archival stereo-imagery acquisitions to inform forest change
- Capacity for multi-temporal DAP structure data to inform site index and age
- Synergistic use of ALS and DAP for improving growth and yield projections
Thank you!

DAP point clouds and underlying technologies are capable and effective at characterizing forest structure and enhancing forest inventories.