

Innovative Forest Inventories

Operational LiDAR Inventory Working Group April 7, 2021

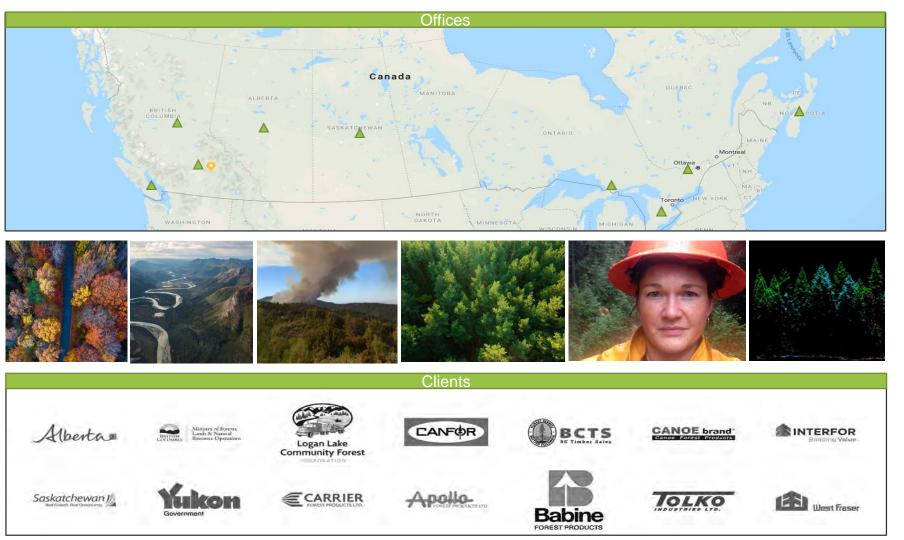
Mike Parlow Team Lead, Remote Sensing Inventories

Forsite Consultants



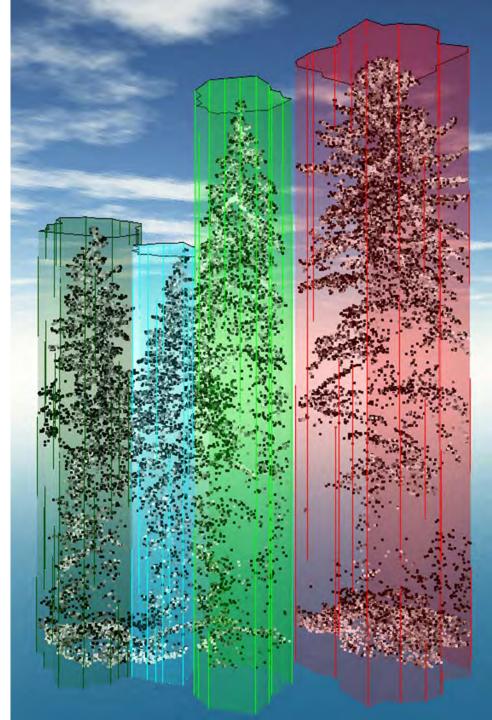
Forsite Consultants Ltd. is an integrated forest management company providing value to our clients through innovative, sustainable, and operationally realistic services. We focus on understanding what matters to our clients and their business and then supporting them in success – from strategic analysis to program implementation to field services. We employ a staff of over 150 employees and maintain 9 office locations in BC, Alberta, Saskatchewan, and Ontario.

The **Resource Management & Technology** (RMT) group is a business unit within Forsite Consultants focused on technological innovation and creative solutions to vegetation management requirements across industries.



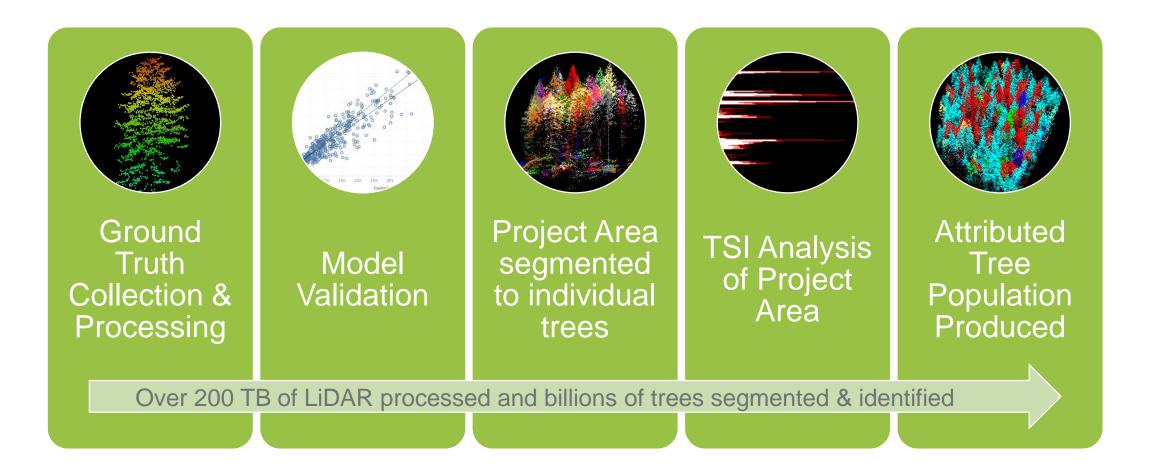
Agenda

Individual Tree Inventory background
 New Segmentation
 Machine Learning Descriptors



Tree Species Identification Process





Inventory Project Overview





Hybrid Enhanced

Operational Forest Inventory

- Field Plot creation & processing

- Area-based Analysis integrated with and built upon the Individual Tree Inventory foundation

Individual Tree Inventory

- Stereo Imagery or Field Crew to capture Stems and sample Areas

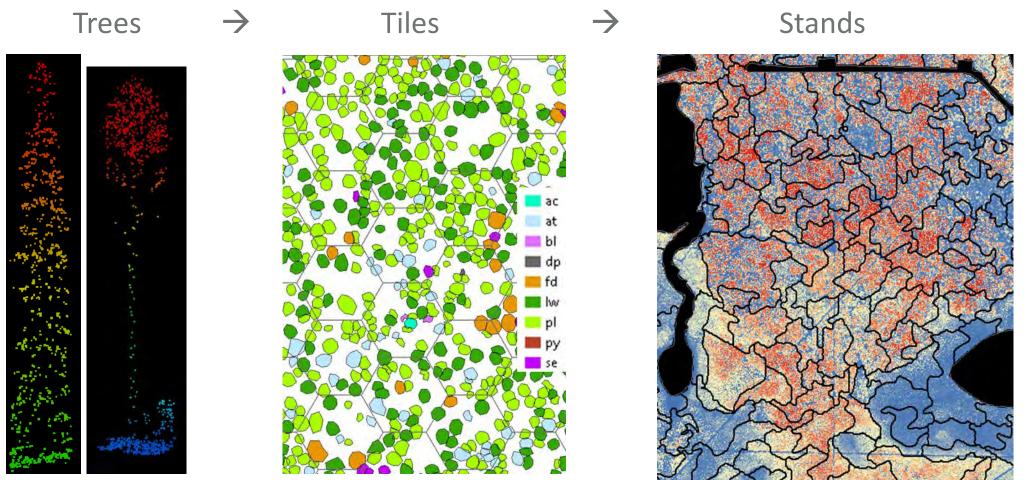
- Machine-learning Model Validation
- Segmentation of individual trees from the point cloud
- Analysis and Production of each segmented Tree in the AOI

Forsite Consultants - Innovative Solutions through Remote Sensing

Operational to Strategic



Linked Inventories – Different Uses, Same Data

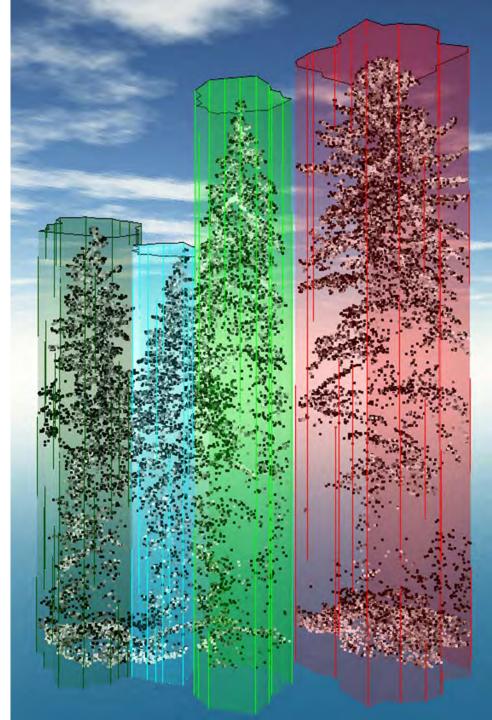


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| e Of Contents ↓ Section 2 ↓ Layers ↓ _Compartr ↓ _Compartr ↓ _Quarterse ↓ _Quarterse ↓ _Quarterse ↓ _Quarterse ↓ _Low : 0 | ction_Grid_ITI | Ψ × es_III | | | | | | | | | | | | | | | | Forsite LiDAR Add-In LiDAR Add-In provides quick operation planning analysis using LiDA-R-dd-In planning analysis using LiDA-R-dd-In- dd About Forest Influence Attribute Transfer FI/AT Setting Slope Analysis DLine Analysis DL/Slope Setting ITI EFI Hex Road Peg Road Peg Sta To analyse tree volumes, select a polygon feature(s) or draw a polygon. Where is the grid layer? _Quartersection_Grid_ITI |
|--|----------------|---|-------------------|-------------|---------|--|-------------------------------|------------|-----------------|--------|-------|----------|--------|--------------|---------------|---------|---|--|
| ITI Summary Sett | ings | | | | | ividual Tree Analysis Spp Com | p: Sw50 Aw36 Other Decid5 Pl4 | Other Coni | fer2 Fb1 Sb1 | | | | | | | | 3 | estimation et al. |
| AB - | | | Log Summary S | ettings | | ngs Export Summary (Total Trees) Tree | Summary (tph) Log Sumr | nary (Me | rch Volume (m3) | Log Su | mmary | (Total L | ogs) M | lean Pie | ce Size (m3) | | | Select a OR Draw a |
| Tree Summary S | ettings | Species Categories | Changelog | | | Category | Statistic | Aw | Other Decid | Fb | | | | | Other Conifer | Total | | Feature Feature |
| | | Aw 🔻 | Choose Log Top | 10 | • | Summary Overview | Gross Volume Total (m3) | 88.8 | 13.3 | 1.7 | 10.5 | 1.6 | 2.2 | 113.7 | 5.1 | 237.0 | | Bun Individual Tree |
| | 15 | Other Decid 👻 | Diameters | 20 | | Summary Overview | Merch Volume Total (m3) | 82.5 | 12.3 | 1.5 | 9.1 | 0.7 | 1.3 | 105.9 | 4.2 | 217.5 | | Analysis |
| Ht Categories | | | (cm) | 30 | | Summary Overview | Net Volume Total (m3) | 74.3 | 11.1 | 1.4 | 8.9 | 0.6 | 1.3 | 103.5 | 4.1 | 205.3 | | |
| (m) | 20 | Fb 👻 | | | | Summary Overview | Stems Total | 192.0 | 26.0 | 8.0 | 32,0 | 12.0 | 28.0 | 146.0 | 28.0 | 472.0 | | L |
| | 25 | PI + | | 40 | | | Total Area (ha) | | | | | - | | | | 4.7 | | |
| | 30 | | | 50 | | | | | | | | | | | | | | Operational pre- |
| | | Lt 🔹 | | 75 | | Stems by Height Category | | 24.0 | 0.0 | 2.0 | 6.0 | 2.0 | 16.0 | 20.0 | 14.0 | 84.0 | | Operational pre- harvest analysis: |
| | 40 | Sb 👻 | | | | Stems by Height Category | | 28.0 | 2.0 | 4.0 | 8.0 | 4.0 | 12.0 | 26.0 | 2.0 | 86.0 | | narvest analysis: |
| | | Sw - | | | | Stems by Height Category | | 108.0 | 22.0 | 2.0 | 16.0 | 2.0 | 0.0 | 46.0 54.0 | 12.0 | 208.0 | | |
| Choose Tree | 12.5 | 540 | Choose Log | 3 | | Stems by Height Category Stems by Height Category | | 32.0 | 2.0 | 0.0 | 2.0 | 4.0 | 0.0 | 0.0 | 0.0 | 94.0 | | Determine |
| DBH | | Other Conifer 🛛 🛨 | Lengths (m) | | | Stems by Height Category | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | volume, stem |
| | 17.5 | | | 8.2 | | orenis by neight category | Mean Ht (m) | 20.9 | 22.6 | 16.2 | 19.8 | 18.9 | 11.9 | 21.9 | 14.3 | 20.1 | - | mix by |
| (cm) | 22.5 | Specifying 'Other Conifer' or 'Other | | 16.4 | | | | 2013 | 22.0 | TOIL | 1010 | 20.5 | | | 14.5 | 2012 | | |
| | 0 | Decid' will capture | | 0 | | Stems by DBH Category | <= 12.5 cm | 22.0 | 0.0 | 2.0 | 6.0 | 6.0 | 16.0 | 16.0 | 14.0 | 82.0 | | species |
| | 0 | all other species. | Combine | djacentlogs | | Stems by DBH Category | <= 17.5 cm | 12.0 | 2.0 | 0.0 | 0.0 | 6.0 | 10.0 | 8.0 | 0.0 | 38.0 | | including |
| | 0 | 1 | to make lor | | | Stems by DBH Category | <= 22.5 cm | 24.0 | 4.0 | 6.0 | 14.0 | 0.0 | 2.0 | 18.0 | 10.0 | 78.0 | | stems by |
| | | Apply Reset | - | | | Stems by DBH Category | > 22.5 cm | 134.0 | 20.0 | 0.0 | 12.0 | 0.0 | 0.0 | 104.0 | 4.0 | 274.0 | | b aight and |
| - | | | | | | | Mean DBH (cm) | 23.8 | 27.7 | | 20.1 | 11.3 | 10.5 | 28.4 | 13.2 | 23.3 | | height and |
| Hex Summary | | | | | | | BA (m2/ha) | 2.0 | 0.3 | 0.0 | 0.2 | 0.0 | 0.1 | 2.3 | 0.1 | 5.1 | | DBH category |
| Tree Ht Catego | | · | | | | | | | | | | | | | | | | 0 / |
| DBH Categorie: | s (cm) | | | | 472 tre | ees, 4.7, ha 4/7/2021 9:58:48 A | | | 5.72 | | X | 382 | 5 | | | ALC: NO | | |

Agenda

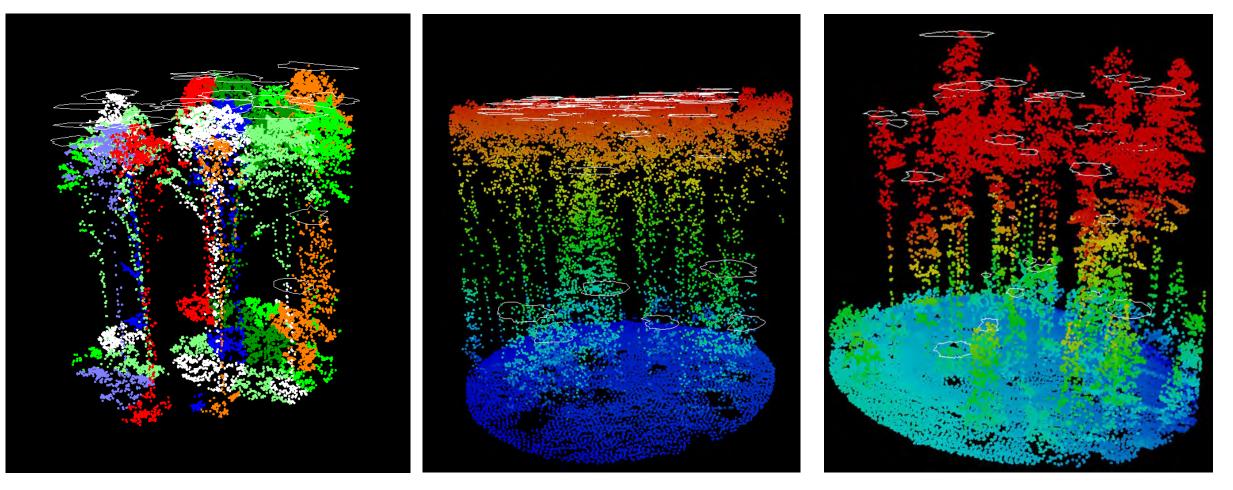
Individual Tree Inventory background
 New Segmentation
 Machine Learning Descriptors



Individual Tree Segmentations



Finding Trees in LiDAR Point Clouds



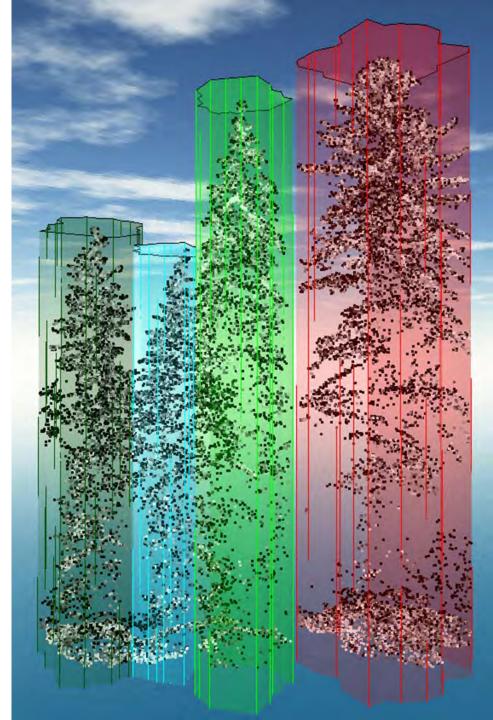
Segmentation Improvements





Agenda

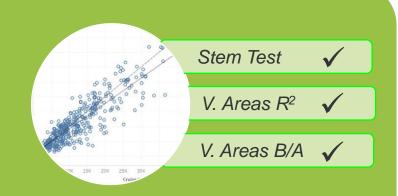
Individual Tree Inventory background
 New Segmentation
 Machine Learning Descriptors



FORSITE

Tree Species Identification Process

Forsite creates numeric descriptors that capture the unique characteristics of each tree including properties specific to given species. These descriptors are then used in a machine-learning process to identify the species of individual trees. The analyst team uses a battery of individual stem tests and area tests to create a robust species prediction model for the project AOI. The following slides detail the results of that analysis.



Species Model Validation

How Accurate is it?



Species Accuracies: General Outcomes Over Many Projects

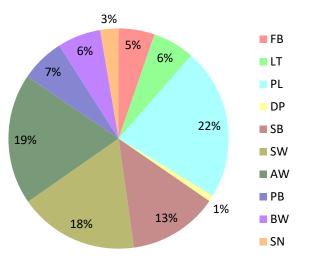
- Bigger trees more accurate (75%-85%) than smaller (65%-75%). Trees comprised of more LiDAR points are more accurately identified than those with fewer points.
- Conifer to Deciduous accuracy and Live/Dead consistently 90-95%. The conifer / deciduous accuracy has been shown to be key for i-Tree calculations

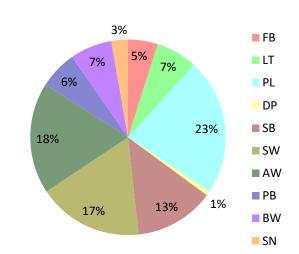
| | | | TSI Calls | | | | | | | | | | | |
|------------|---|----|-----------|-----|-----|-----|----|----|----|----|-------|---------|--|--|
| from the p | e test results: Samples are randomly drawn roject area and reflect the general species analysis area. | | | | | | | | | | | | | |
| | | Fb | Lt | Pl | Sb | Sw | Aw | Pb | Bw | De | Total | Correct | | |
| | Balsam Fir (Fb) | 7 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 88% | | |
| | Tamarack Larch (Lt) | 0 | 8 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 11 | 73% | | |
| ح | Lodgepole Pine (PI) | 3 | 8 | 212 | 8 | 38 | 6 | 3 | 1 | 0 | 279 | 76% | | |
| Truth | Black Spruce (Sb) | 5 | 2 | 5 | 126 | 4 | 1 | 0 | 0 | 0 | 143 | 88% | | |
| Lpun | White Spruce (Sw) | 6 | 0 | 5 | 5 | 108 | 1 | 2 | 0 | 0 | 127 | 85% | | |
| Grou | Trembling Aspen (Aw) | 0 | 0 | 3 | 0 | 6 | 58 | 0 | 1 | 0 | 68 | 85% | | |
| 6 | Balsam Poplar (Pb) | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 0 | 6 | 50% | | |
| | White Birch (Bw) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 | 100% | | |
| | Dead (De) | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 11 | 12 | 92% | | |
| | | | | | | | | | | | 659 | 82% | | |

Species Mixes: Training Areas vs Modeled Results



Training Areas Canopy Cover





Modeled (TSI) Canopy Cover

248 one hectare areas used to help train the species model. Excellent fit achieved.

| Species | FB | LT | PL | DP | SB | SW | AW | PB | BW | SN |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| R Square | 0.909 | 0.965 | 0.956 | 0.818 | 0.951 | 0.915 | 0.944 | 0.931 | 0.904 | 0.975 |
| Standard Error | 0.033 | 0.044 | 0.060 | 0.019 | 0.060 | 0.061 | 0.054 | 0.036 | 0.041 | 0.033 |
| Observations | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 |

| | Conifer | Decid | Dead |
|----------------|---------|-------|-------|
| R Square | 0.975 | 0.971 | 0.985 |
| Standard Error | 0.057 | 0.058 | 0.029 |
| Observations | 248 | 248 | 248 |

Validation Area Review

| FORSITE |
|-------------------------------|
| Forest Management Specialists |

| Varea_342 | FB | LT | PL | SB | SW | AW | PB | BW | DE |
|------------|------|------|------|------|-------|------|------|------|------|
| Stereo CC% | 2% | 0% | 4% | 6% | 86% | 1% | 0% | 0% | 1% |
| TSI CC% | 0.7% | 0.6% | 5.4% | 4.4% | 83.2% | 2.1% | 1.0% | 0.3% | 2.3% |

FB LT Pl

DP SB

Sw Aw

Pb Bw SN 

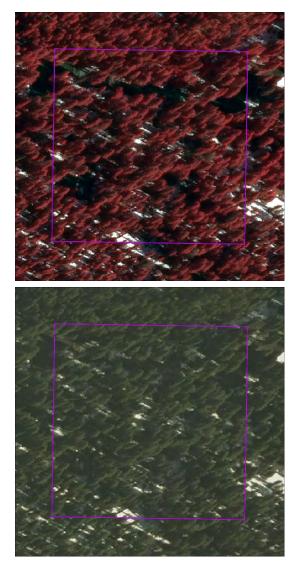
Sw stand with minor component of Sb and Pl.

Average Height: 19.3m

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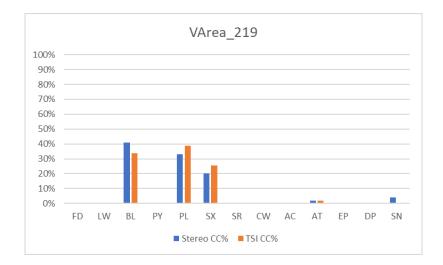
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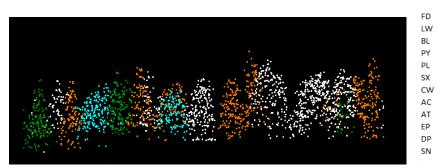


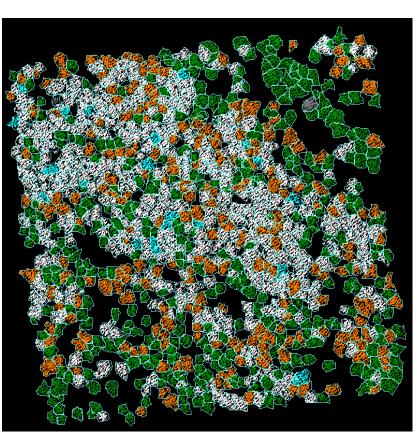
Validation Area review



| VArea_219 | FD | LW | BL | PY | PL | SX | SR | CW | AC | AT | EP | DP | SN | Comments |
|------------|----|----|-----|----|-----|-----|----|----|----|----|----|----|----|---|
| Stereo CC% | 0% | 0% | 41% | 0% | 33% | 20% | 0% | 0% | 0% | 2% | 0% | 0% | 4% | Short balsam fir stand with |
| TSI CC% | 0% | 0% | 34% | 0% | 39% | 25% | 0% | 0% | 0% | 2% | 0% | 0% | 0% | lodgepole pine and spruce. Average height: 7.1 m |









Validation Area Review

FB LT PL

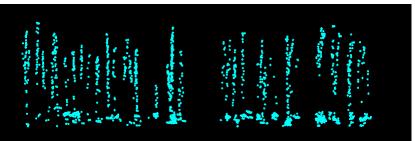
DP

SB SW AW

PB BW SN

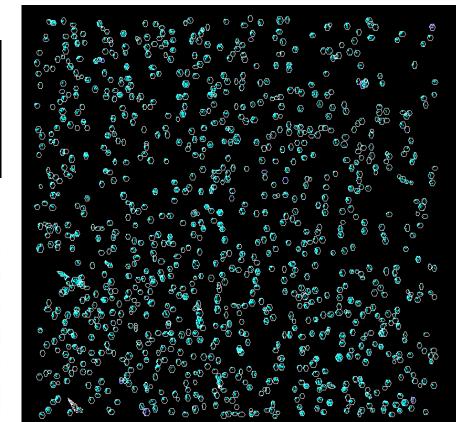


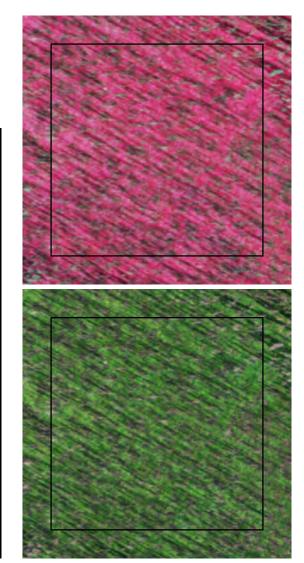
| Ph2_All_Fill_04 | FB | LT | PL | SB | SW | AW | PB | BW | DE |
|-----------------|------|------|------|------|------|------|------|------|-------|
| Stereo CC% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 1% | 98% |
| TSI CC% | 0.0% | 0.0% | 0.0% | 0.2% | 0.0% | 0.6% | 0.0% | 0.4% | 98.7% |



A burnt, Sn leading validation area.

Average Height: 13.2m





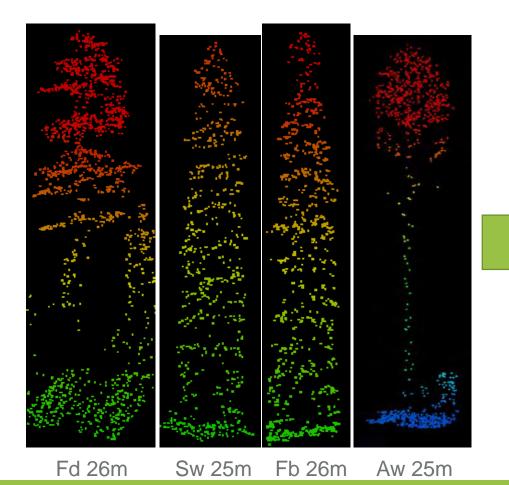
2021 Operational Lidar Inventory Meeting Secret Word for SAF CFE Credits: **multispectral**

Enter the secret word by 11:00pm on Wednesday, April 7th.

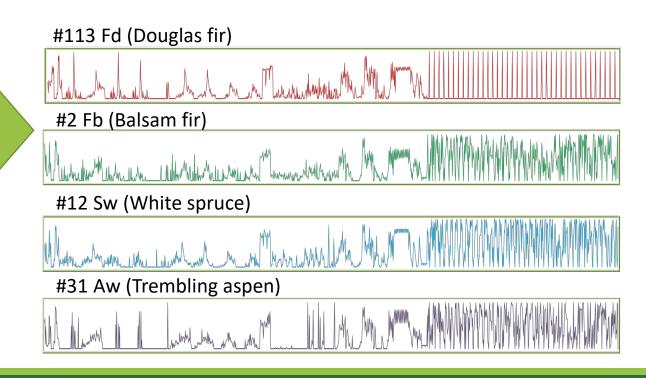
Use this link: <u>https://www.surveymonkey.com/r/2021OLlcredits</u>

Species Prediction (Tree by Tree)

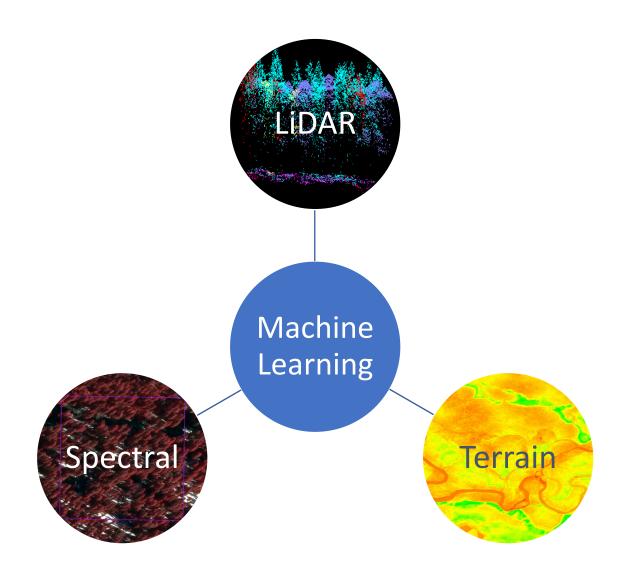




• **Descriptors** are numeric representations of individual tree characteristics. They are created from a range of inputs; LiDAR, imagery, terrain metrics. These descriptors are then fed into the support vector machine to identify tree species.



Testing Descriptor Types

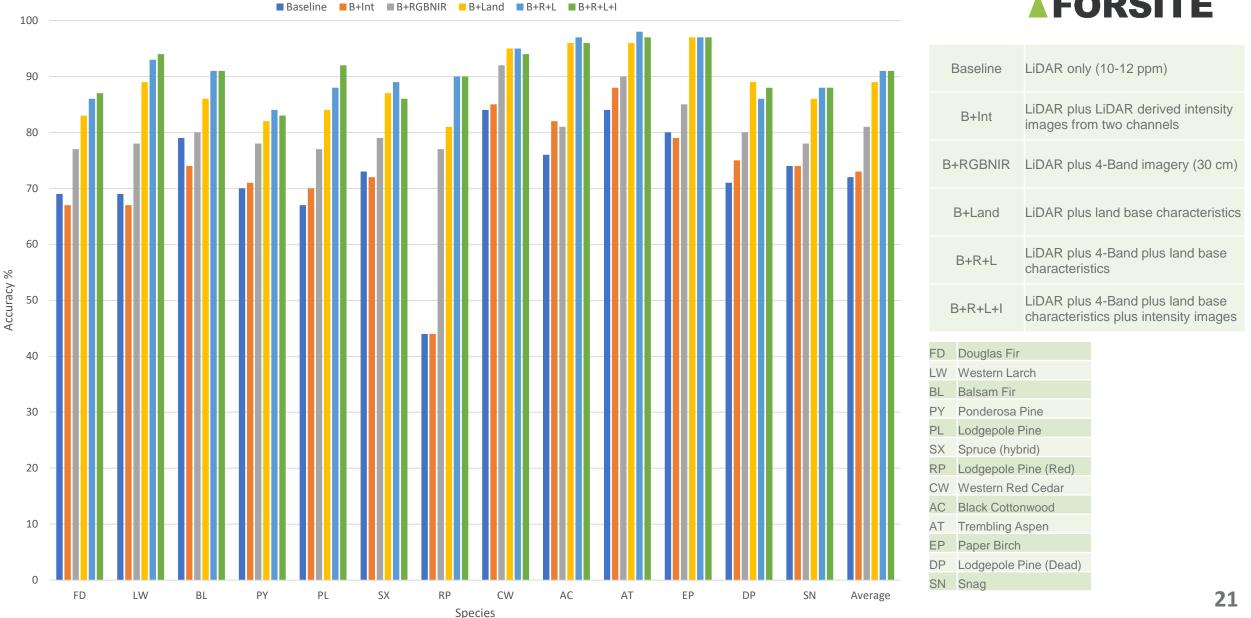




• Test set is 4,395 trees (the Ground Truth data) and includes 13 species classes.

| Baseline | LiDAR only (10-12 ppm) |
|----------|--|
| B+Int | LiDAR plus LiDAR derived intensity images from two channels |
| B+RGBNIR | LiDAR plus 4-Band imagery (30 cm) |
| B+Land | LiDAR plus land base characteristics |
| B+R+L | LiDAR plus 4-Band plus land base characteristics |
| B+R+L+I | LiDAR plus 4-Band plus land base characteristics plus intensity images |

Descriptor Test Results

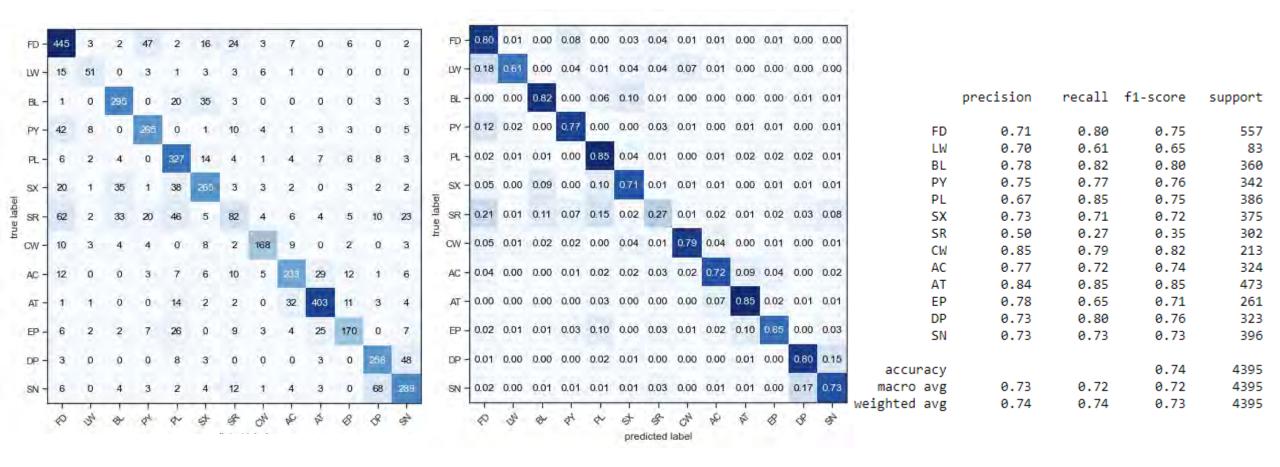




All Ground Truth Descriptor evaluation:



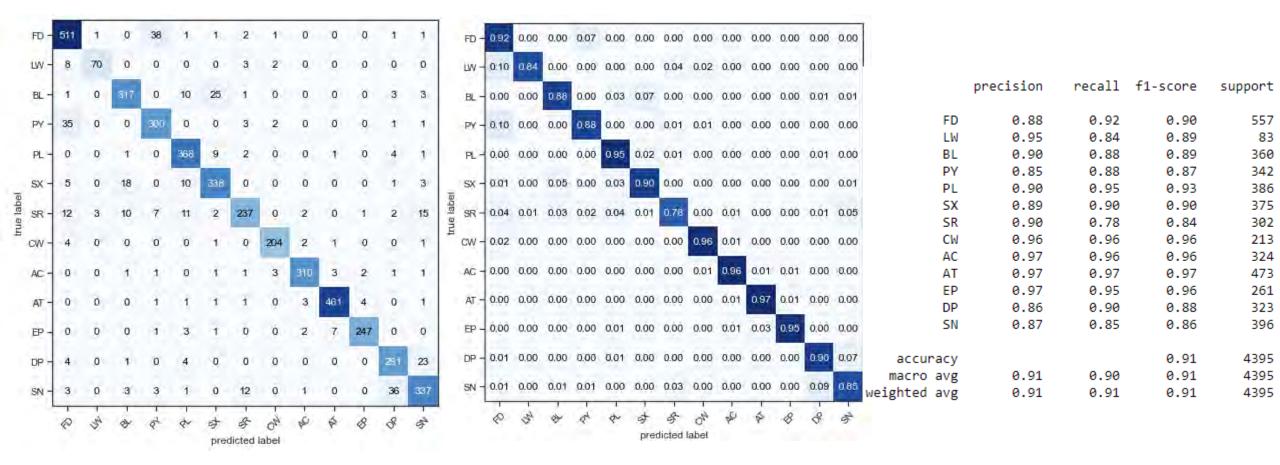
LiDAR (geometry, density, intensity)

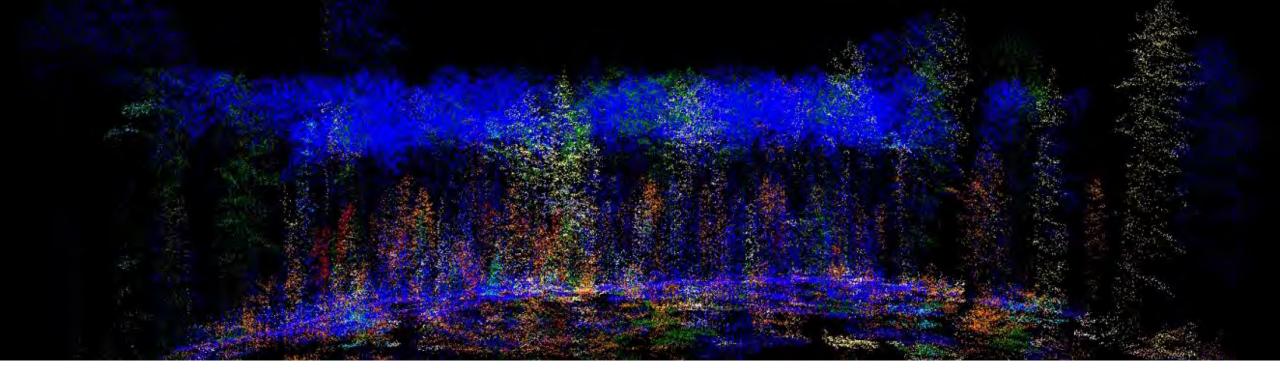


All Ground Truth Descriptor evaluation:

LiDAR plus 4-Band plus land base characteristics plus intensity images







Thank you!



Mike Parlow

Team Lead Remote Sensing Inventories

cell 250-954-7850