



Remote sensing of species mixtures in conifer plantations using LiDAR height and intensity data



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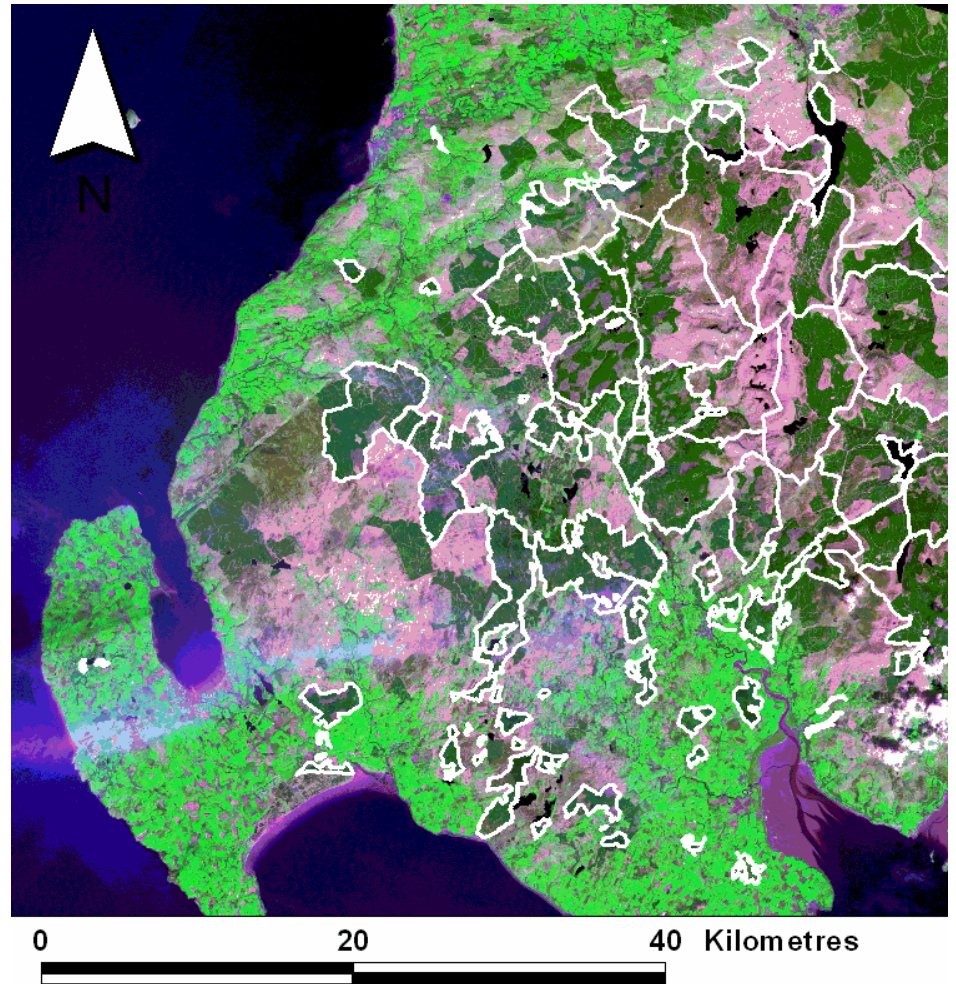
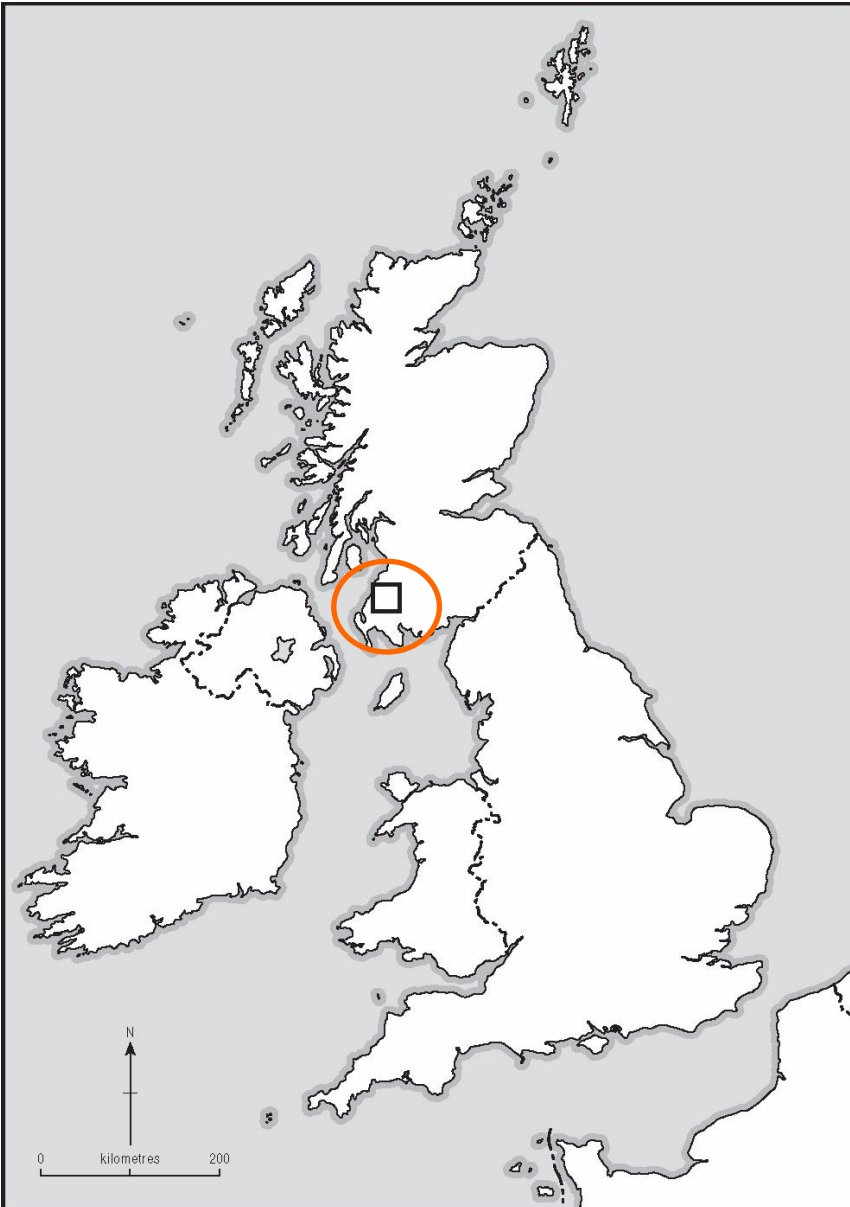
²Galloway Forest District, Forestry Commission Scotland



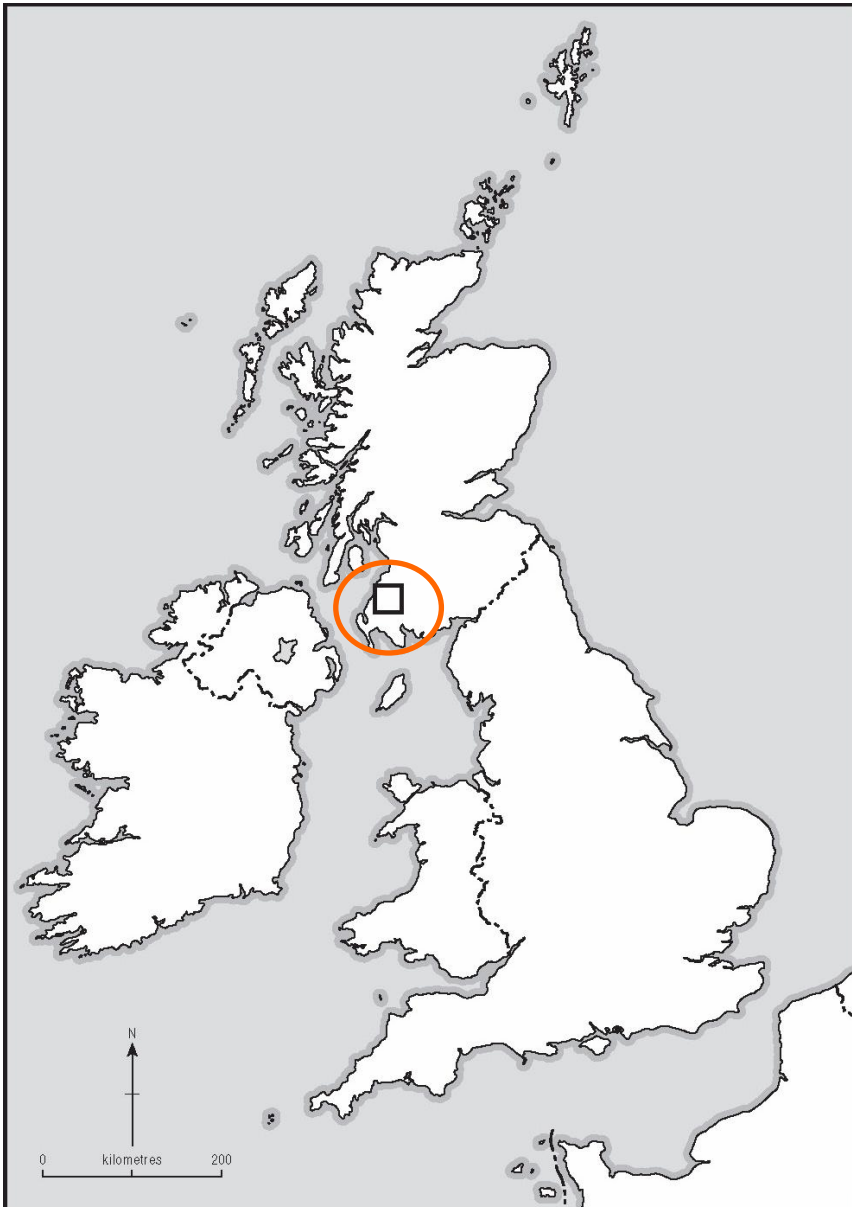
Conifer mixtures

Galloway Forest District, Scotland

60, 000 hectares



Conifer mixtures



Galloway Forest District, Scotland

60, 000 hectares

22% planted using species mixtures

Sitka dominated

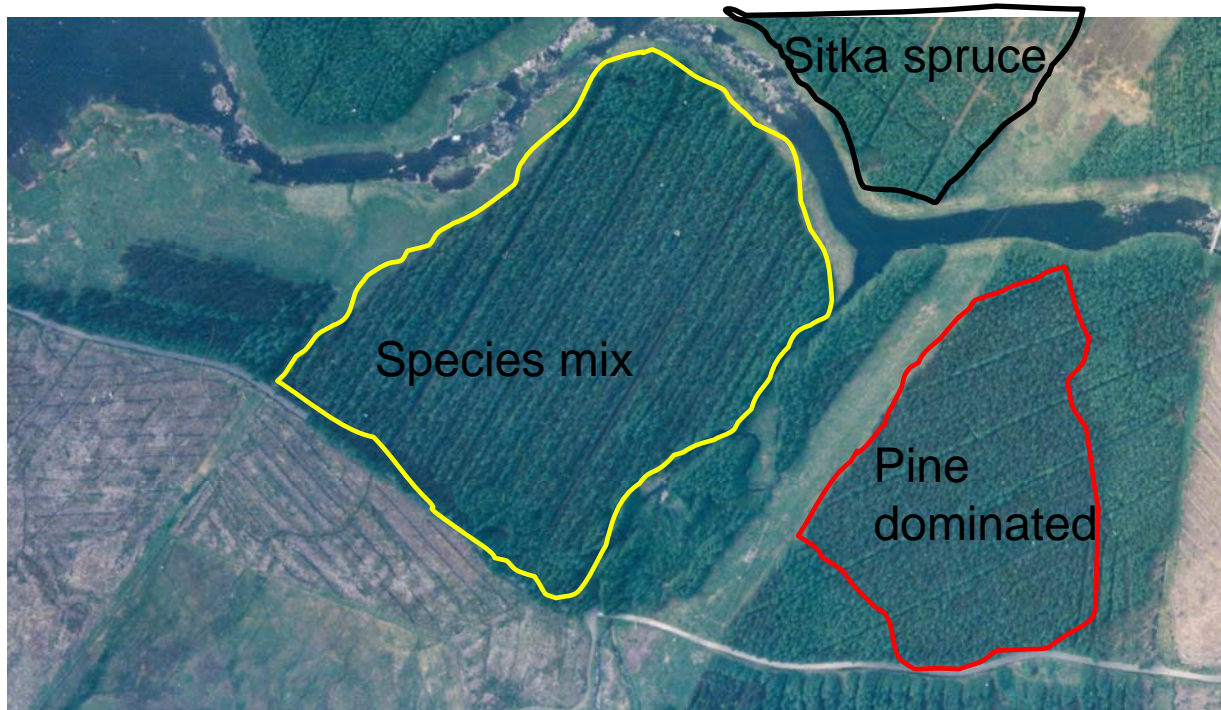
19 m

Sitka/pine
mixture

15 m



Current methods



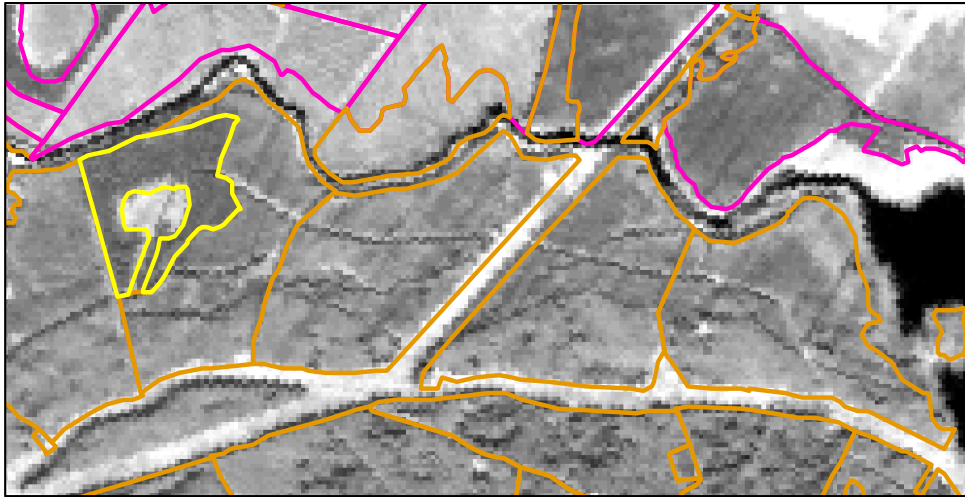
Species mixture = Pine and Sitka spruce planted together

Species mapping

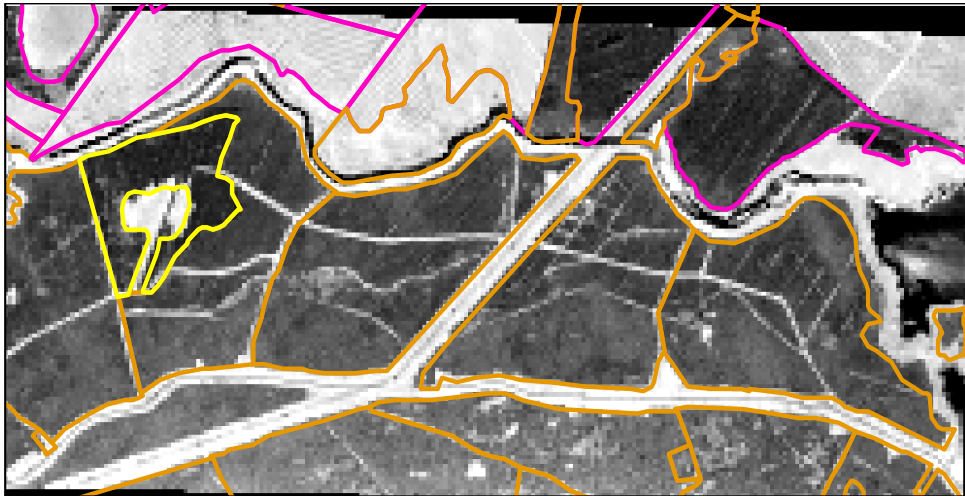
1. Spectral: LiDAR Intensity & SPOT 5
2. Canopy density: LiDAR
3. Combined estimate

Outcome = Quantification of volume
by species

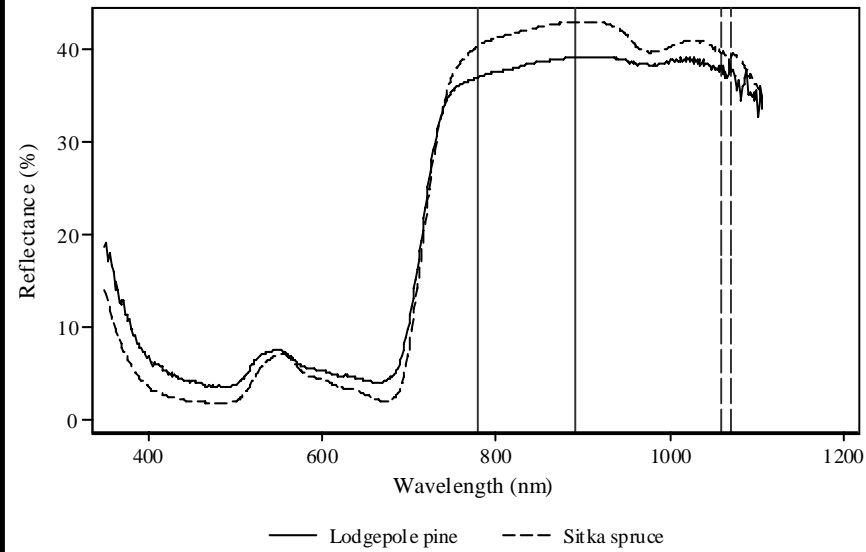
1. Spectral: SPOT 5 & LIDAR



SPOT NIR 10 m

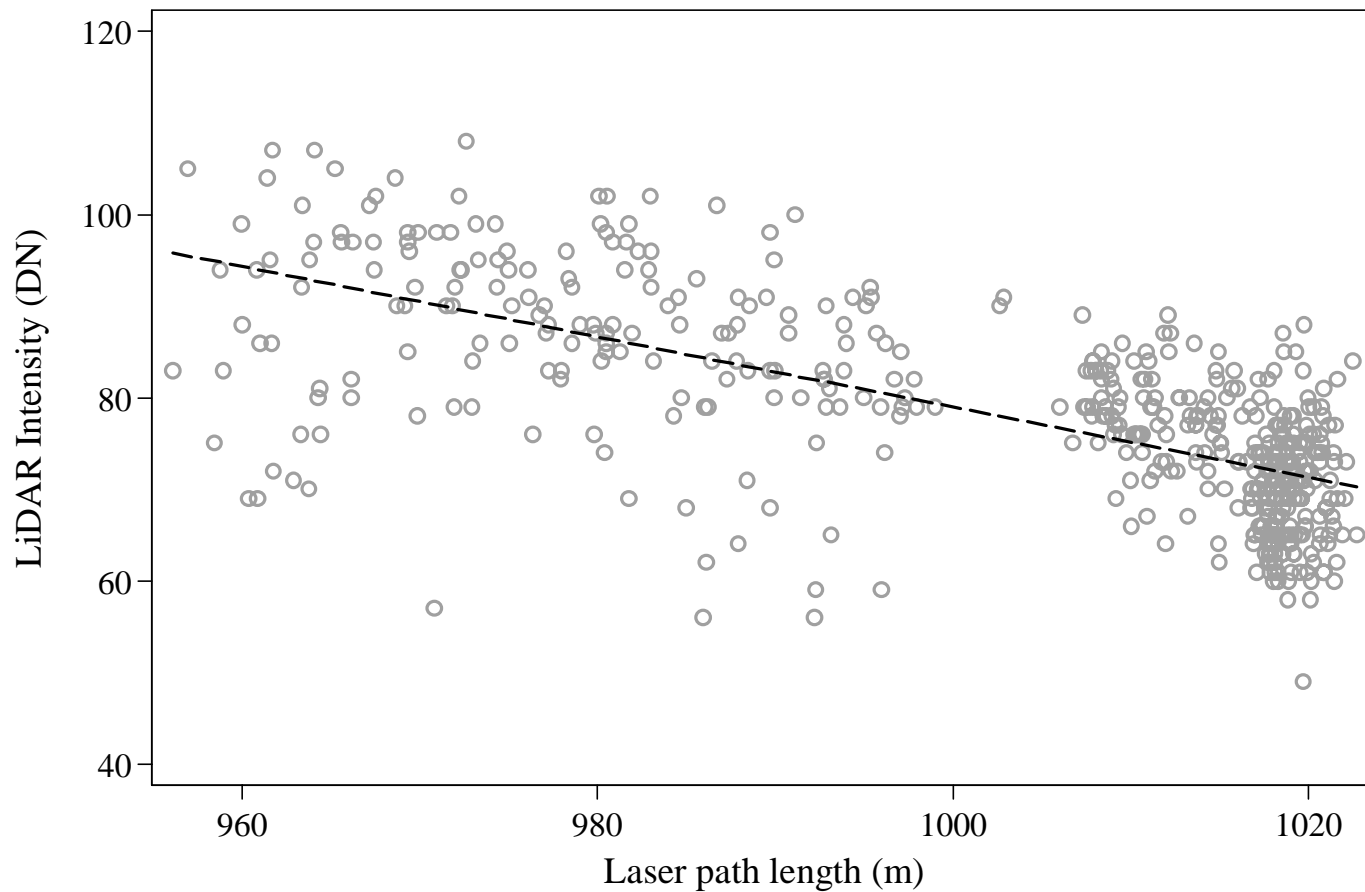


LiDAR NIR 10 m

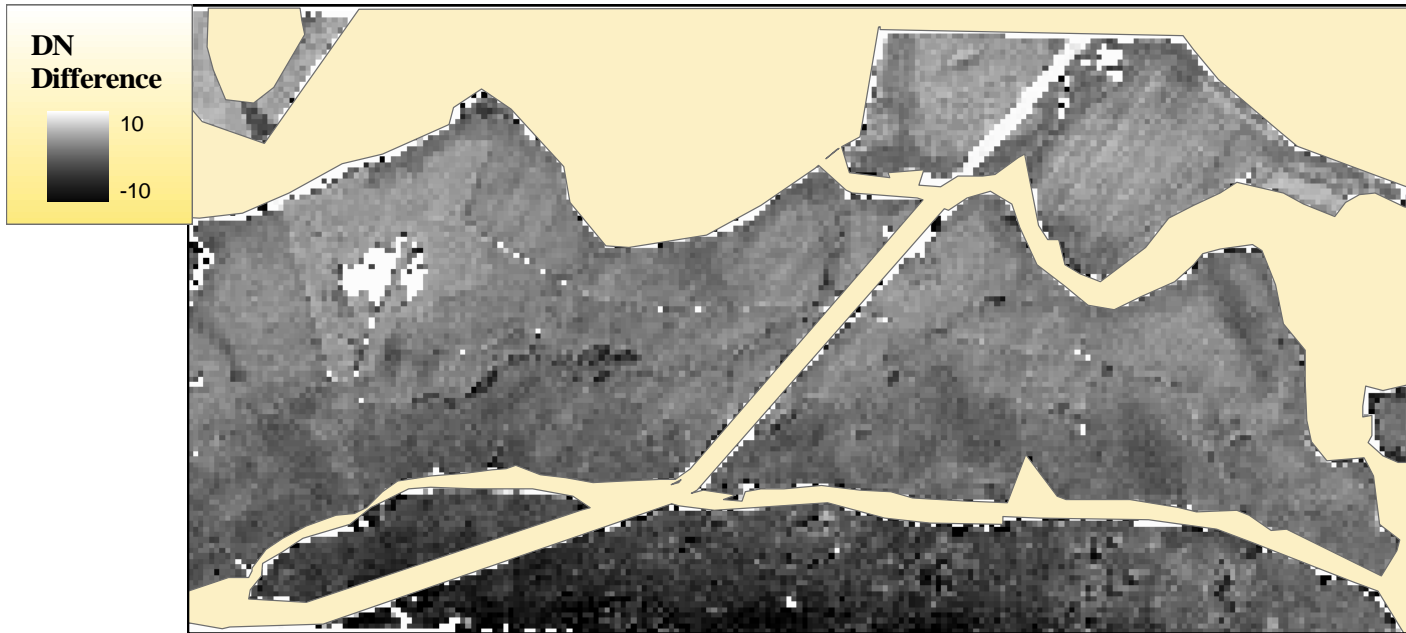


Spectral curves

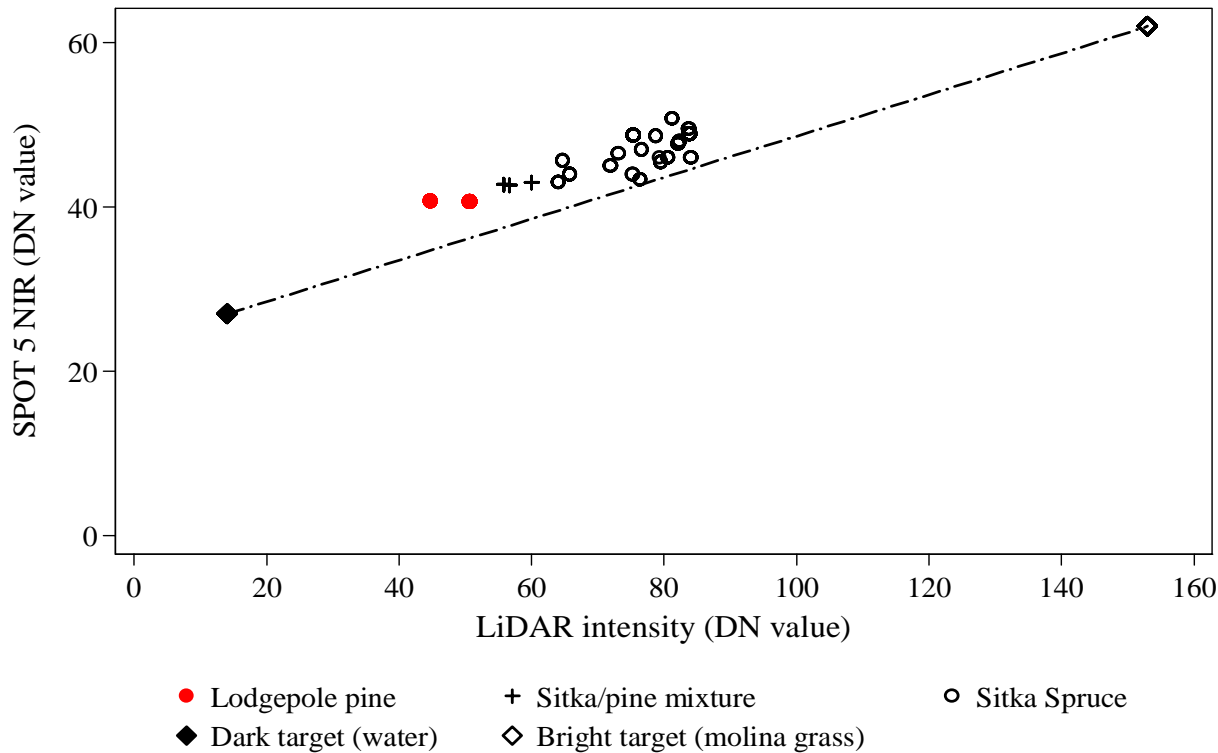
1. LiDAR Path length correction



LiDAR Path length correction



1. Spectral: SPOT 5 & LIDAR



Species are separated

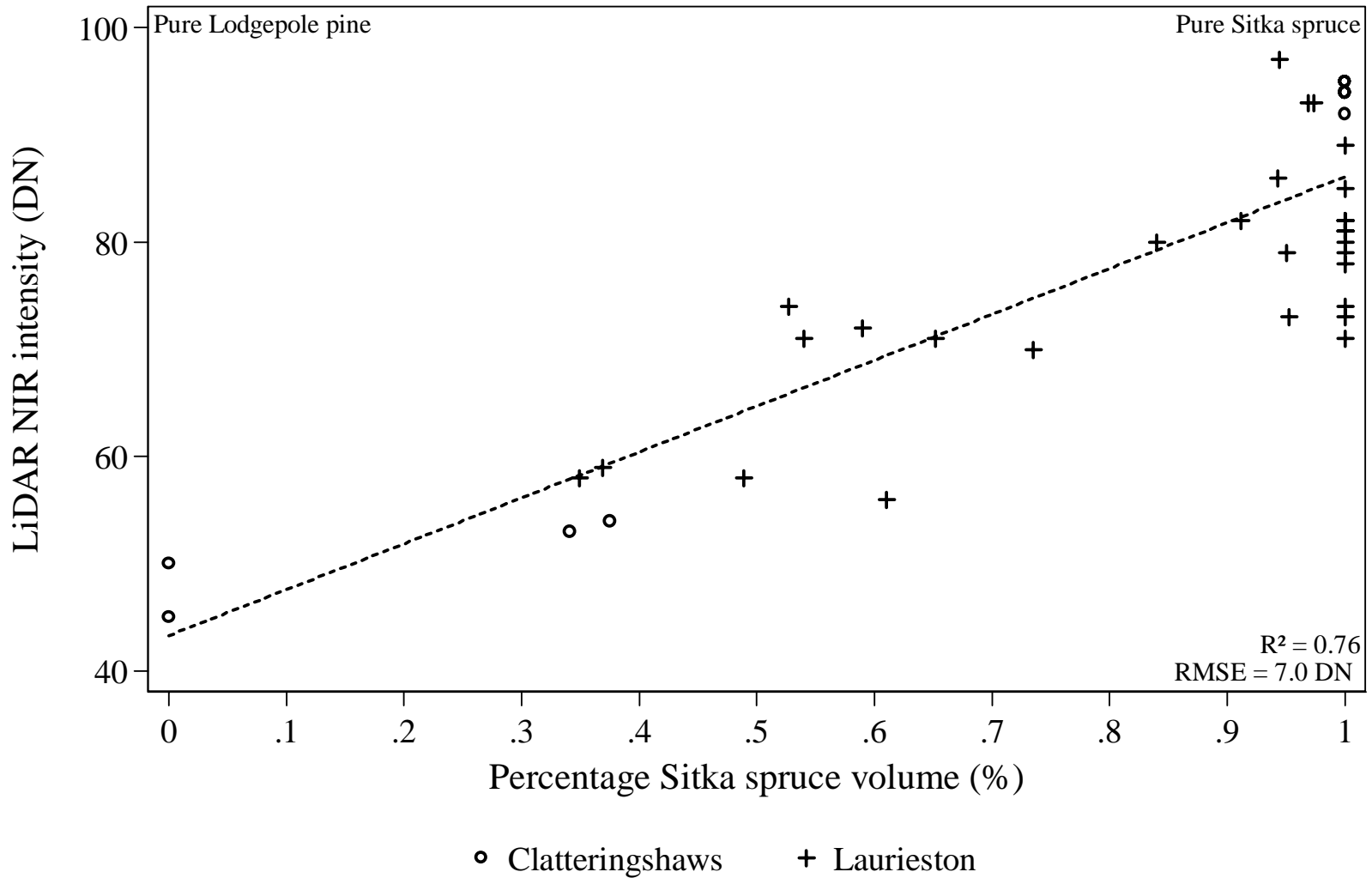
LiDAR NIR more sensitive than SPOT

Plot of NIR response

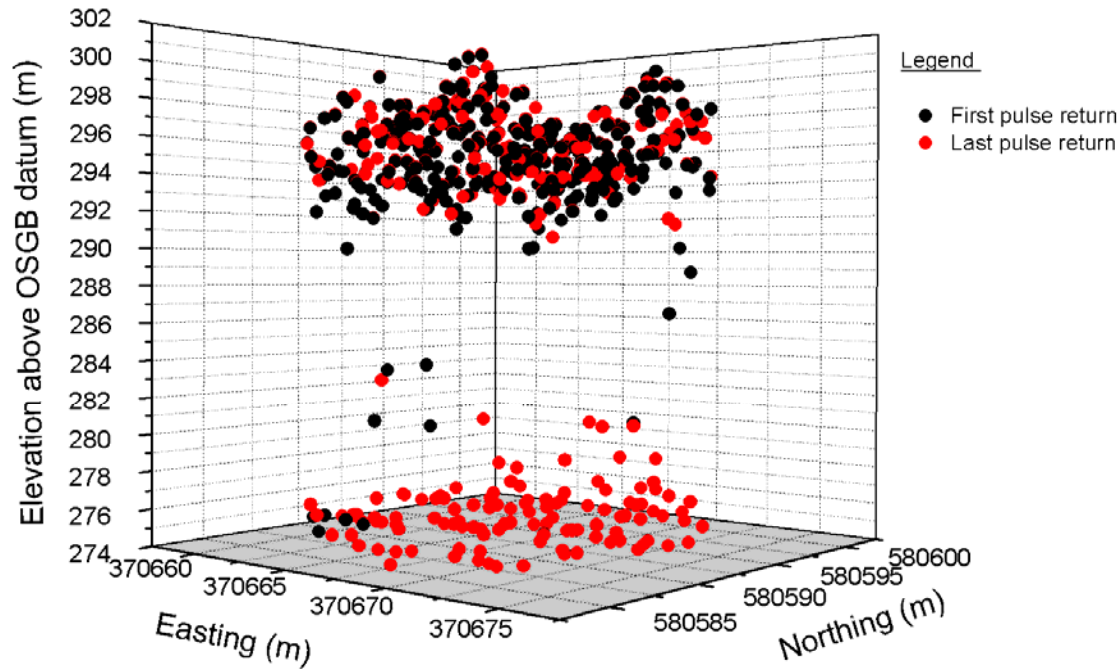
Field plot data (0.02ha)

Crop type	Tree species	Obs	Top height (m)				Volume (m ³ /ha)			
			Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
		No. field plots								
Pure	Sitka spruce	35	17.5	2.2	16.1	25.6	573.5	160.0	186.0	936.2
Pure	Lodgepole pine*	62 pixels	15.8	0.9	13.0	18.0	N/A			
Species mixture	Sitka spruce	19	16.9	1.8	14.3	19.0	125.1	30.5	80.3	156.2
	Lodgepole pine		15.9	1.4	14.3	17.9	182.4	48.1	137.3	256.6

1. LiDAR Int75% vs ground data



LiDAR first and last pulse distribution

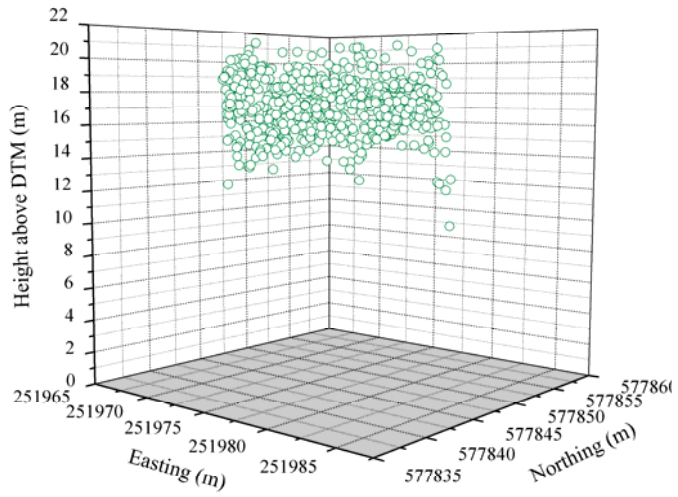


LiDAR first & last pulse distribution

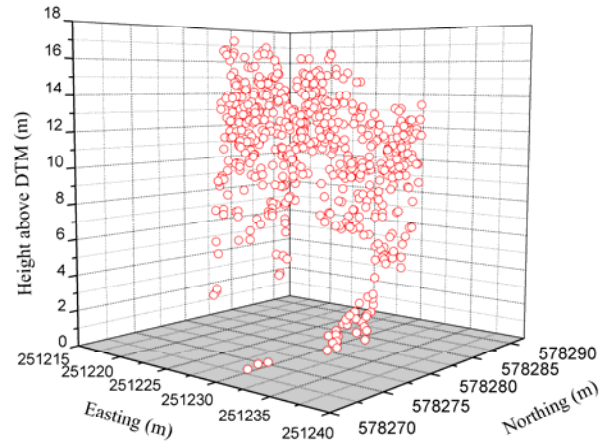
Calculated Measures

- Coefficient of variation
- Skewness
- % ground returns
- Mean height

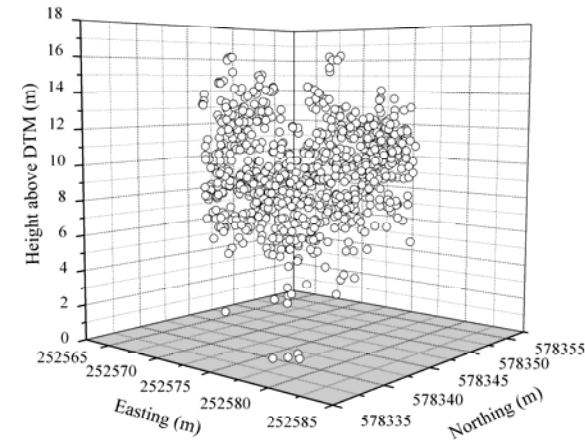
Pure Sitka spruce



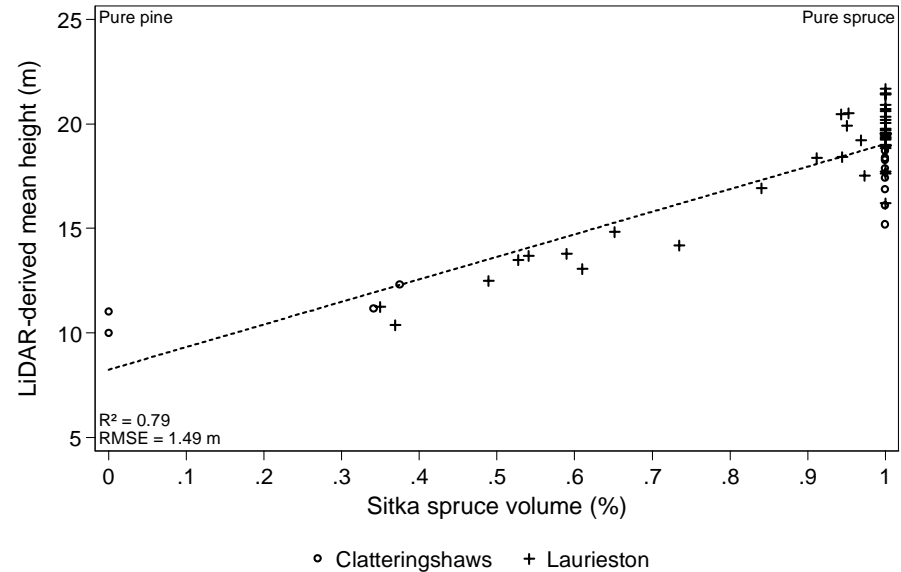
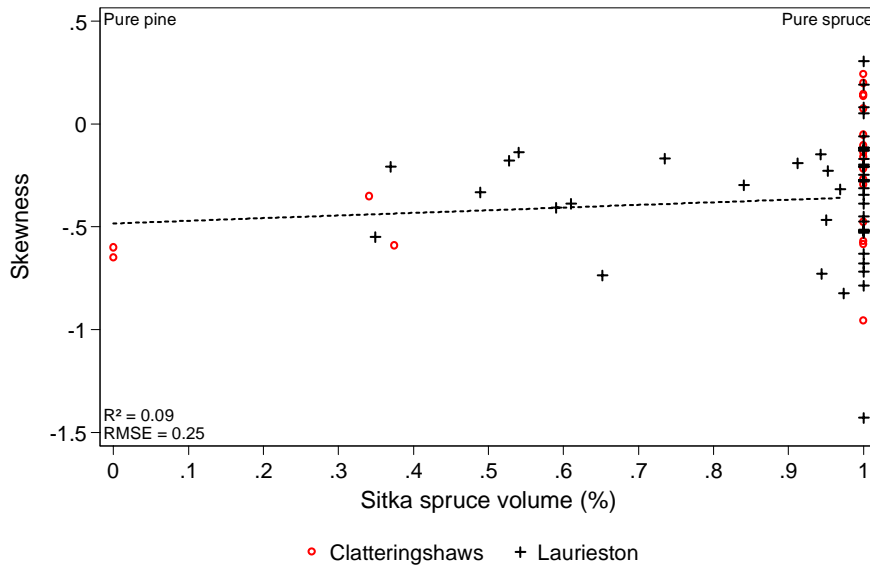
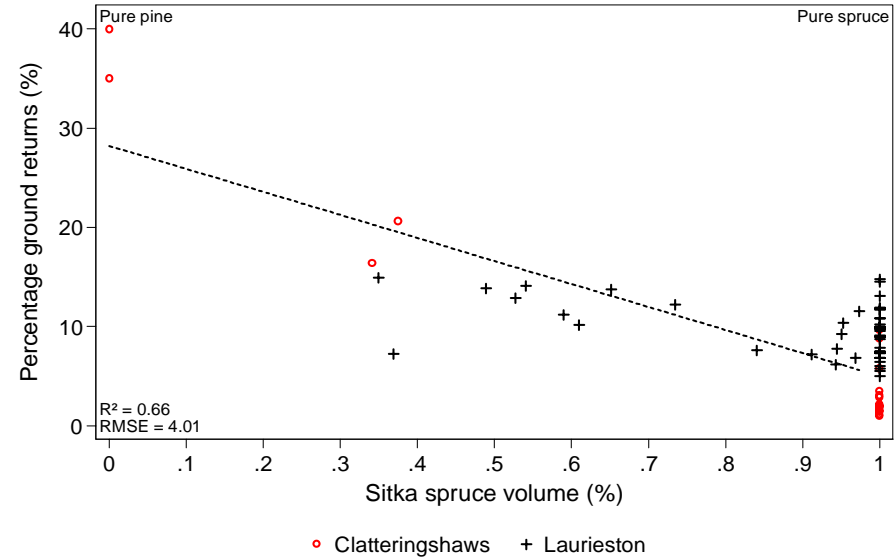
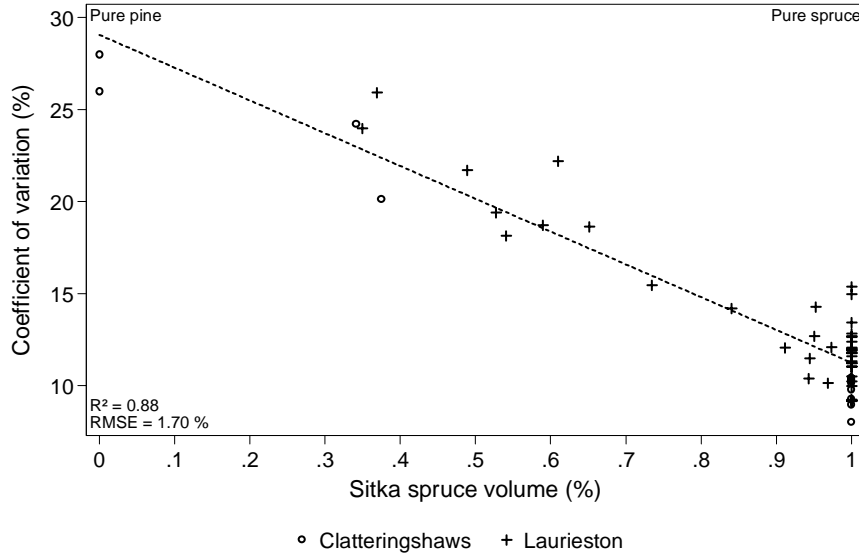
Pure lodgepole pine



Intimate mixture

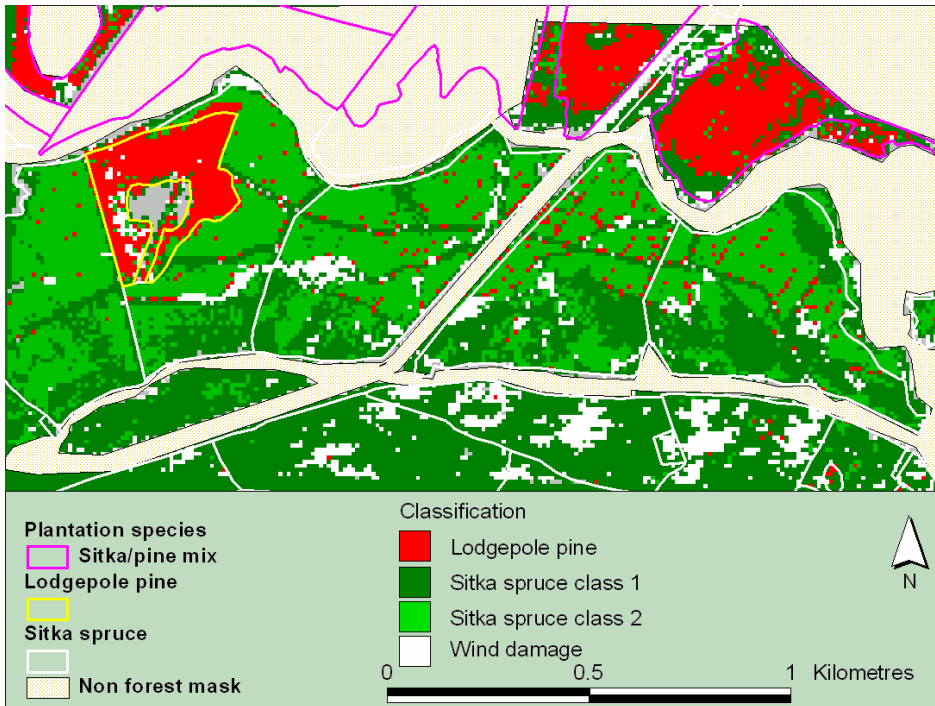


2. LiDAR canopy measures vs ground data



Linear regression			
Variable(s) <i>n</i> = 54	Description	<i>R</i>²	RMSE
Int75%	75 th percentile LiDAR intensity: First pulse returns	0.76	7.0
mean	LiDAR-derived mean height: First pulse returns	0.79	1.49
CV	Coefficient of variation: First pulse returns	0.88	1.70
skewness	Skewness of height of first pulse returns	0.09	0.25
%Zero	Percent last pulse ground returns	0.66	4.01
Multiple regression			
CV, mean		0.91	0.07
CV, mean, %Zero		0.95	0.05
CV, mean, %Zero, Int75%		0.96	0.05
CV, mean, %Zero, Int75%, skewness		0.97	0.05

Species distribution maps



LiDAR intensity & canopy density measures



SPOT 5 all spectral bands



LiDAR canopy density measures only

Conclusions

1. LiDAR intensity data useful for species and volume estimation
2. LiDAR pulse distribution data useful for species and volume estimation
3. LiDAR measures used together can be used to map species, volume by species, as well as wind and other damaged areas to very high levels of accuracy



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Project web site: ForestSAFE

www.svo.se/forestsafe