



Innovative Forest Inventories

Operational LiDAR Inventory Working Group
April 7, 2021

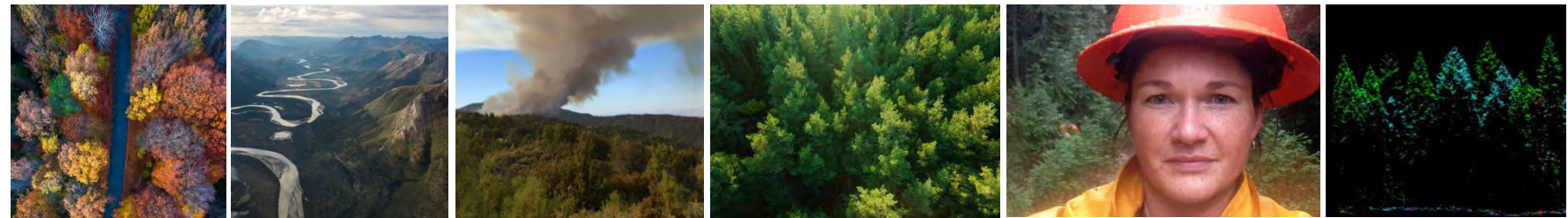
Mike Parlow
Team Lead, Remote Sensing Inventories

Forsite Consultants



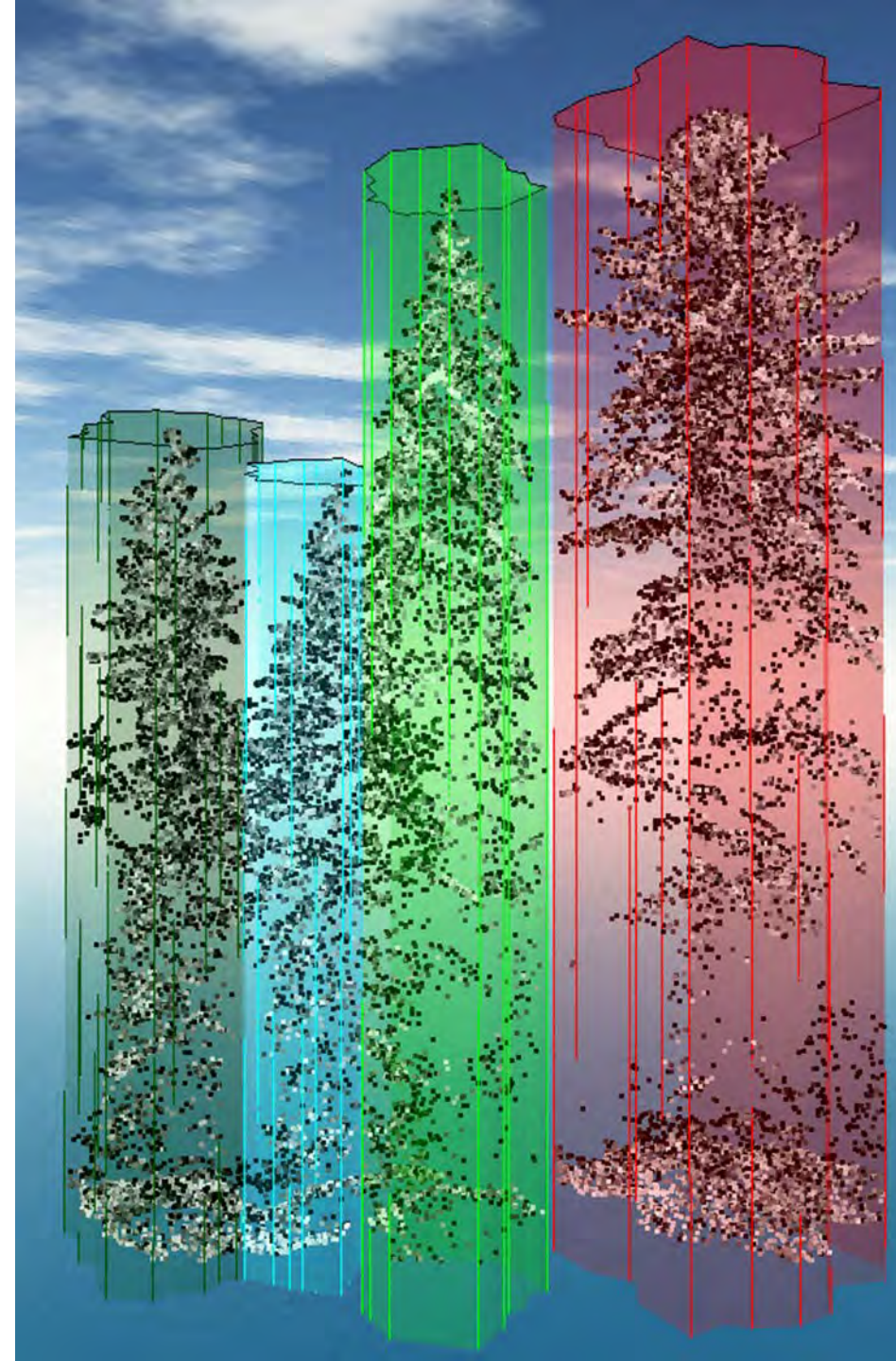
Forsite Consultants Ltd. is an integrated forest management company providing value to our clients through innovative, sustainable, and operationally realistic services. We focus on understanding what matters to our clients and their business and then supporting them in success – from strategic analysis 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

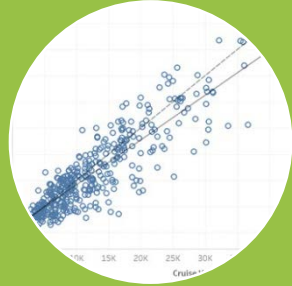
- Individual Tree Inventory background
- New Segmentation
- Machine Learning Descriptors



Tree Species Identification Process



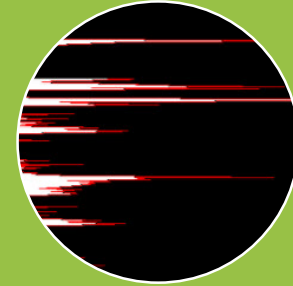
Ground
Truth
Collection &
Processing



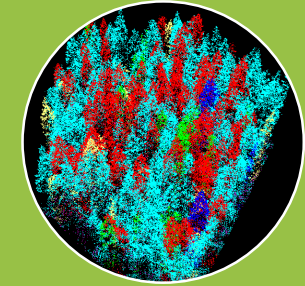
Model
Validation



Project Area
segmented
to individual
trees



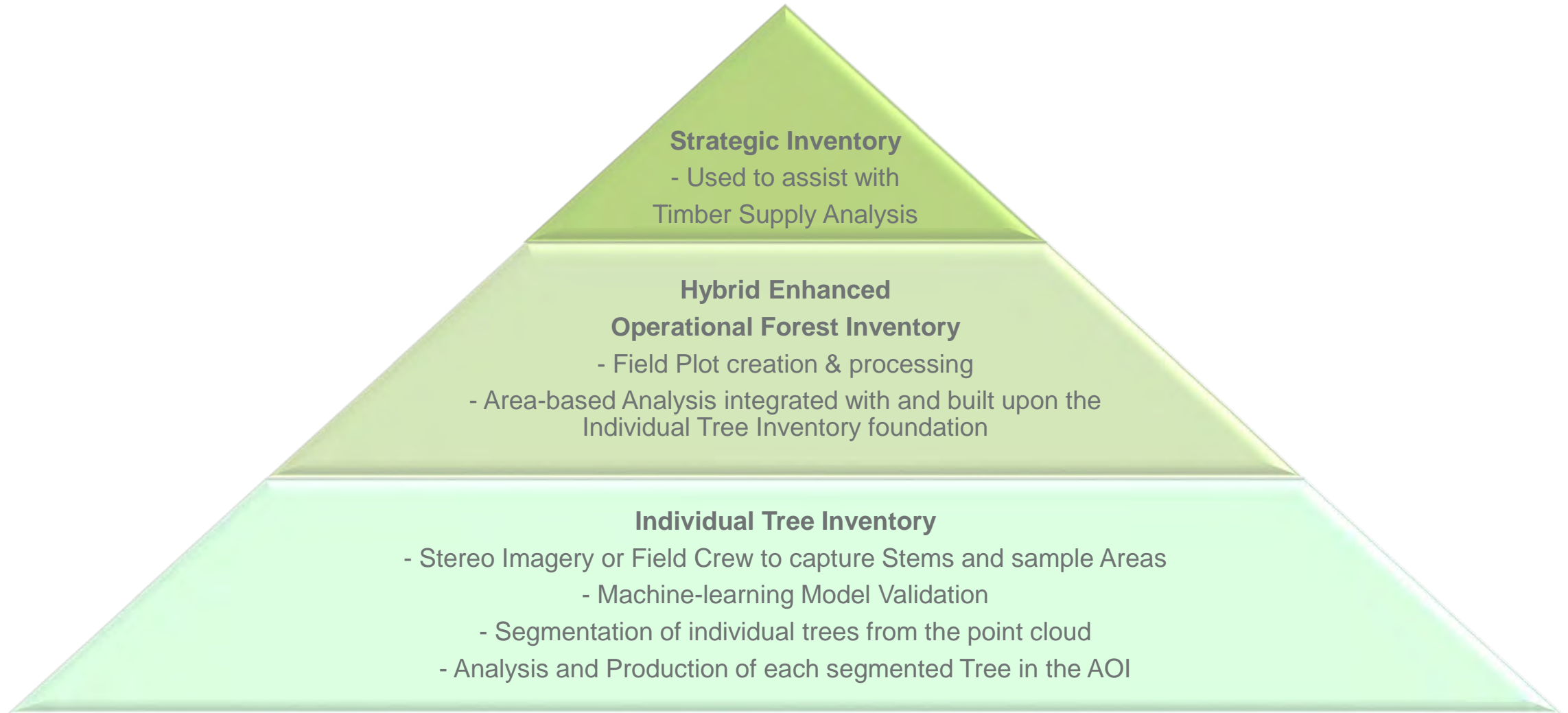
TSI Analysis
of Project
Area



Attributed
Tree
Population
Produced

Over 200 TB of LiDAR processed and billions of trees segmented & identified

Inventory Project Overview



Operational to Strategic

Linked Inventories – Different Uses, Same Data

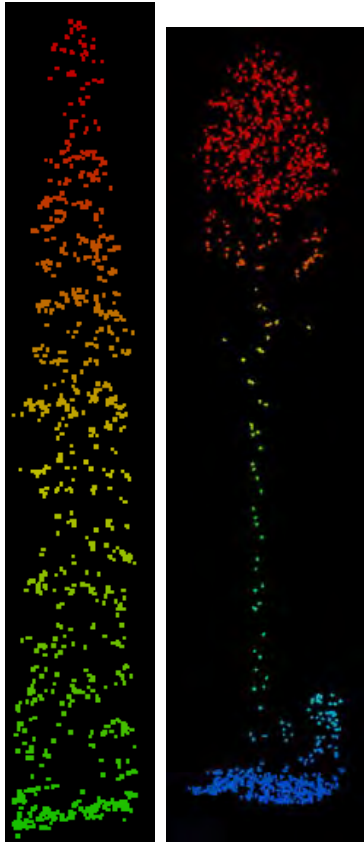
Trees



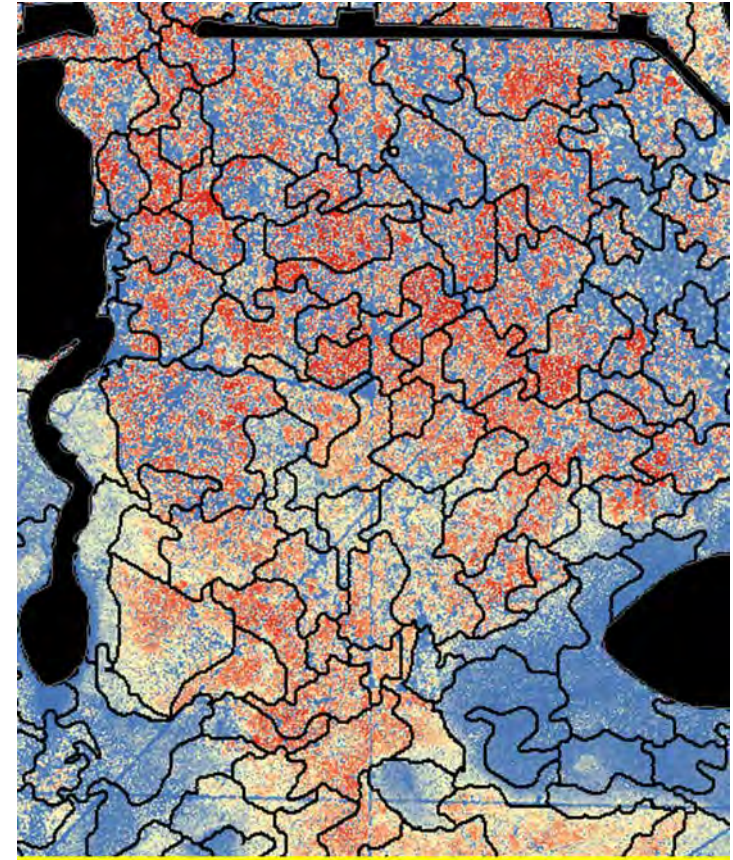
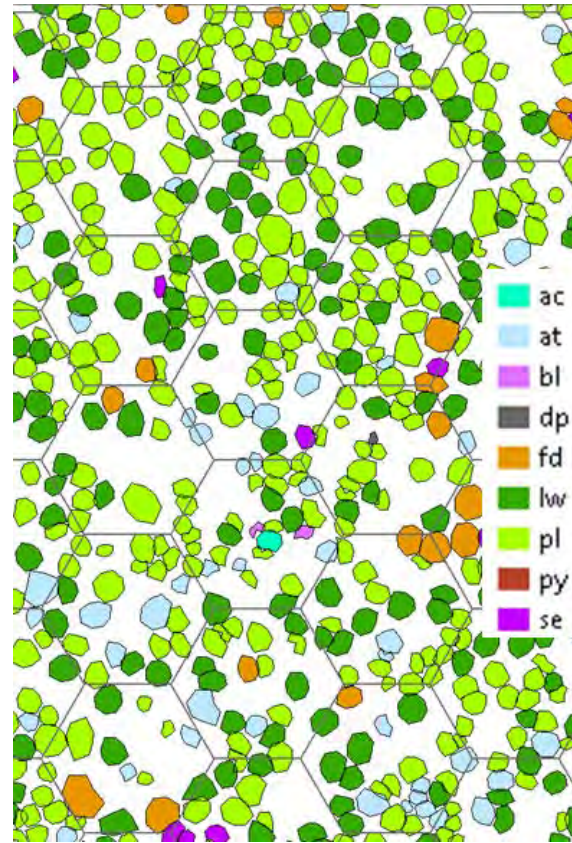
Tiles



Stands

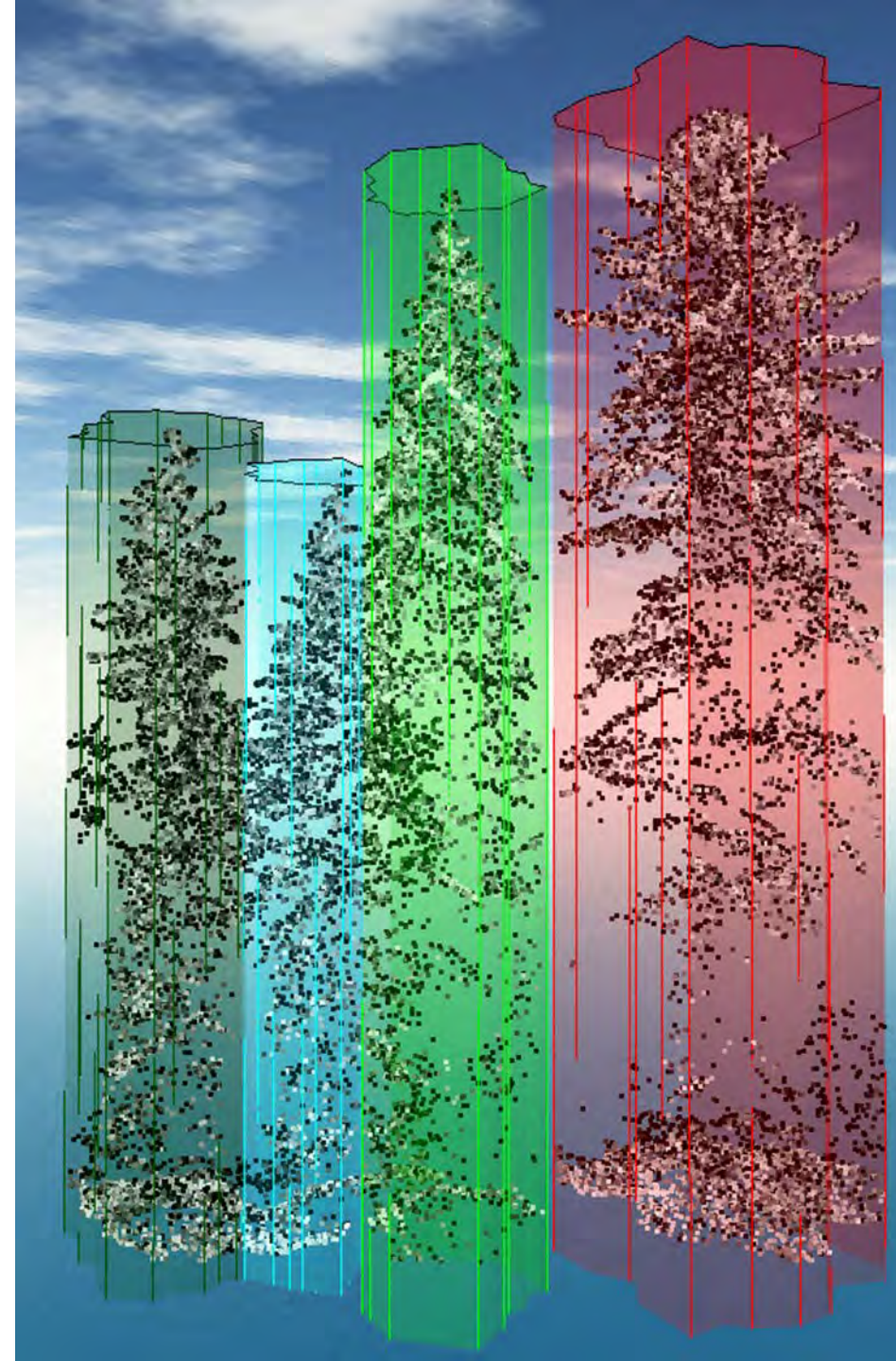


BI 26m AT 25m



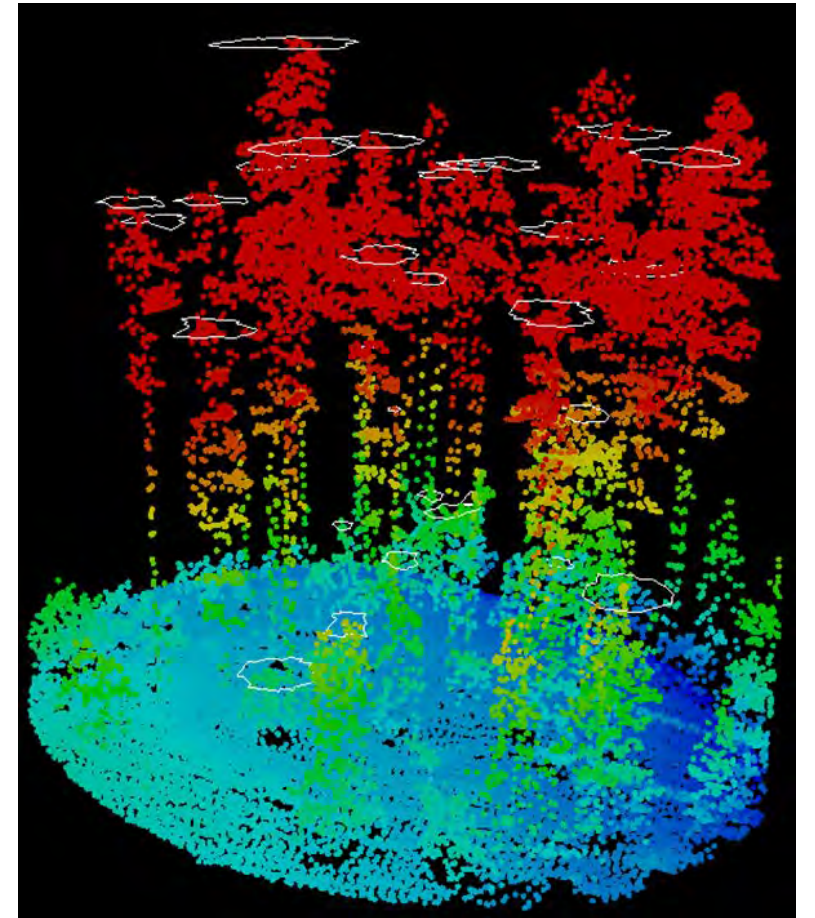
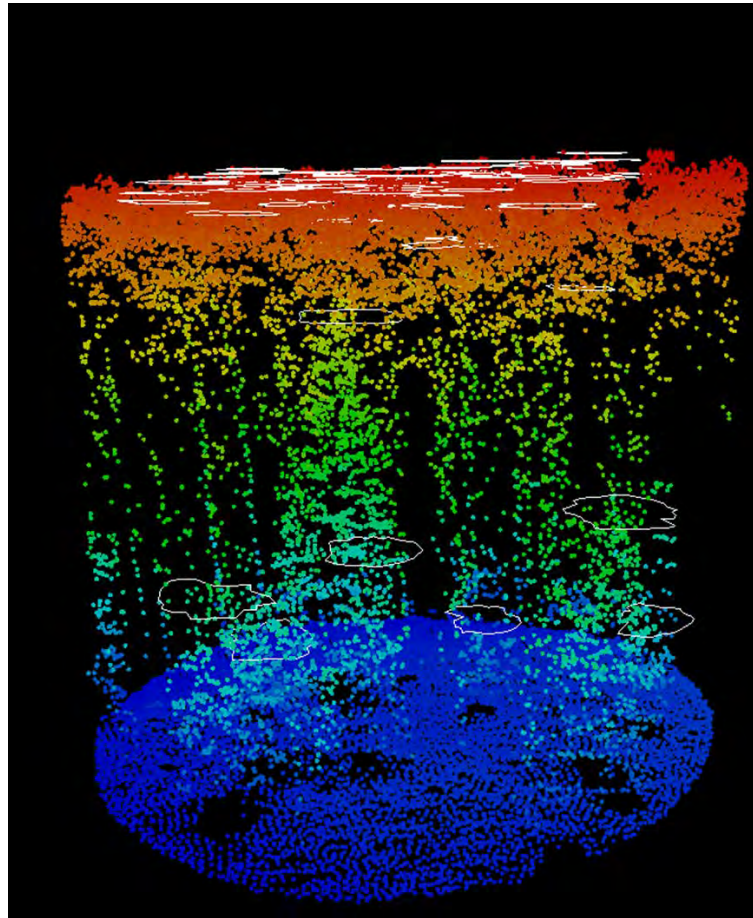
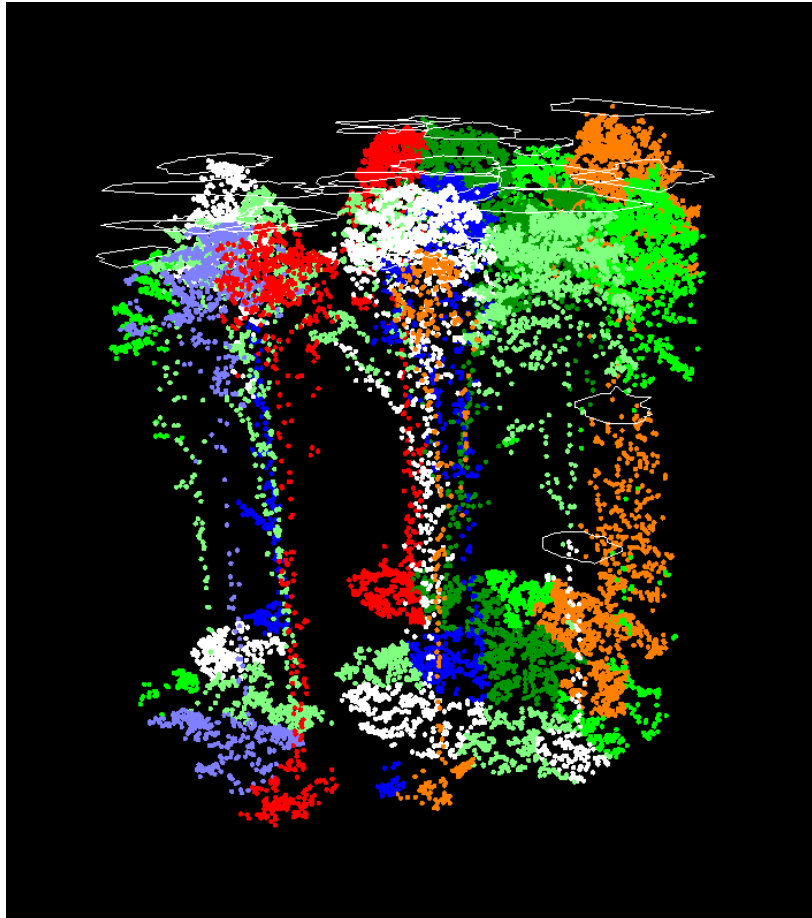
Agenda

- Individual Tree Inventory background
- **New Segmentation**
- Machine Learning Descriptors

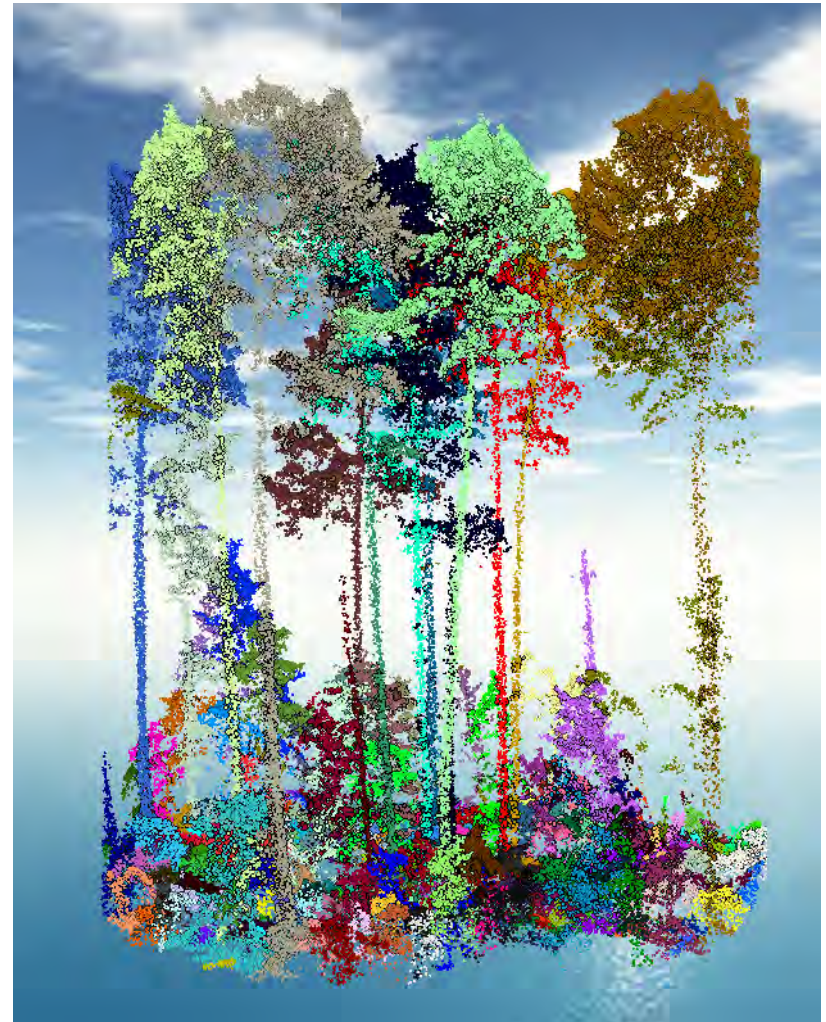
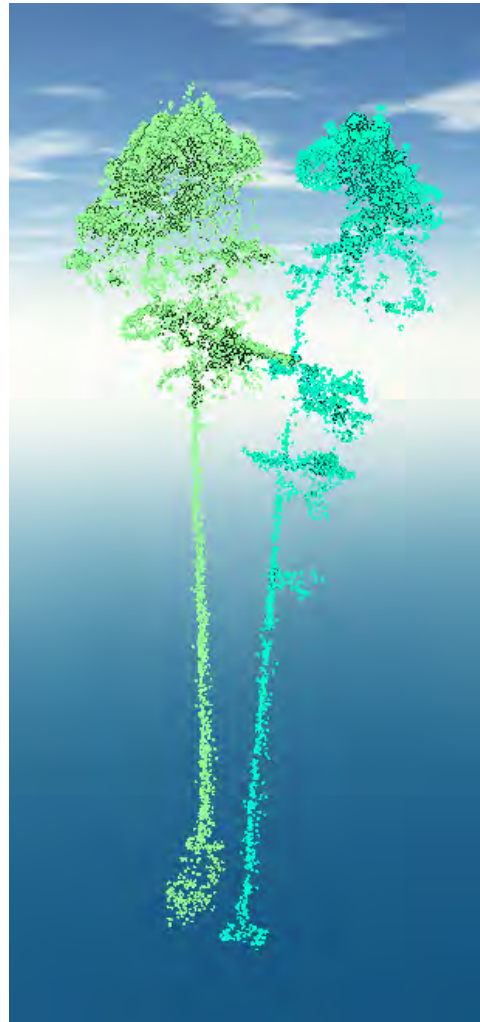
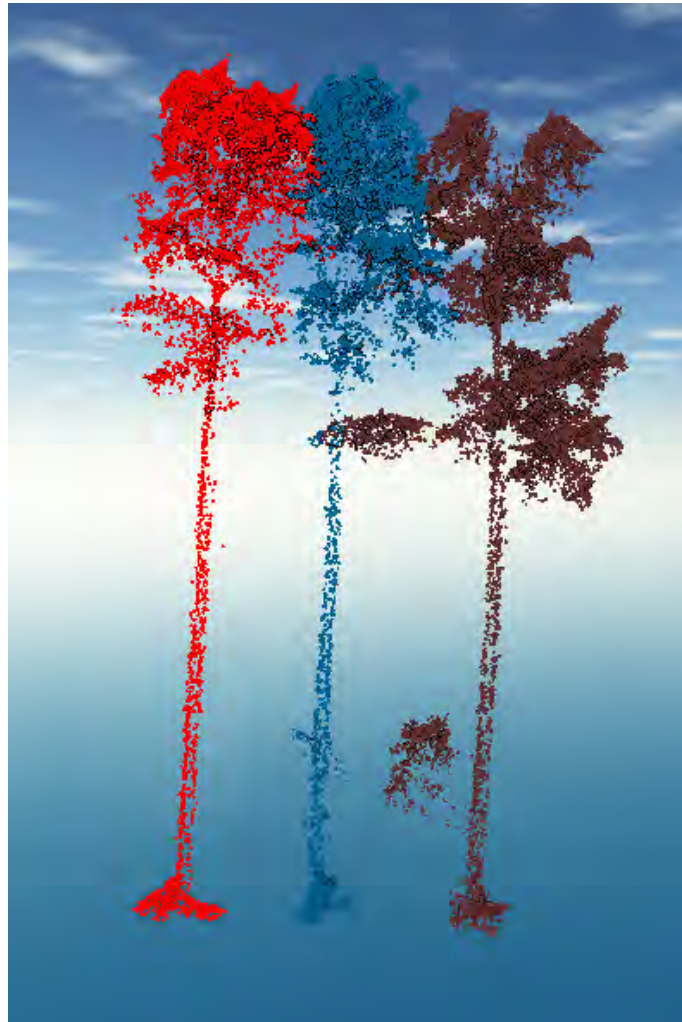


Individual Tree Segmentations

Finding Trees in LiDAR Point Clouds

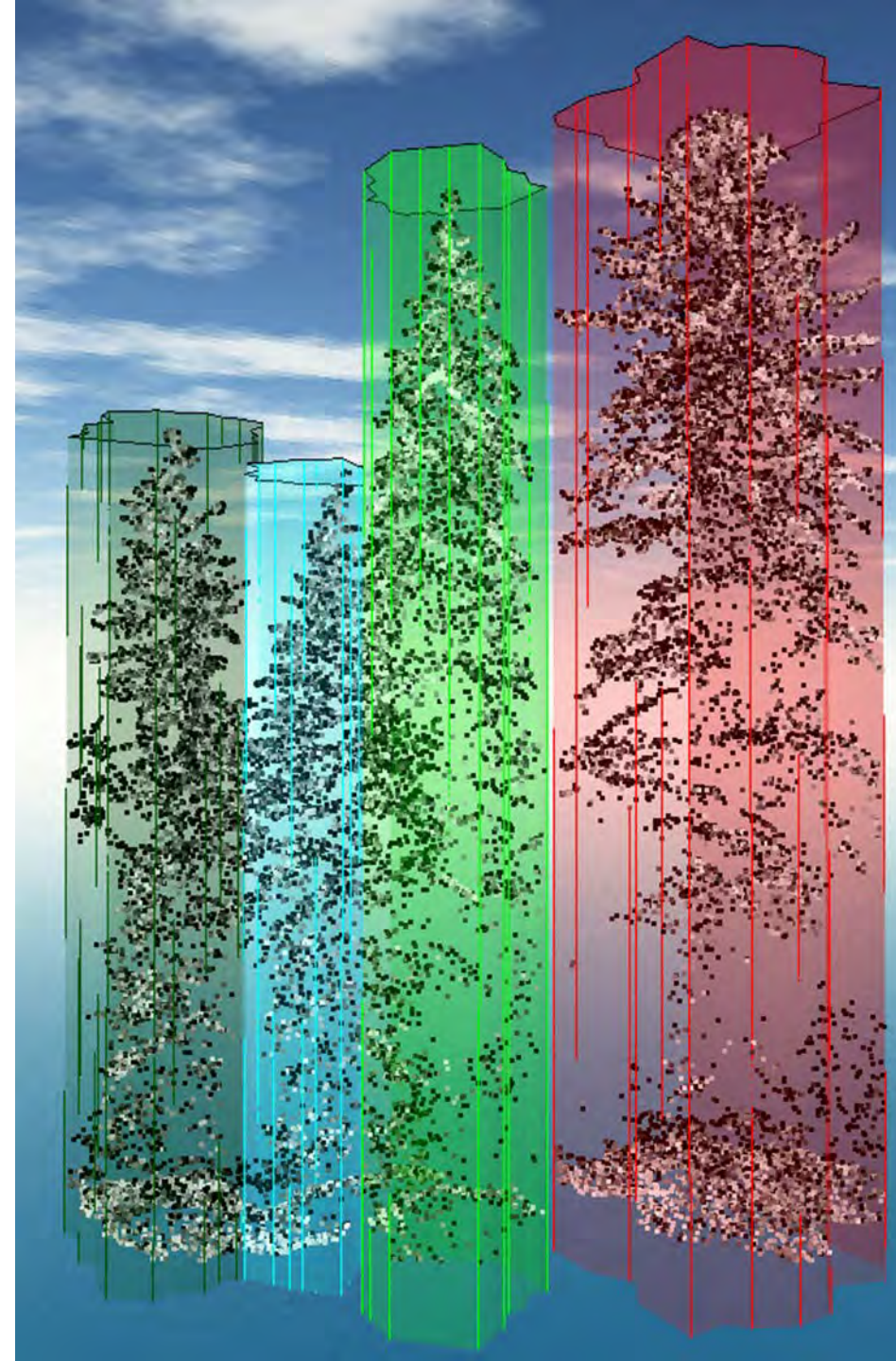


Segmentation Improvements



Agenda

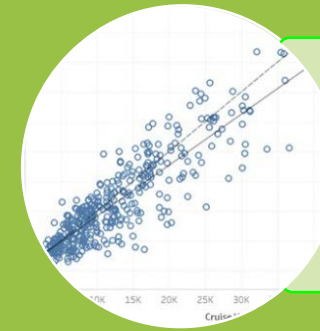
- Individual Tree Inventory background
- New Segmentation
- **Machine Learning Descriptors**



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.



Stem Test ✓

V. Areas R^2 ✓

V. Areas B/A ✓

Species Model Validation



How Accurate is it?



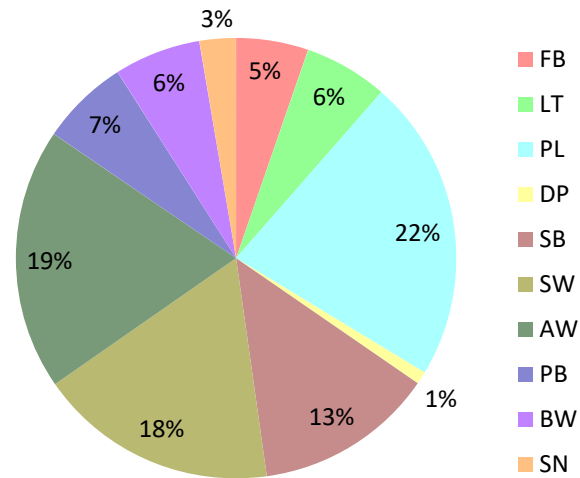
Species Accuracies: General Outcomes Over Many Projects

- ▶ 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

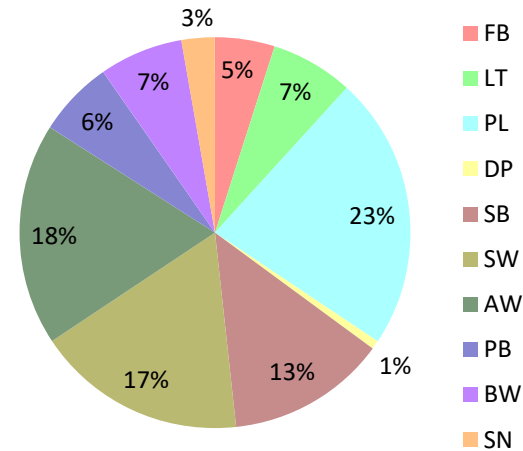
Land base test results: Samples are randomly drawn from the project area and reflect the general species mix of the analysis area.		TSI Calls										Correct
		Fb	Lt	Pl	Sb	Sw	Aw	Pb	Bw	De	Total	
Ground Truth	Balsam Fir (Fb)	7	0	1	0	0	0	0	0	0	8	88%
	Tamarack Larch (Lt)	0	8	2	1	0	0	0	0	0	11	73%
	Lodgepole Pine (Pl)	3	8	212	8	38	6	3	1	0	279	76%
	Black Spruce (Sb)	5	2	5	126	4	1	0	0	0	143	88%
	White Spruce (Sw)	6	0	5	5	108	1	2	0	0	127	85%
	Trembling Aspen (Aw)	0	0	3	0	6	58	0	1	0	68	85%
	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	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



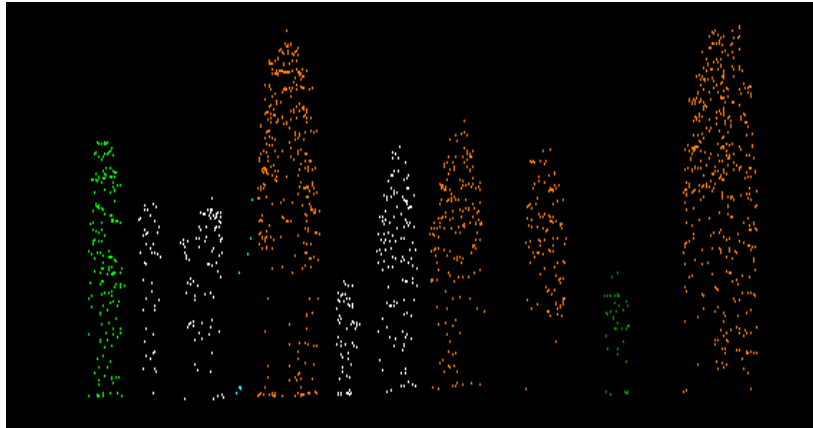
248 one hectare areas used to help train the species model. Excellent fit achieved.

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

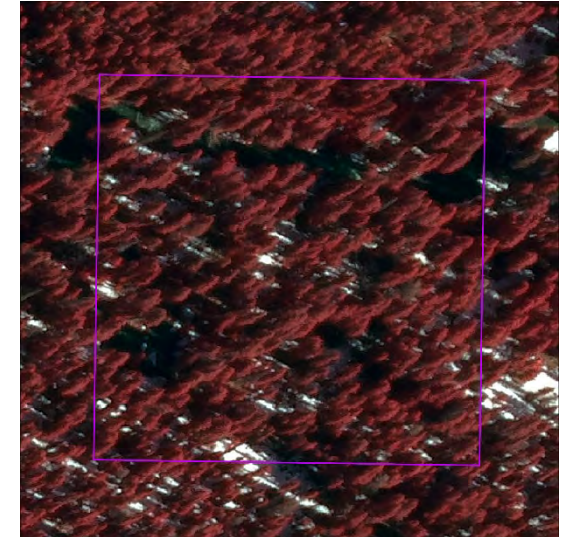
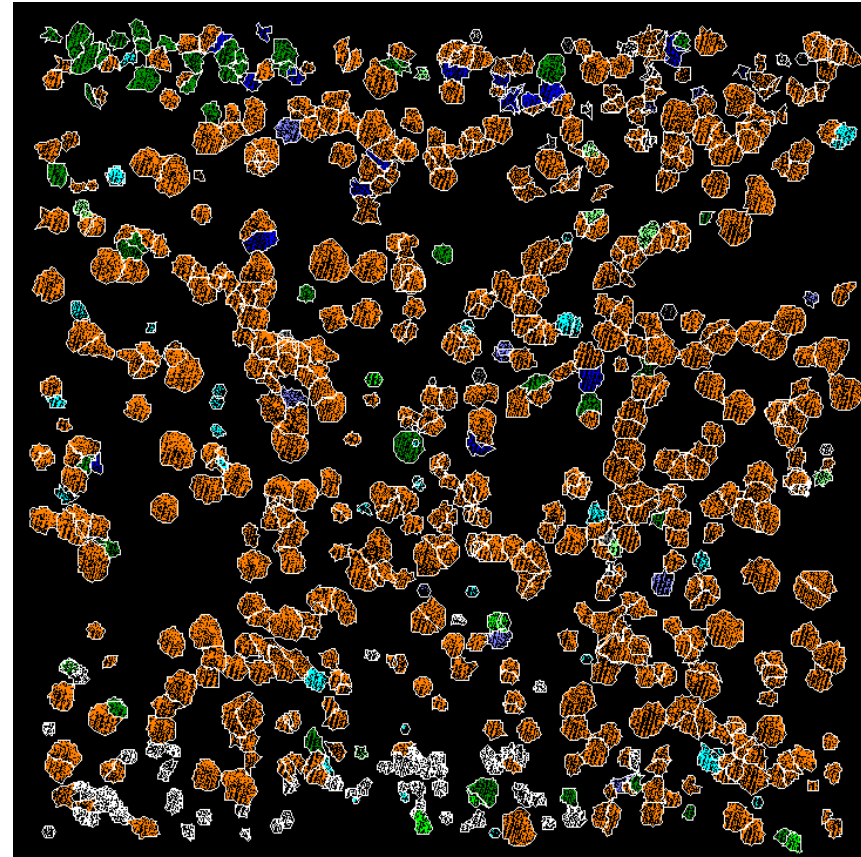
Varea_342	FB	LT	PL	SB	SW	AW	PB	BW	DE
Stereo CC%	2%	0%	4%	6%	86%	1%	0%	0%	1%
TSI CC%	0.7%	0.6%	5.4%	4.4%	83.2%	2.1%	1.0%	0.3%	2.3%



Sw stand with minor component of Sb and Pl.

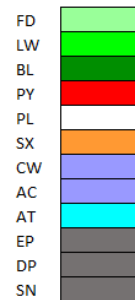
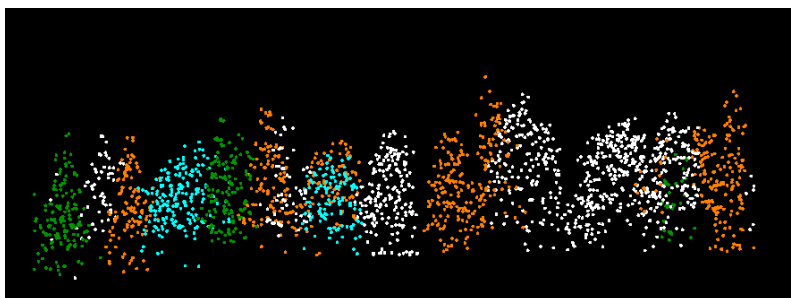
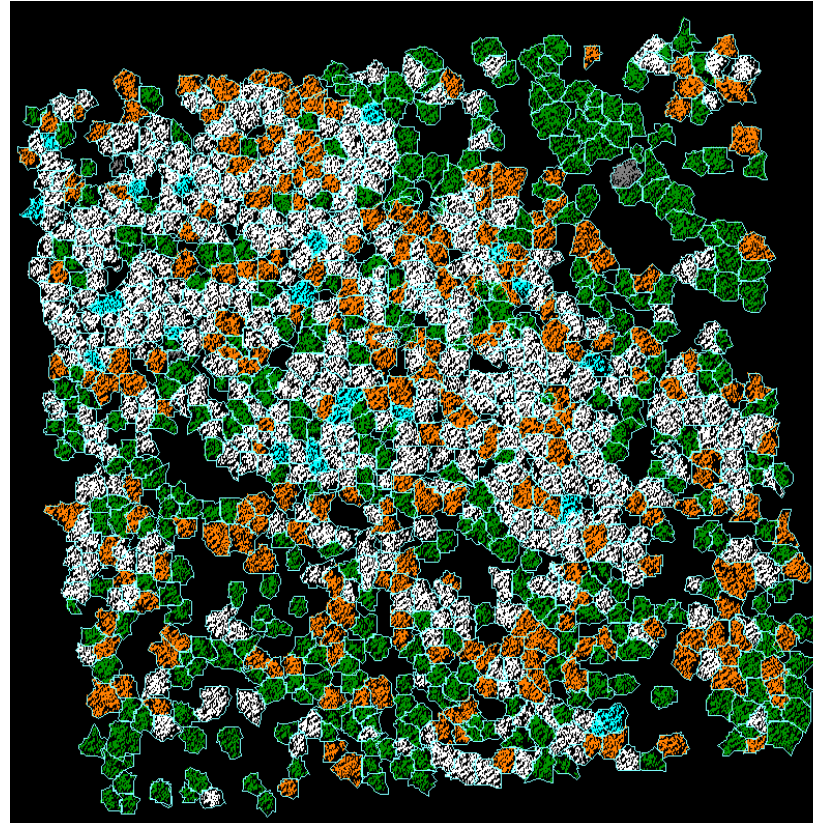
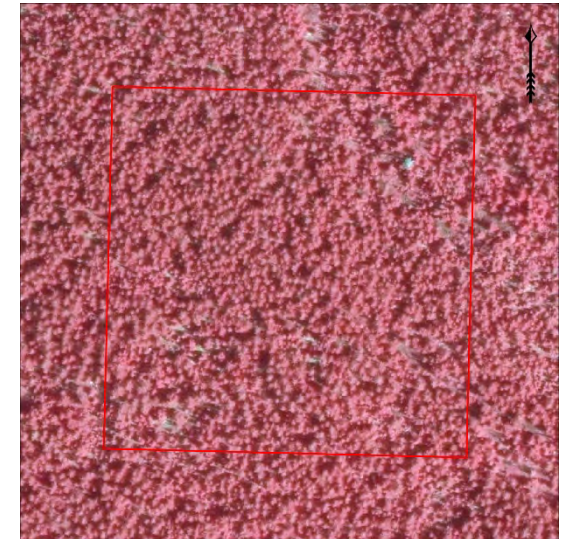
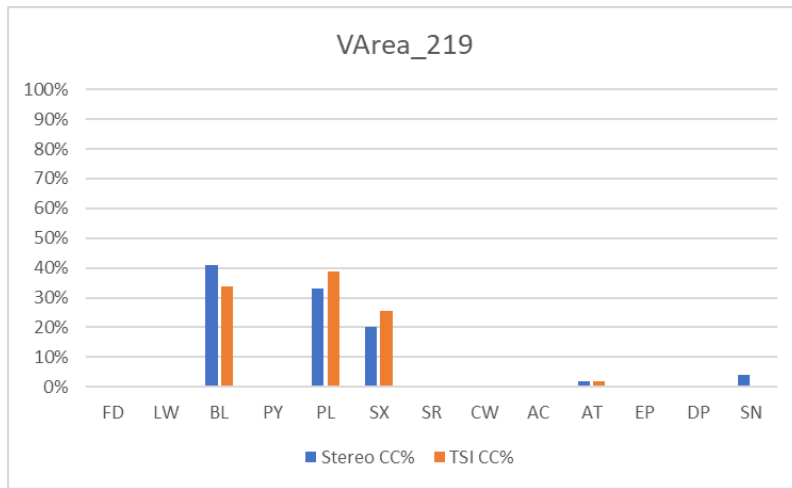
Average Height: 19.3m

FB	
LT	
PI	
DP	
SB	
Sw	
Aw	
Pb	
Bw	
SN	



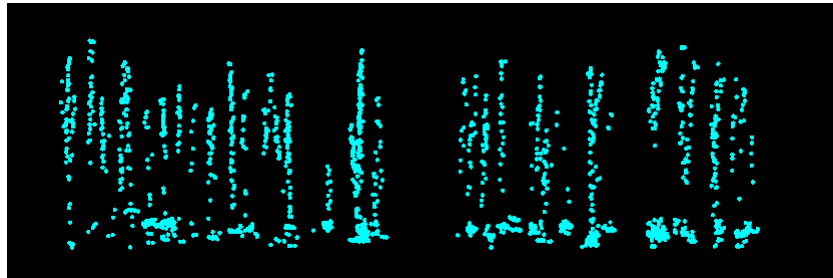
Validation Area review

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 lodgepole pine and spruce. Average height: 7.1 m
TSI CC%	0%	0%	34%	0%	39%	25%	0%	0%	0%	2%	0%	0%	0%	



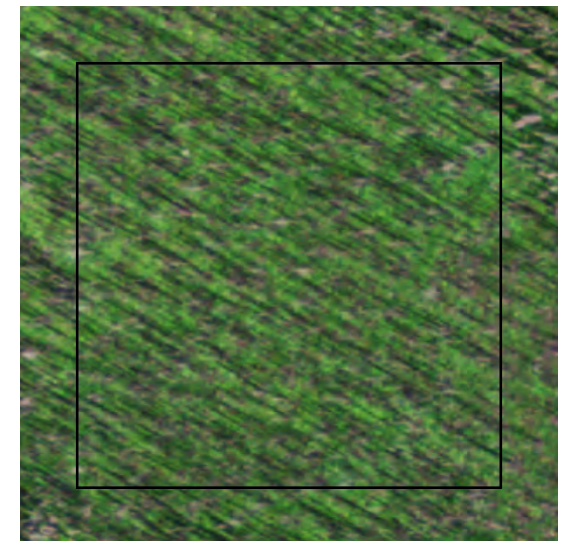
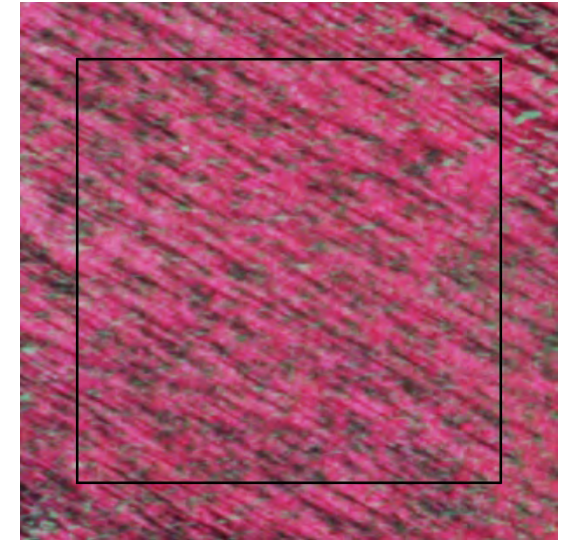
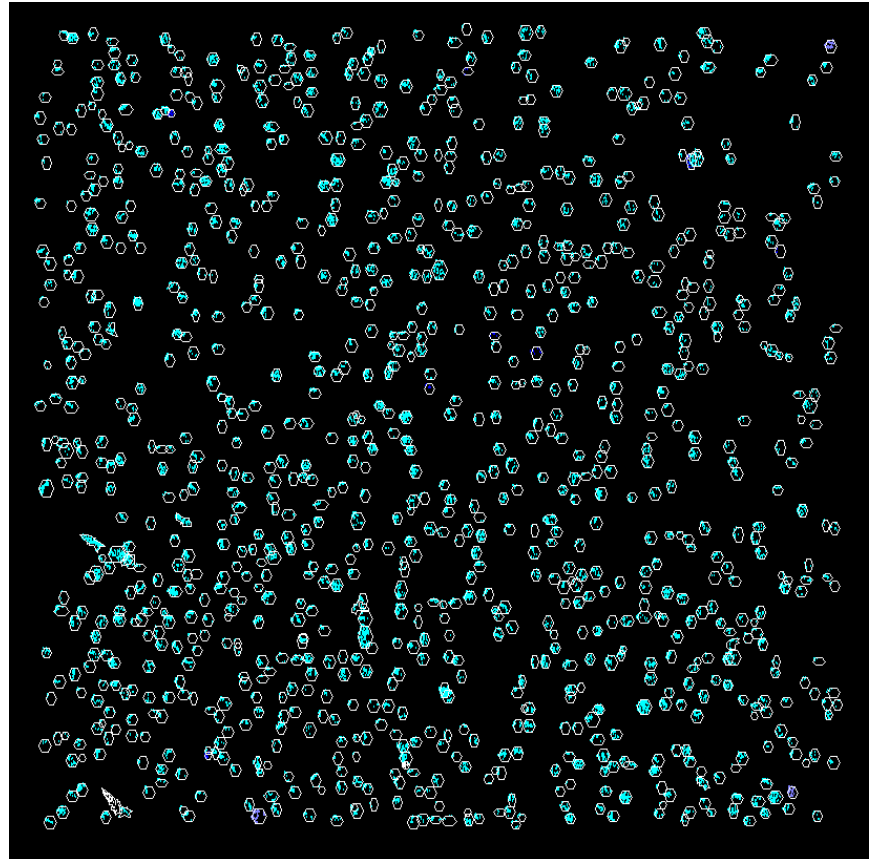
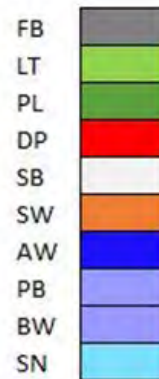
Validation Area Review

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

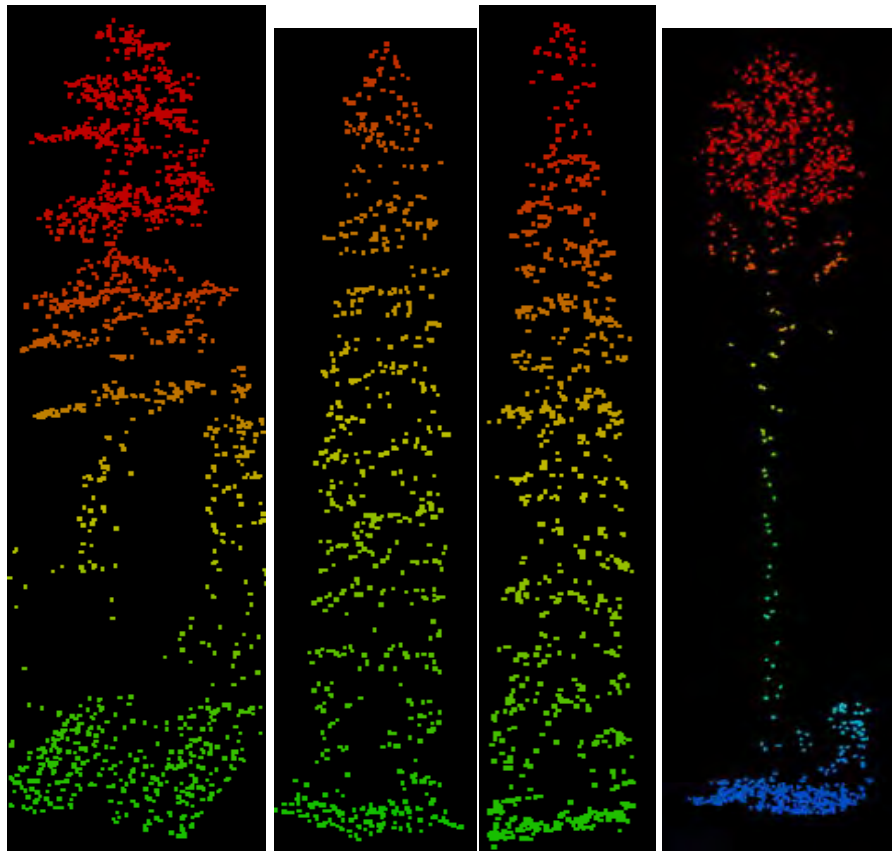
Enter the secret word by 11:00pm on Wednesday, April
7th.

Use this link:

<https://www.surveymonkey.com/r/2021OLCredits>

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.

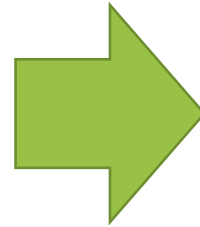


Fd 26m

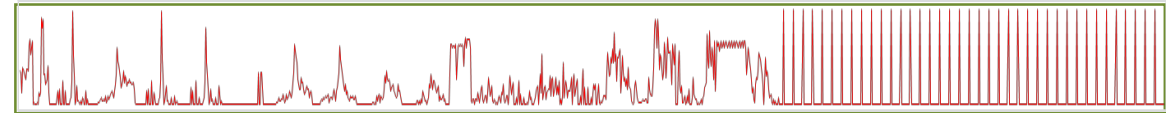
Sw 25m

Fb 26m

Aw 25m



#113 Fd (Douglas fir)



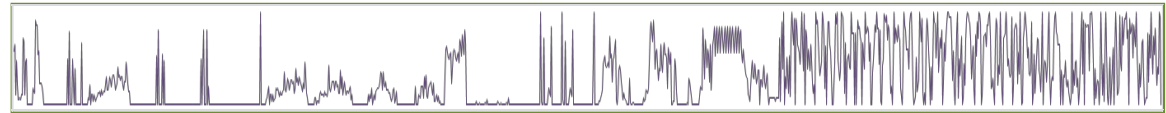
#2 Fb (Balsam fir)



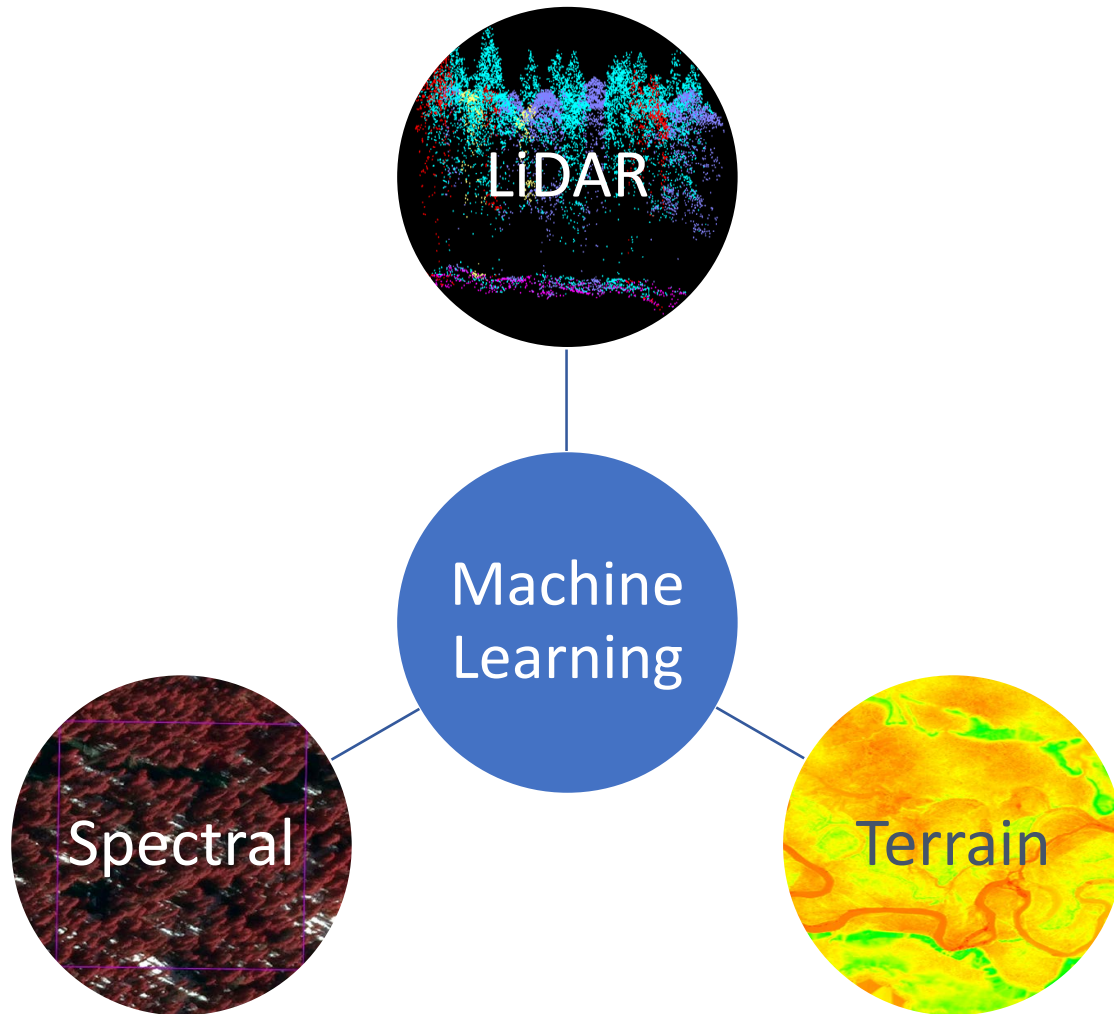
#12 Sw (White spruce)



#31 Aw (Trembling aspen)



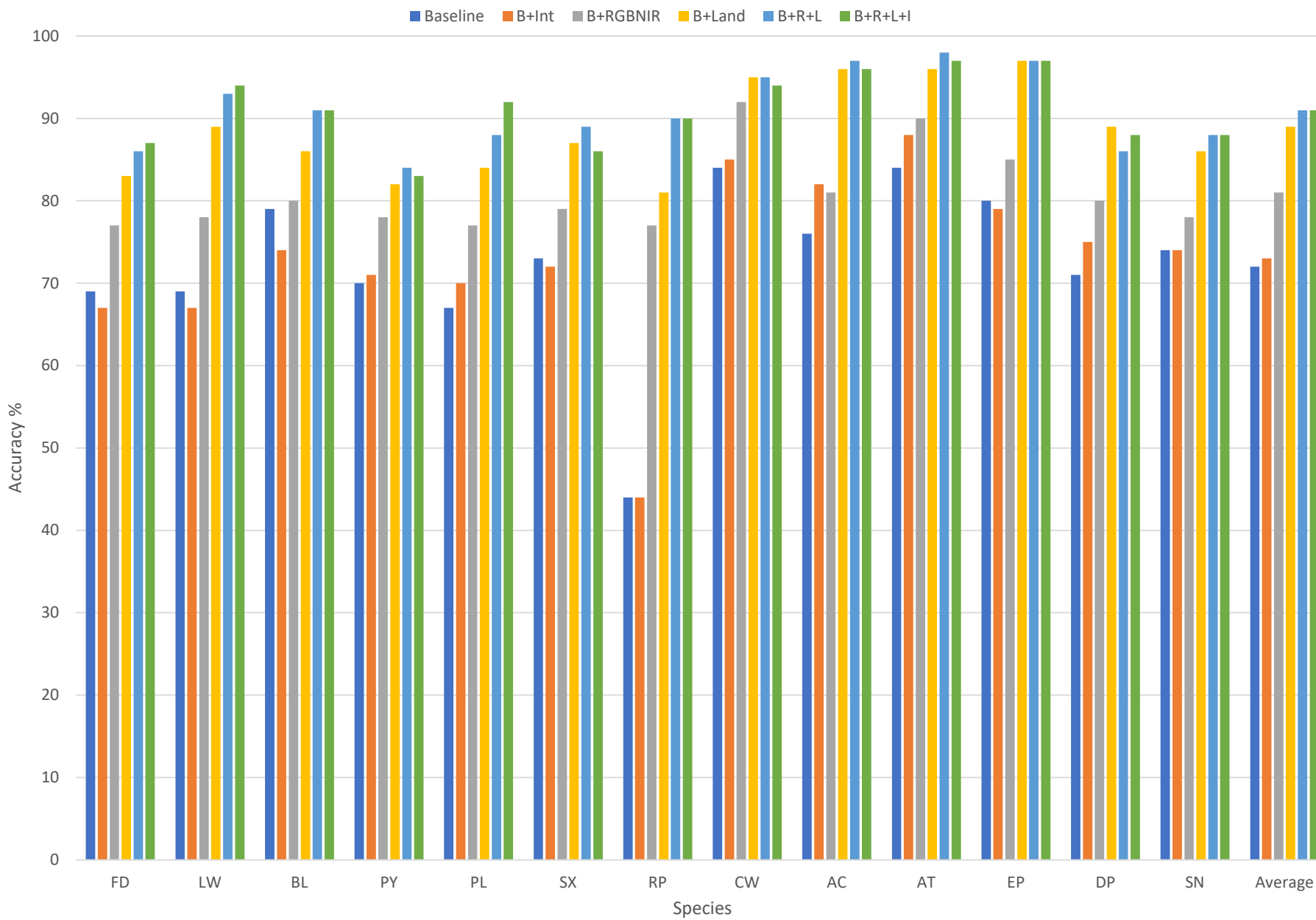
Testing Descriptor Types



- 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

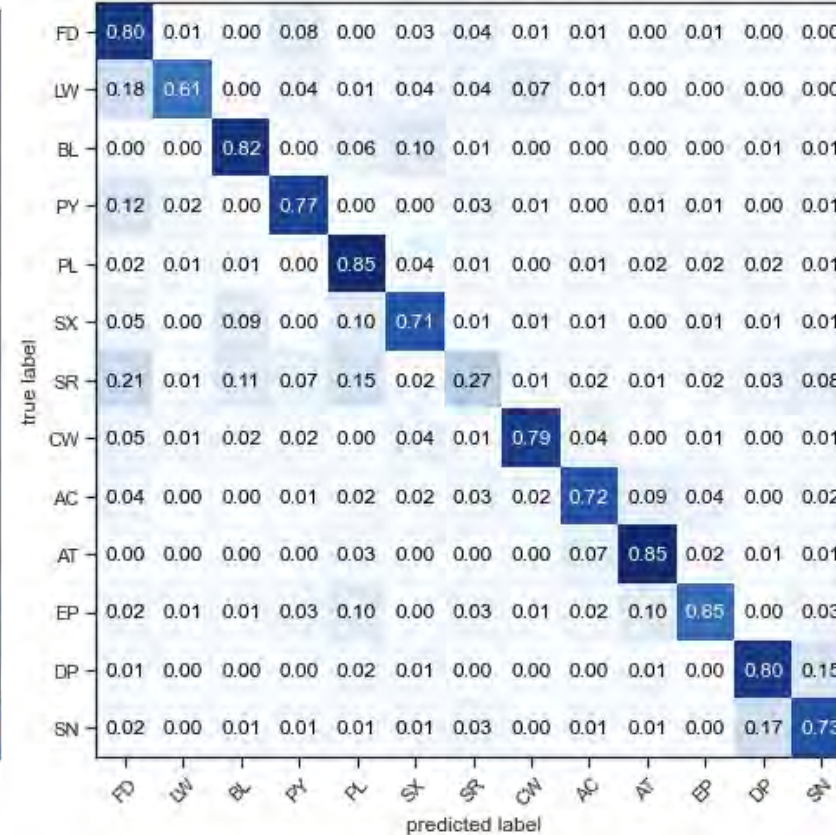
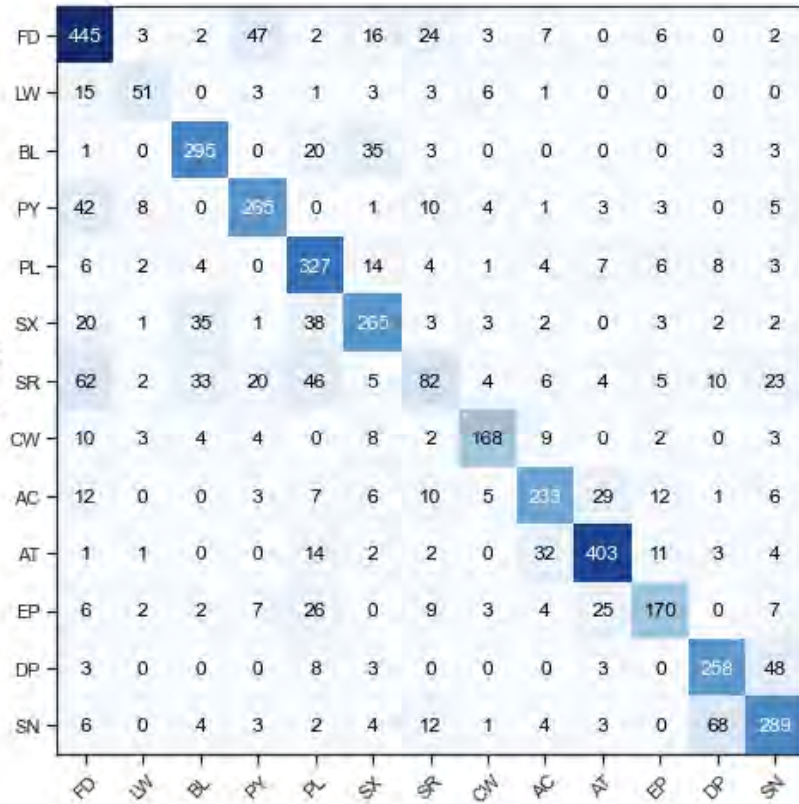
Descriptor Test Results



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

FD	Douglas Fir
LW	Western Larch
BL	Balsam Fir
PY	Ponderosa Pine
PL	Lodgepole Pine
SX	Spruce (hybrid)
RP	Lodgepole Pine (Red)
CW	Western Red Cedar
AC	Black Cottonwood
AT	Trembling Aspen
EP	Paper Birch
DP	Lodgepole Pine (Dead)
SN	Snag

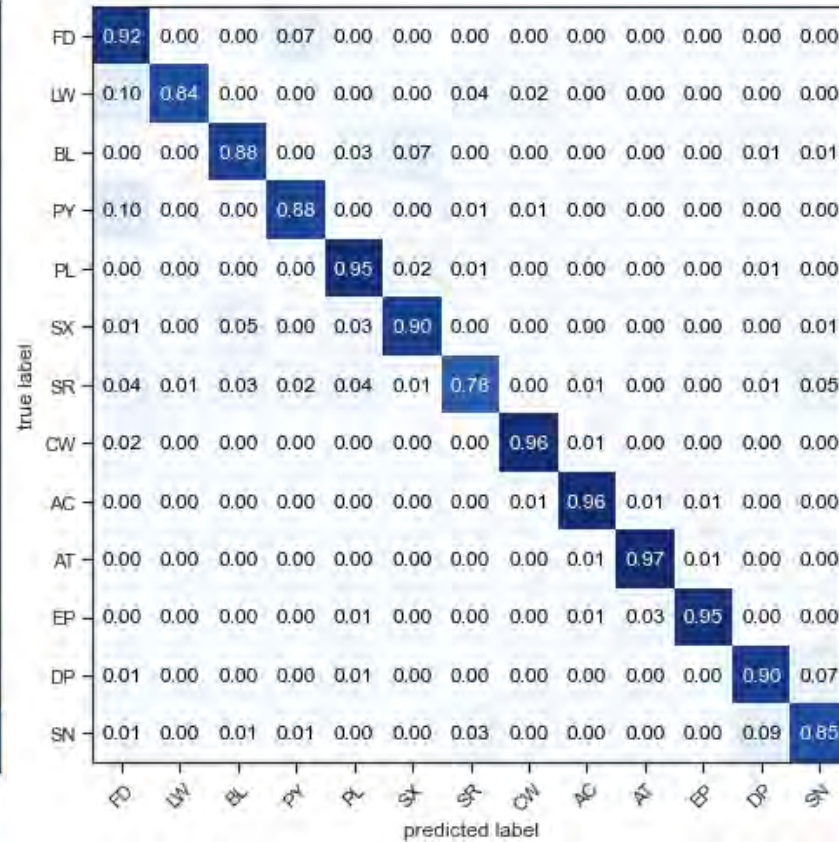
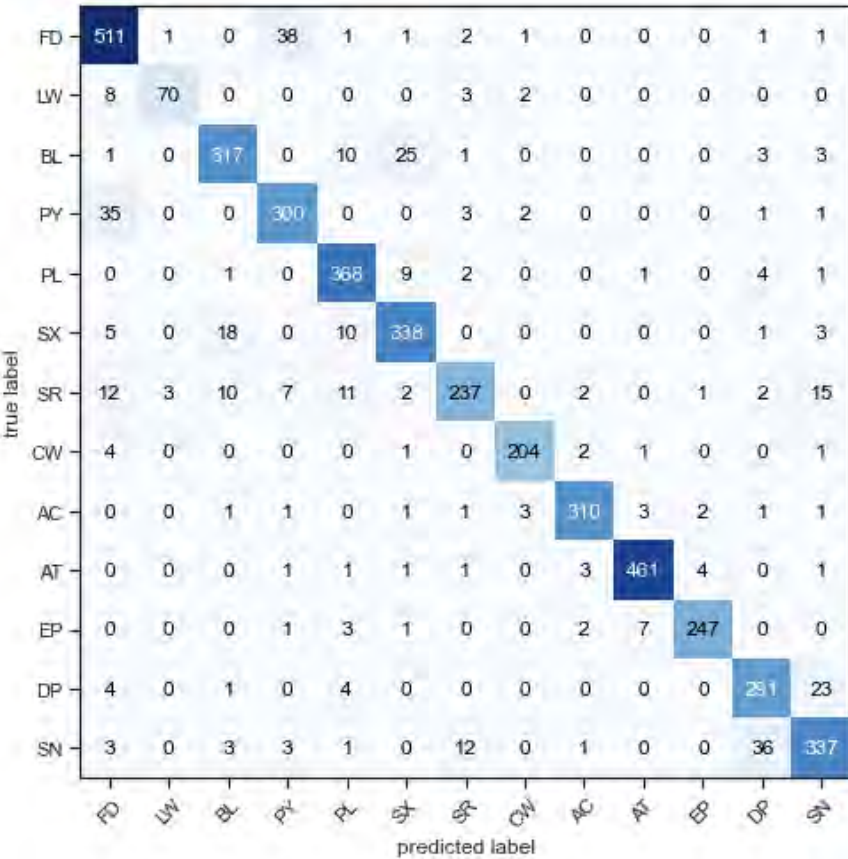
All Ground Truth Descriptor evaluation: LiDAR (geometry, density, intensity)



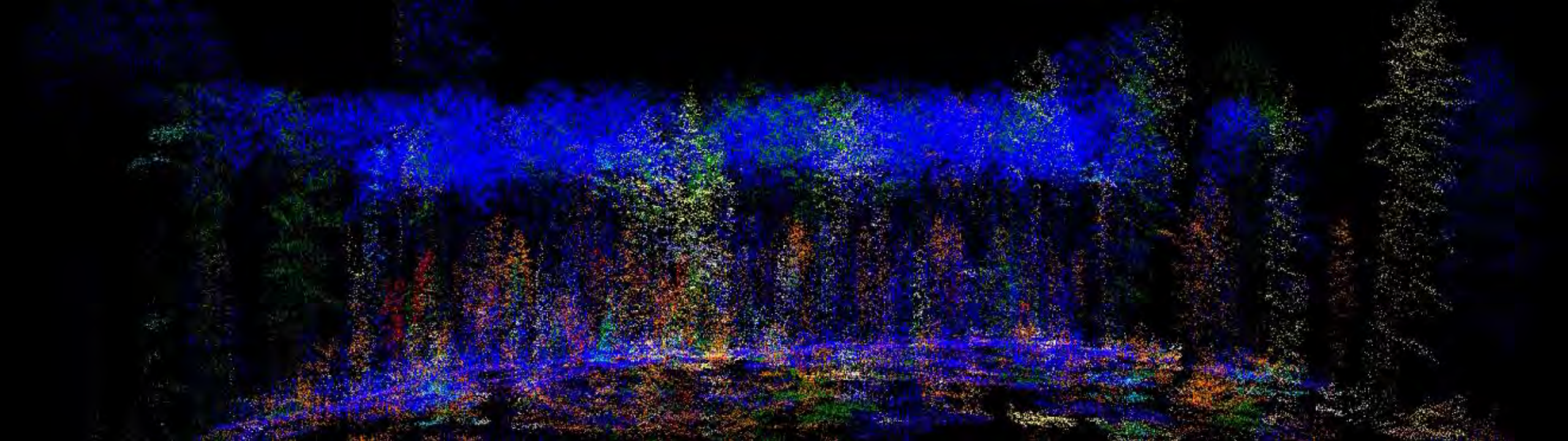
	precision	recall	f1-score	support
FD	0.71	0.80	0.75	557
LW	0.70	0.61	0.65	83
BL	0.78	0.82	0.80	360
PY	0.75	0.77	0.76	342
PL	0.67	0.85	0.75	386
SX	0.73	0.71	0.72	375
SR	0.50	0.27	0.35	302
CW	0.85	0.79	0.82	213
AC	0.77	0.72	0.74	324
AT	0.84	0.85	0.85	473
EP	0.78	0.65	0.71	261
DP	0.73	0.80	0.76	323
SN	0.73	0.73	0.73	396
accuracy			0.74	4395
macro avg	0.73	0.72	0.72	4395
weighted avg	0.74	0.74	0.73	4395

All Ground Truth Descriptor evaluation:

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



	precision	recall	f1-score	support
FD	0.88	0.92	0.90	557
LW	0.95	0.84	0.89	83
BL	0.90	0.88	0.89	360
PY	0.85	0.88	0.87	342
PL	0.90	0.95	0.93	386
SX	0.89	0.90	0.90	375
SR	0.90	0.78	0.84	302
CW	0.96	0.96	0.96	213
AC	0.97	0.96	0.96	324
AT	0.97	0.97	0.97	473
EP	0.97	0.95	0.96	261
DP	0.86	0.90	0.88	323
SN	0.87	0.85	0.86	396
accuracy			0.91	4395
macro avg	0.91	0.90	0.91	4395
weighted avg	0.91	0.91	0.91	4395



Thank you!



Mike Parlow

Team Lead
Remote Sensing Inventories

cell 250-954-7850