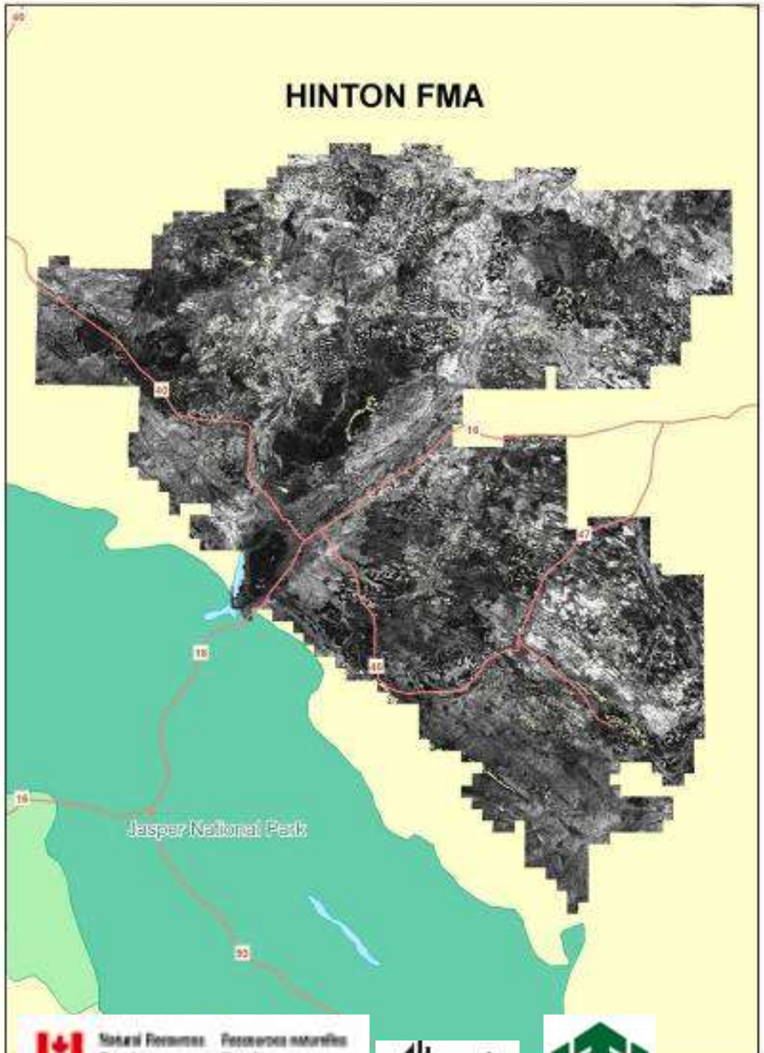
A Canadian Foothills Project



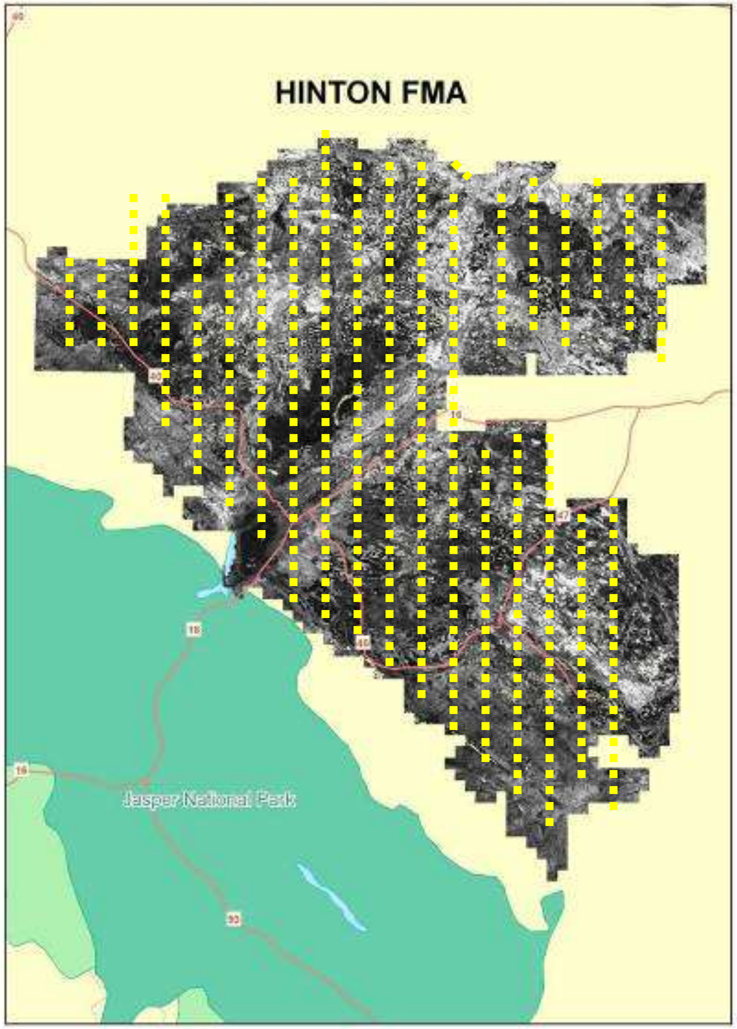
Study Area

- Hinton FMA ~990,000 ha; 385,000 AVI polygons

- Clients, Partners & Collaborators
  - West Fraser Mills, Hinton Wood Prods.
  - AB Sustainable Resource Development
  - CFS, Pacific Forestry Centre
    - Dr. Mike Wulder, Dr. Gordon Frazer, Joanne White, Geordie Hobart
  - University of BC
    - Dr. Nicholas Coops, Dr. Thomas Hilker, Danny Grills, Martin van Leeuwen, Chris Bater

Partners: WFM - Hinton Wood Prod.; Alberta SRD; CFS–PFC; UBC

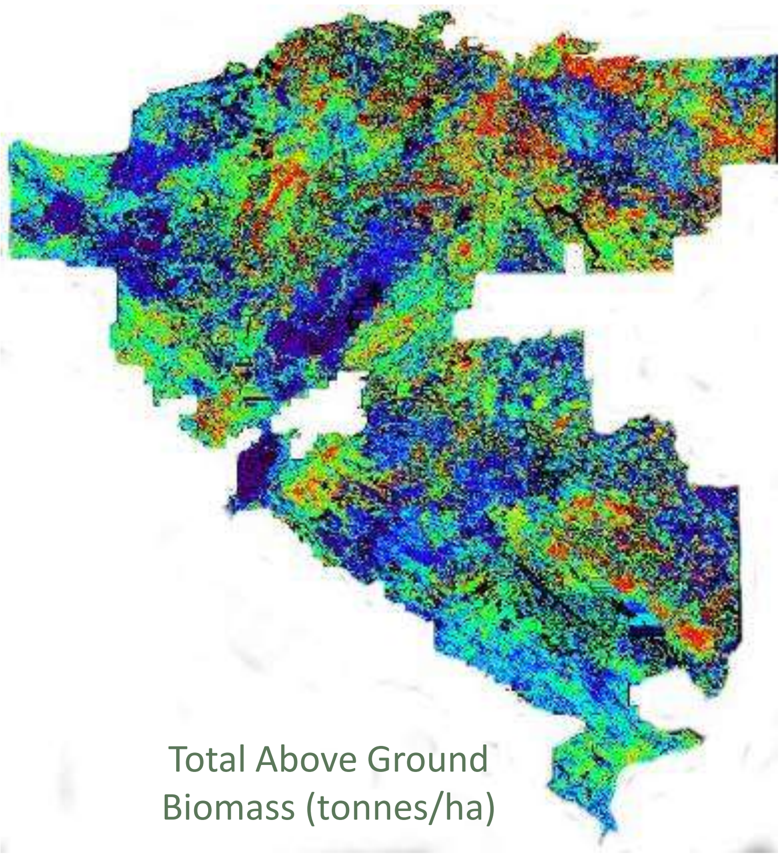
Ground Calibration → Prediction Model Development



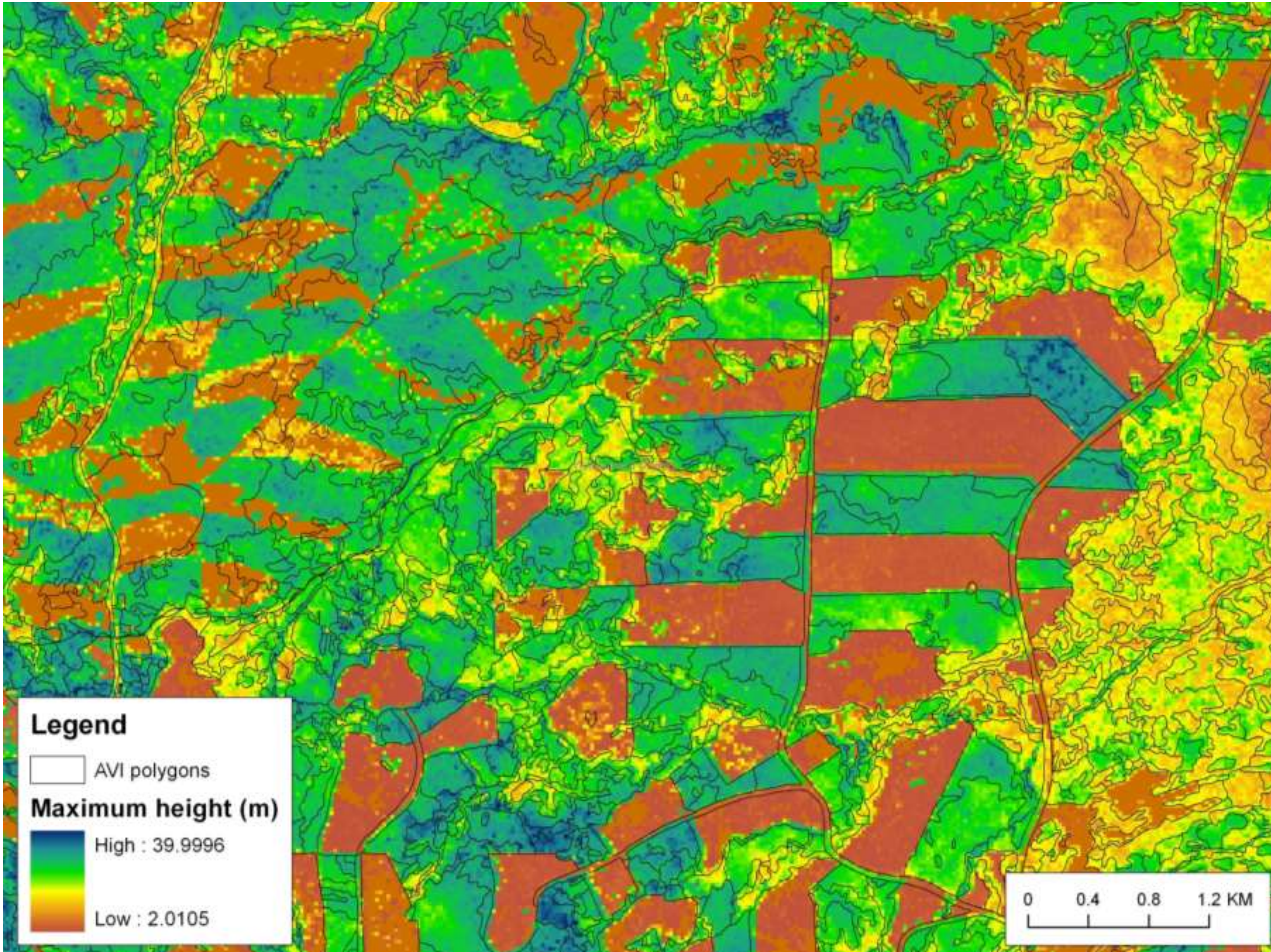
- HWP maintains a network of systematically distributed *Permanent Growth Sample Plots*
  - team used 788 of >3200 available plots to develop Prediction Models
  - Ordinary Least Squares multiple regression and a non-parametric tool *"Random Forests"* (resident in "R" statistical software) used to create prediction models
  - separate models developed for each of 3 "forest types", *based on AVI spp. composition*
    - "conifer-leading", "mixed" & "deciduous-leading"

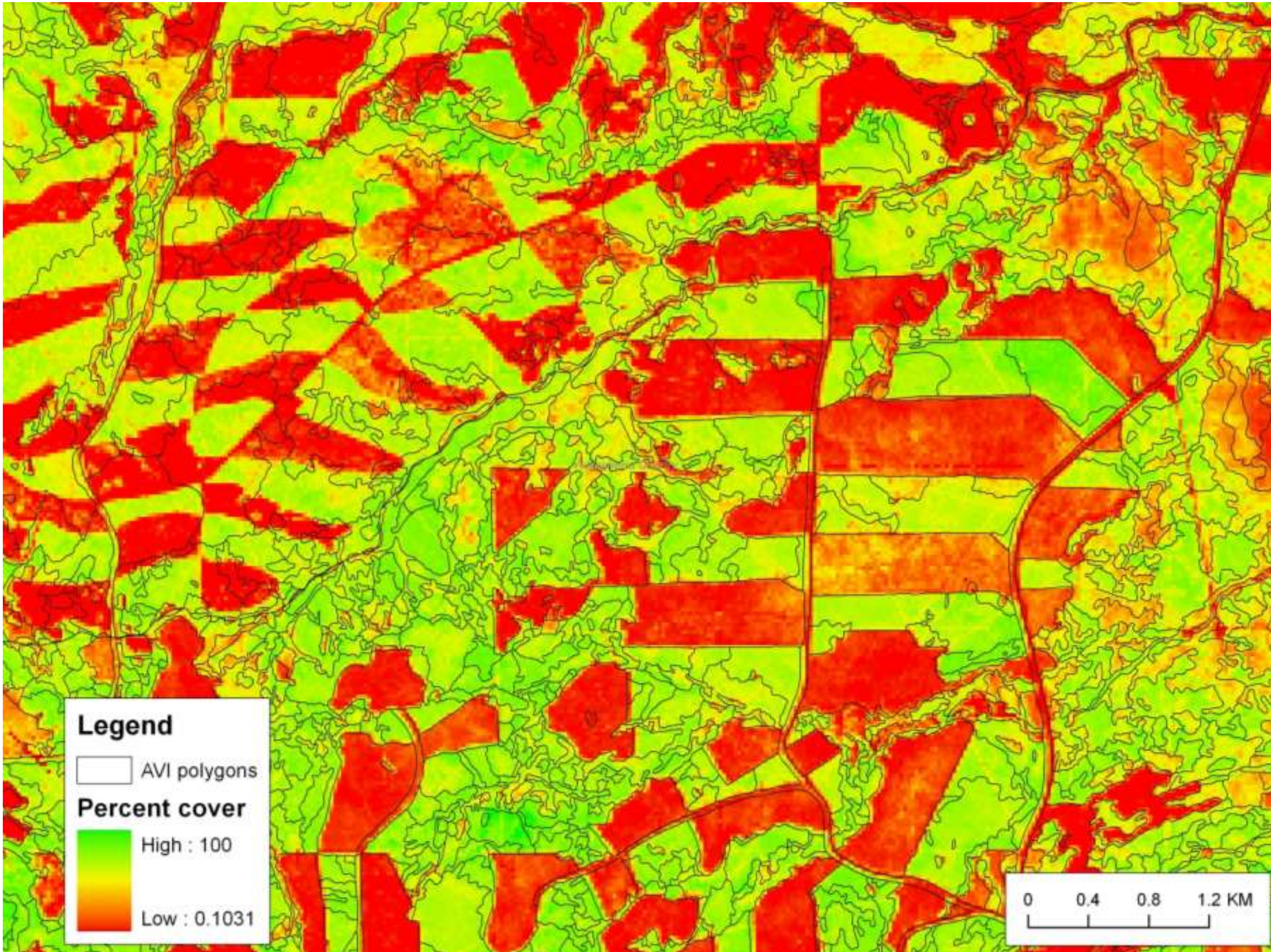
Predicted Inventory Variables → GIS Layers

- Mapped @ *"plot-level"* & @ AVI *"polygon-level"*
  - Top Height, Mean Height, & Modal Height
  - Quadratic Mean Diameter & Basal Area
  - Total & Merchantable Volume
  - Total Above Ground Biomass
- Also mapped all canopy metrics and several generalized plot/elevation characteristics
  - e.g. terrain wetness index, plan & profile curvature, solar radiation, hill shade, slope & aspect

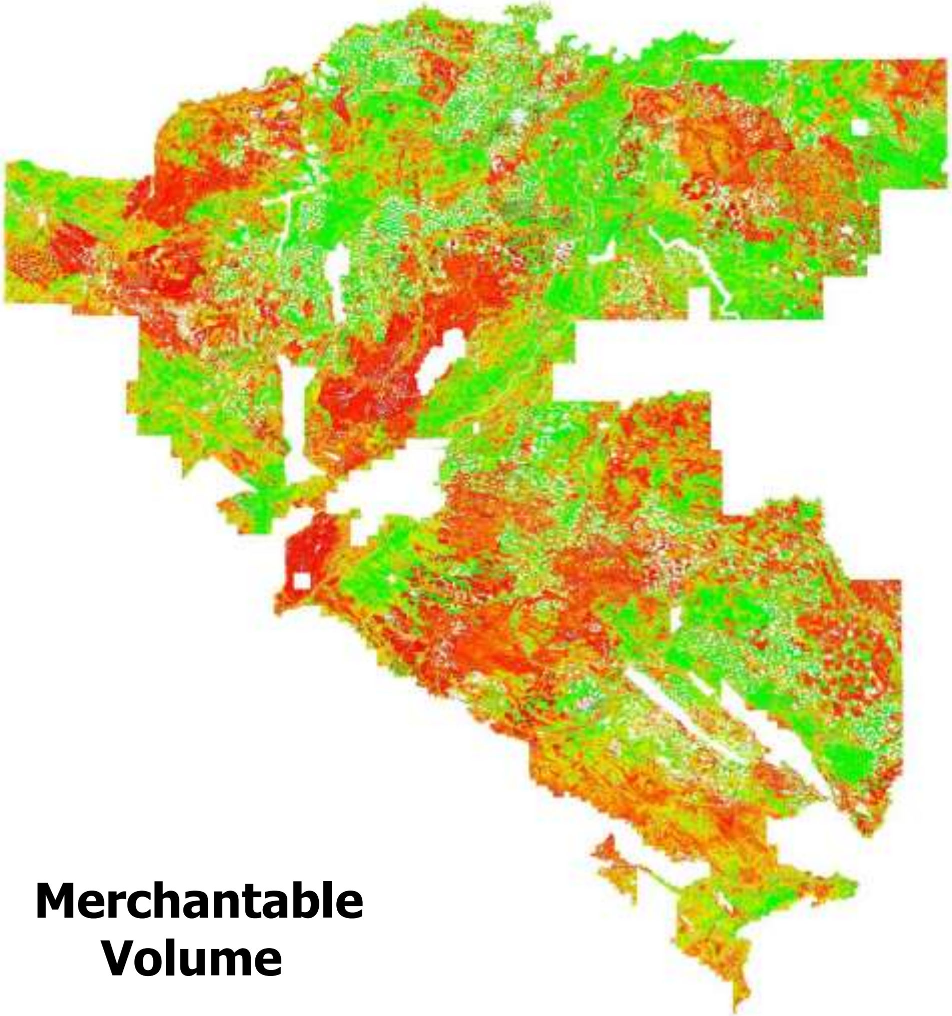


Total Above Ground Biomass (tonnes/ha)

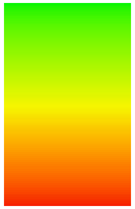

Legend
AVI polygons
Maximum height (m)
High : 39.9996
Low : 2.0105
0
0.4
0.8
1.2 KM

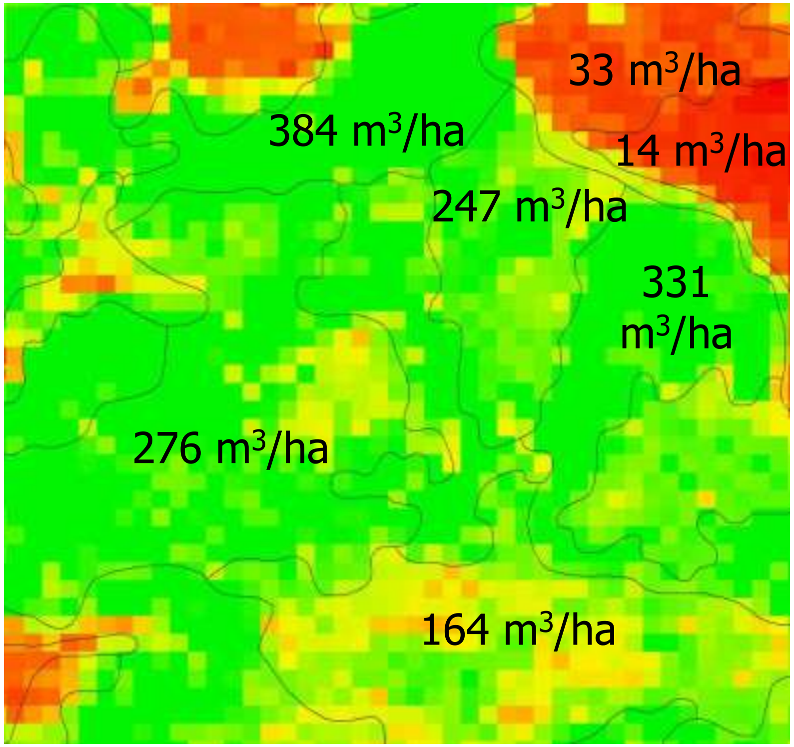


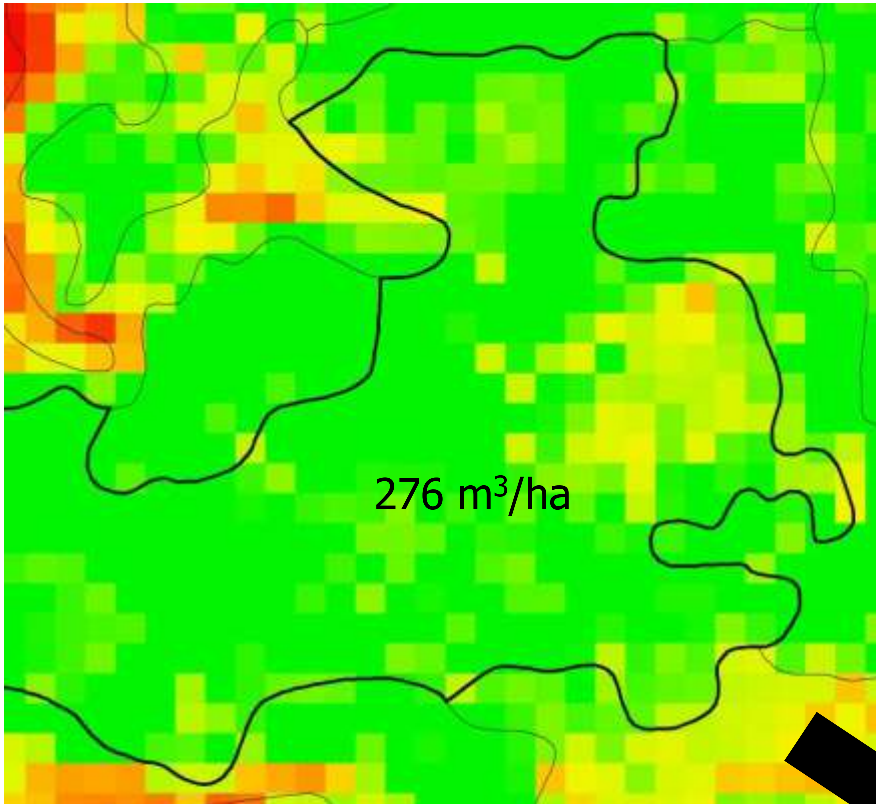
Legend
AVI polygons
Percent cover
High : 100
Low : 0.1031
0
0.4
0.8
1.2 KM



Merchantable Volume



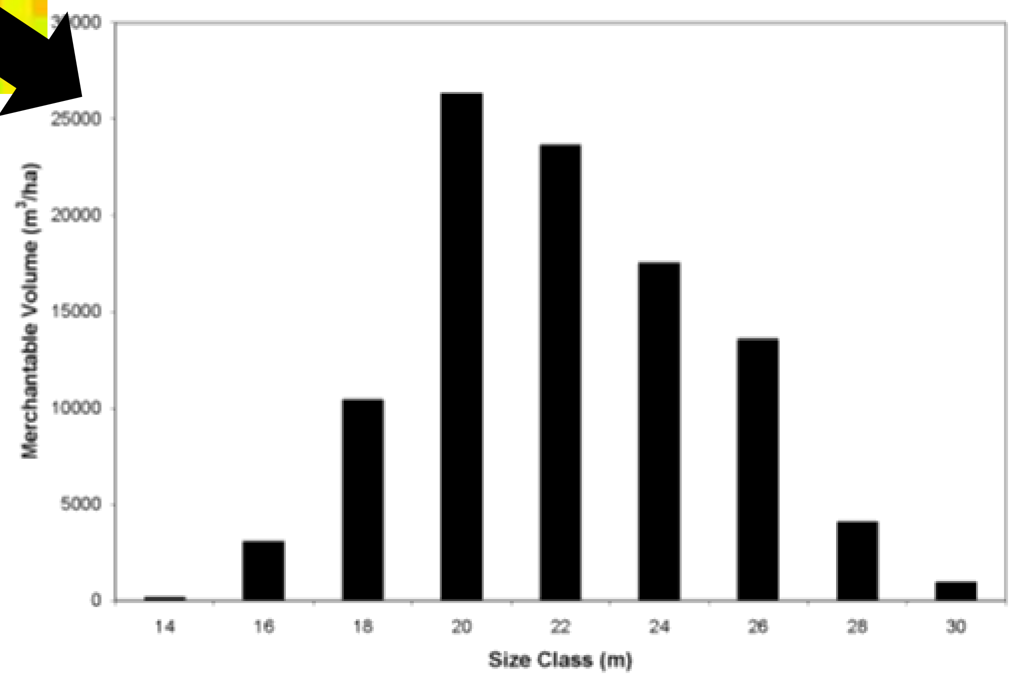




Within-block variability:

Count:	365 cells
Minimum:	102 m^3/ha
Maximum:	480 m^3/ha
Mean:	276 m^3/ha
Std Dev:	70 m^3/ha

95% CI: 276 m^3/ha ± 7.18 m^3/ha



Merchantable Volume

Validation

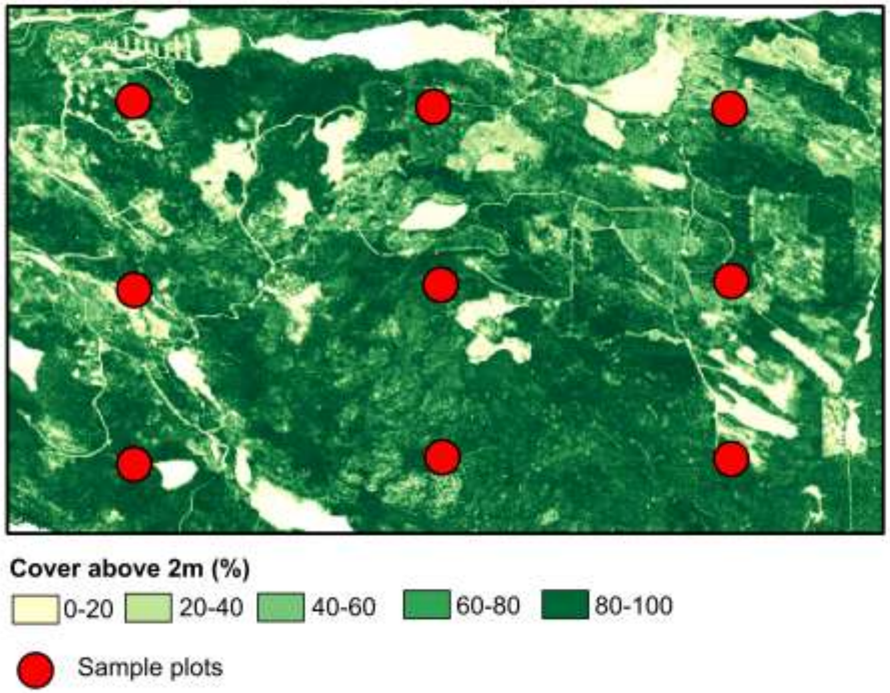
Weight-scaled volume from 272 cutblocks harvested since LiDAR acquisition compared to predictions from LiDAR & Cover Type Adjusted Volume Tables

Block Size (m^3 X1000)	Source of Prediction	Predicted Volume – Scaled Volume	Statistically significant?
< 5 n = 138	LiDAR CT Vol. Table	-6.7% -23.7%	No Yes
5 – 10 n = 76	LiDAR CT Vol. Table	+1.8% -17.4%	No Yes
10 – 15 n = 25	LiDAR CT Vol. Table	-1.2% -22.3%	No Yes
15 – 20 n = 15	LiDAR CT Vol. Table	-4.4% -23.5%	No Yes
>20 n = 18	LiDAR CT Vol. Table	+6.6% -17.4%	No No

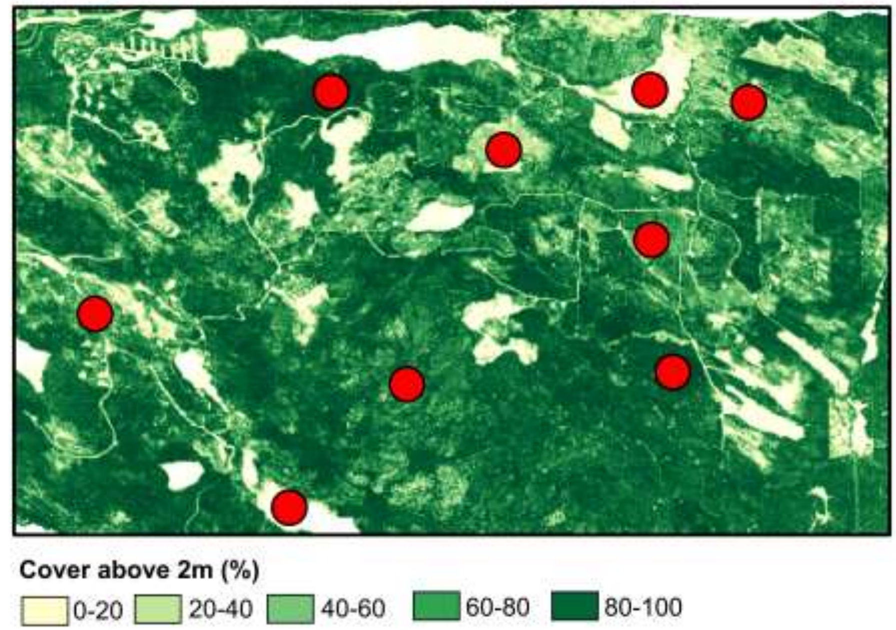
Information courtesy Hinton Wood Products A division of West Fraser Mills Ltd.

Selection of ground plots

Pre-existing Inventory Plots



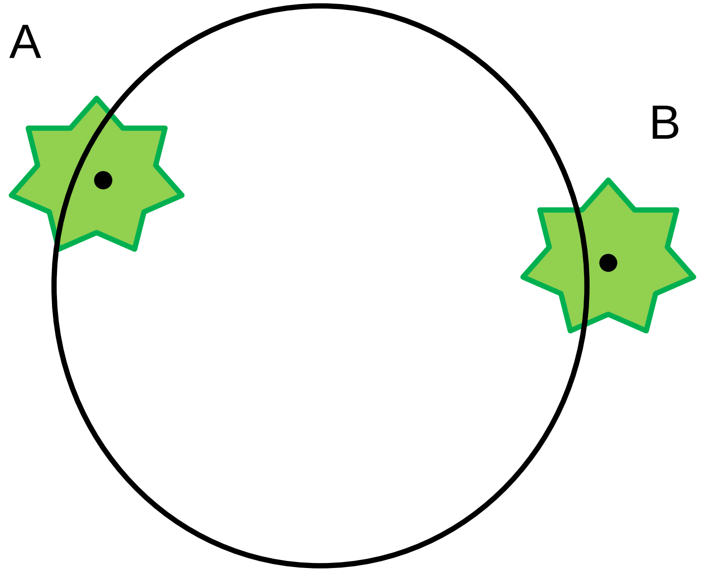
Stratified random sample



Select ground plots to capture full range of structural variability

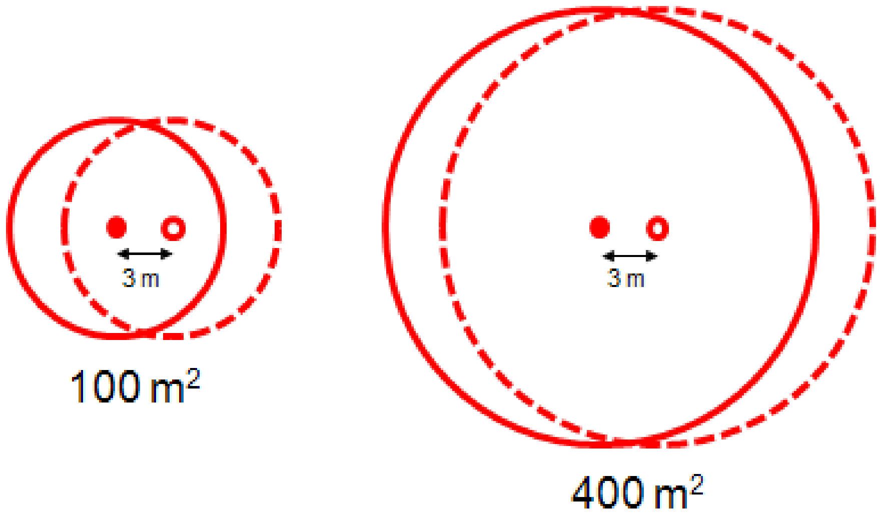
Ground Plot Data Characteristics: Size

- Larger plots are needed to:
  - Reduce perimeter-to-area ratio
  - Reduce likelihood of edge effects



Ground Plot Data Characteristics: Size

- Larger plots are needed to:
  - Reduce perimeter-to-area ratio
  - Reduce likelihood of edge effects
  - Minimize geolocation error



Ground Plot Data Characteristics: Size

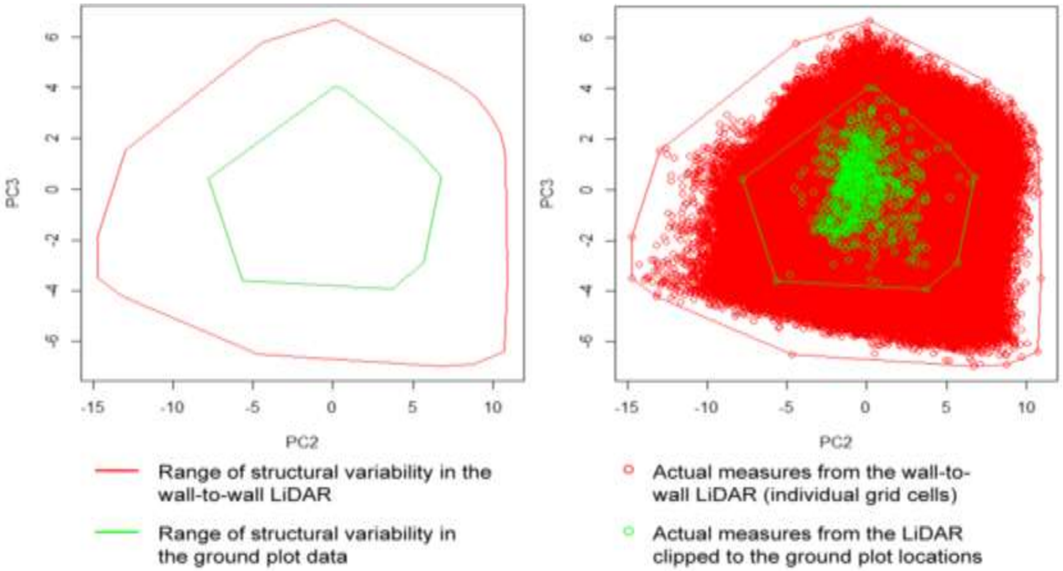
- Larger plots are needed to:
  - Reduce perimeter-to-area ratio
  - Reduce likelihood of edge effects
  - Minimize geolocation error

  - No universal optimum plots size
  - 200–625 m^2
  - minimize edge effects
  - minimize planimetric co-registration error
  - maximize sampling efficiency, precision, and accuracy of target and explanatory variables

Ground Plot Data: Representativeness

Higher errors in modelled outcomes associated with ground calibration data that does not capture the full range of structural variability as captured by the ALS data

Models perform best when operating within the bounds of their original calibration data.



Ground Plot Data:
Selection of ground plot locations

- Structurally-guided sample
  - Use a few key ALS metrics to stratify the area of interest (height, COV of height, canopy cover)
  - Select the required number of samples within each strata

Ground Plot Data: Positioning

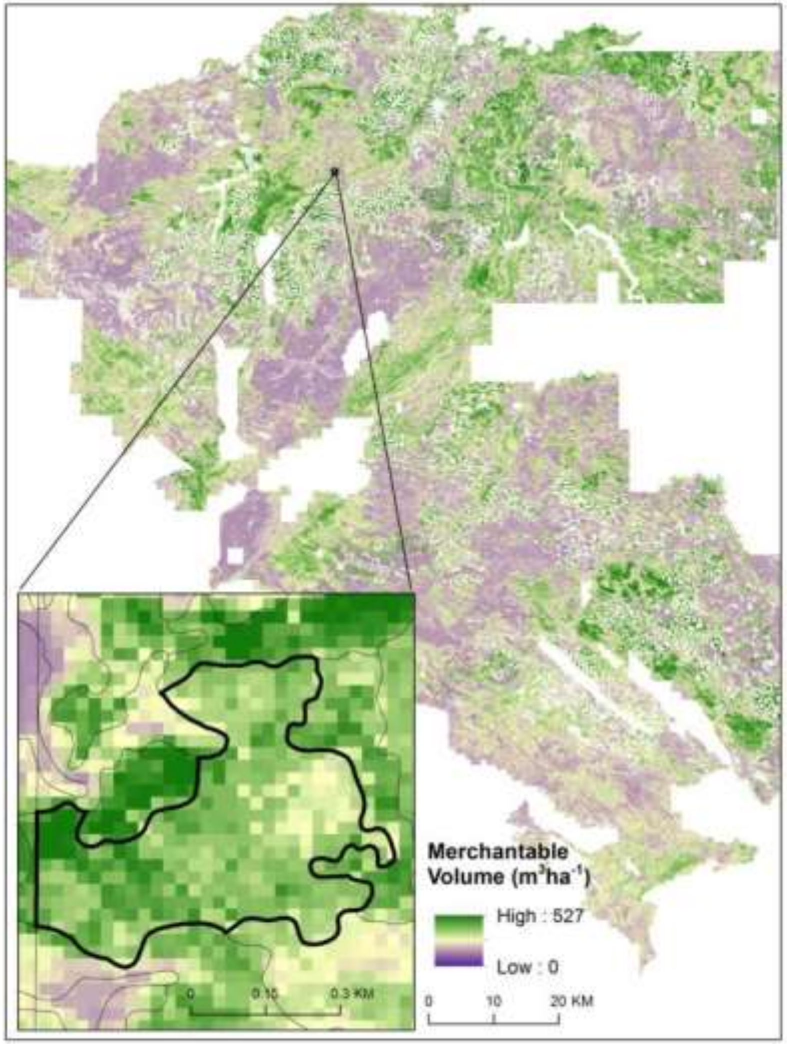
- Accurate geo-referencing is fundamental to maximize the predictive power of the model
- Recall that larger plots can help mitigate the impact of geo-location error
- GPS positioning is challenging in forest environments
  - Mapping-grade GPS receivers
  - 500 points/location
  - Post-processing correction

Modelling

	Parametric regression	Random forests
Advantages	• Transparent, easy to understand. • Model is an equation that clearly quantifies the relationship between the predictors and the variable being predicted. • Sample size determination is possible for given accuracy and precision requirements.	• Categorical variables may be predicted and (or) used as predictors. • Faster and simpler to develop (does not require sophisticated statistical expertise). • Does not require individual strata based models to be developed, provided calibration data represent the different strata involved. • Does not require a pre-existing polygon-based inventory to implement strata-based models.
Disadvantages	• Transformation of ALS metrics (*X*) or ground plot measures may be necessary to meet the assumptions of regression-based approaches, complicating interpretation and implementation. • More statistical expertise and time are required to create the models. • With strata-specific models, pre-existing stratification across the entire forest (i.e., an existing inventory layer) becomes prerequisite to implementation. • Prediction errors will occur within polygons when individual grid cells do not match the overall strata assignment (e.g., pockets of aspen within a "spruce" polygon).	• "Black box" nature of the models. • No equation output that is analogous to parametric regression. • More critical to ensure that the full range of conditions are sampled, as this approach does not extrapolate like regression.

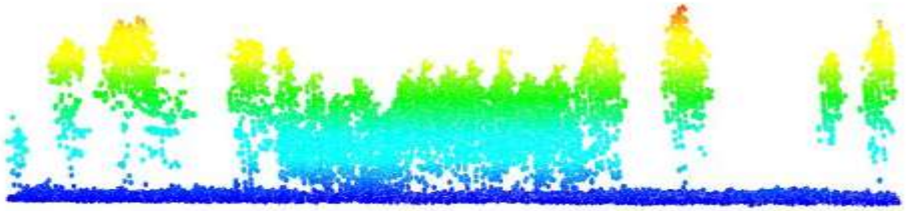
Mapping

- Once validated models can be applied to the entire area of interest using wall-to-wall metrics
- Common "no data" mask
- Models developed for specific forest types must be applied correctly
- Wall-to-wall rasters can be integrated into existing stand level inventories



Conclusions

- Using LiDAR technology, we can:
  - Directly measure tree heights
  - Calculate accurate estimates of stem volume and basal area
    - Accurate plot data is CRITICAL to accurate estimations of forest attributes
      - GPS location of plot centers
      - Short time lag between field measurements and LiDAR data collection
- LiDAR technology is continuing to improve
  - More pulses per square meter (from 4 to 8 to 12)
    - More accurate tree heights
    - Easier to identify individual trees
  - Methods to process LiDAR data are improving as well



LiDAR visualizations produced with FUSION/LDA software – USDA Forest Service

Thank you

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Resources

- Best Practices Guide
  - http://cfs.nrcan.gc.ca/publications?id=34887
- Forestry Chronicle December 2013 Practitioner's Corner
  - http://pubs.cif-ifc.org/doi/pdfplus/10.5558/tfc2013-132
- BC Forest Professional Newsletter (Nov/Dec 2013)
  - http://www.abcfp.ca/publications_forms/magazine.asp
  - http://cfs.nrcan.gc.ca/publications?id=35300
- CIF Enhanced Forest Inventory website
  - http://cif-ifc.org/site/enhancedforestinventory

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