

Applications of Multispectral LiDAR in forest mapping

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Information from LiDAR for forest mapping

- Structural information from LiDAR has been used for mapping of various forest properties, for example
 - Biomass and stem volume
 - Canopy cover
 - Forest 3D structure
- Multispectral LiDAR (MS-LiDAR) provides both structural and spectral information
- Spectral information is expected to provide information about tree species and other forest properties where the color is important



Information from LiDAR for forest mapping

- **Mapping from MS-LiDAR found in literature**
- Tree species mapping – color differs slightly between tree species
- Individual tree delineation – spectral differences between trees
- Land cover mapping
- Digital terrain models, especially around water bodies
- Forest fuel mapping
- Analysis of forest health and vitality



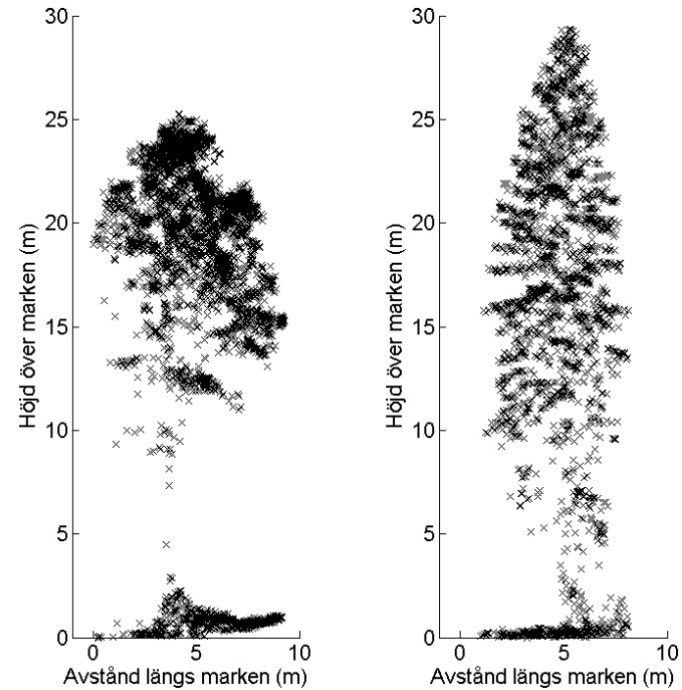
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Properties of trees from LiDAR

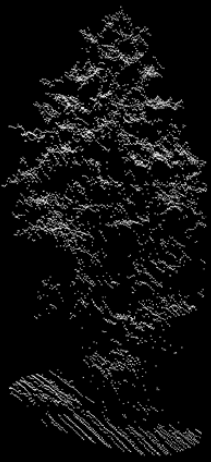
- With dense LiDAR data, objects can be detected and modelled
- Individual trees can be delineated, at least to some degree
- The shape and proportion of the tree crown is related to the tree species
- However, structural features overlap between different tree species
- How can multispectral LiDAR contribute to tree species classification?



Exploring MS-LiDAR for tree species classification

- Pilot study with 179 observations of nine tree species (solitary trees)
- Data collected in 2016 in southwest Sweden
- Airborne laser scanning with Optech Titan X
 - 1550 nm (SWIR)
 - 1064 nm (NIR)
 - 532 nm (green)
- Flight altitude 400 m agl, approximately 30-40 returns/m² and wavelength
- Range correction of intensity





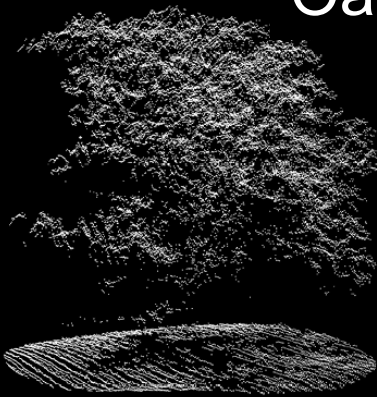
Alder



Ash



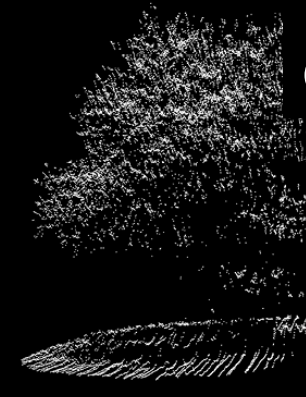
Birch



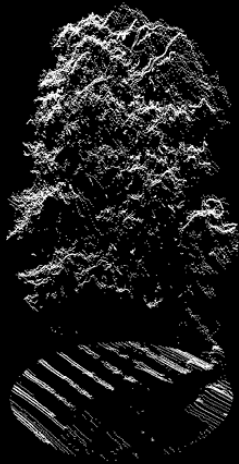
Oak



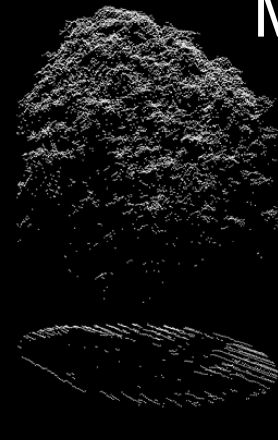
Spruce



Wild
cherry



Linden



Maple



Pine



Exploring MS-LiDAR for tree species classification

- Manual delineation of trees from the LiDAR data
- Extraction of features separately for each wavelength from
 1. 3D canopy structure (coordinates) and
 2. intensity
- Classification of tree species using Linear Discriminant Analysis (LDA) from the different feature sets



Exploring MS-LiDAR for tree species classification

- Classification of tree species from different feature sets

Overall acc.	Structure	Intensity	All
Multispectral	41%	76%	77%
Monospectral (1064 nm)	36%	68%	67%

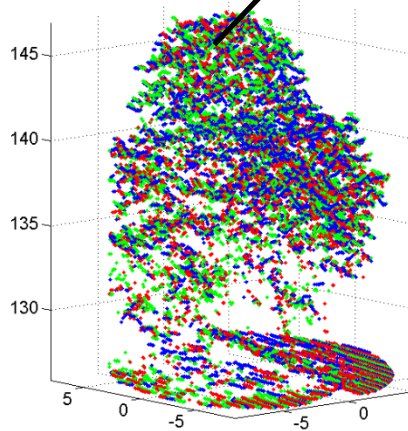
- When all features were included, the highest ranked features were from intensity



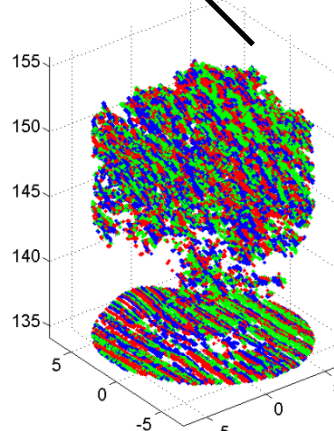
Exploring MS-LiDAR for tree species classification

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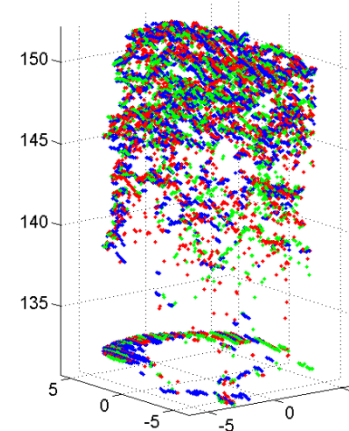
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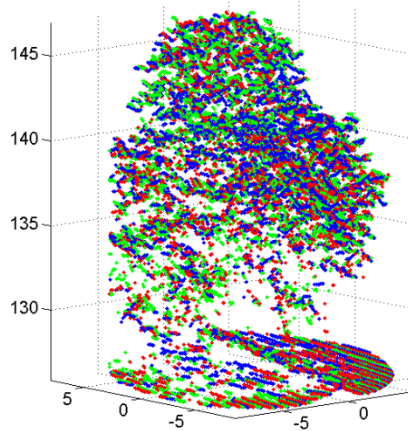
Maple



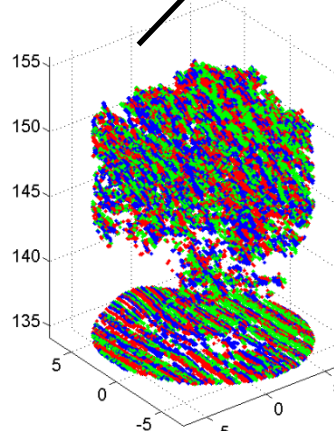
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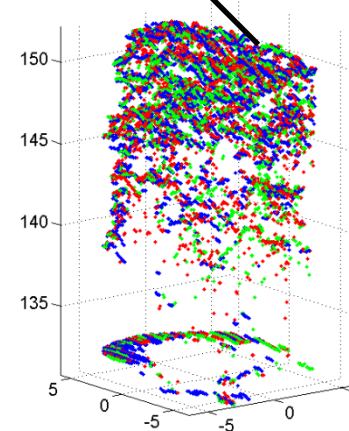
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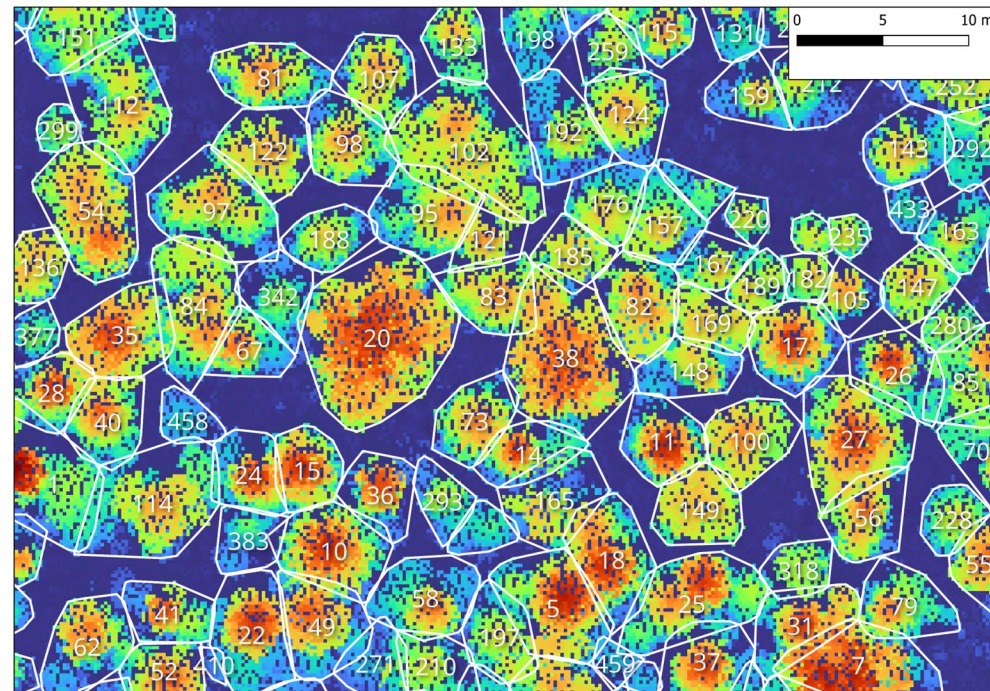
Classifying tree species from dual-wavelength LiDAR

- Large-scale setting: 1520 ha study area, 256 sample plots
- Data collected in 2019 in central Sweden
- Tree species classes: pine, spruce, and broadleaf species
- Airborne laser scanning with Riegl VQ-1560i-DW
 - 1064 nm (NIR)
 - 532 nm (green)
- Flight altitude 800 m agl, approximately 30 returns/m² and wavelength



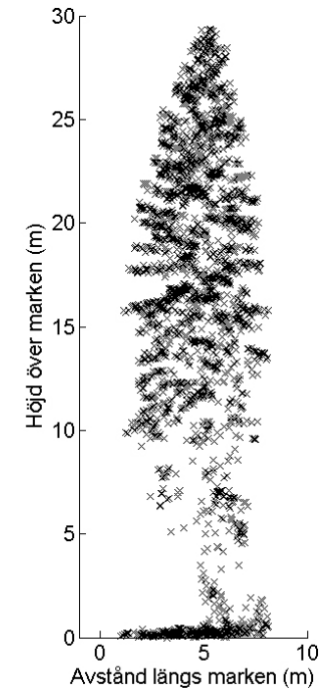
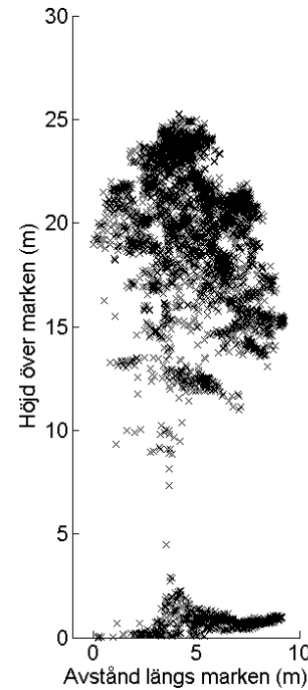
Classifying tree species from dual-wavelength LiDAR

- Automatic delineation of individual tree crowns
- Extraction of features from 1. the combined point cloud and 2. NIR only
 - 3D canopy structure
 - Intensity
 - Proportions of different returns



Classifying tree species from dual-wavelength LiDAR

- Linking of delineated tree crowns to field-inventoried trees
- Classification of tree species using LDA from the different feature sets
- Estimation of stem volume for the delineated tree crowns



Classifying tree species from dual-wavelength LiDAR

- Confusion matrix for classification results

Combined point cloud

	Pine	Spruce	Broad-leaf	UA
Pine	347	21	23	89
Spruce	30	346	24	86
Broad-leaf	11	21	341	91
PA	89	89	88	89

NIR only

	Pine	Spruce	Broad-leaf	UA
Pine	323	18	58	81
Spruce	19	325	58	81
Broad-leaf	46	45	272	75
PA	83	84	70	79



Classifying tree species from dual-wavelength LiDAR

- Confusion matrix for classification results

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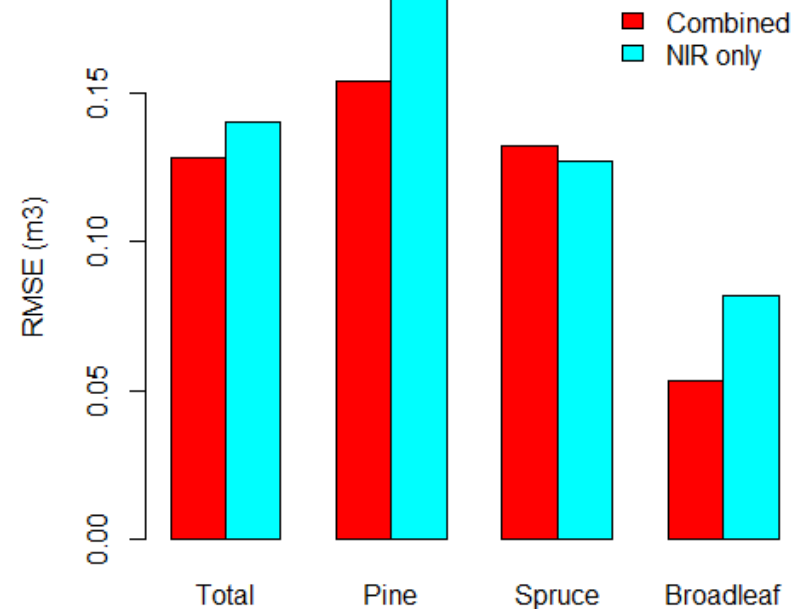
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Classifying tree species from dual-wavelength LiDAR

- Accuracy of estimated stem volume per tree species
- More accurate tree species classification resulted in higher accuracy



Alternative to individual trees – mini raster

- Individual tree methods require dense LiDAR data
- Is a statistical approach possible instead?
- In area-based methods, metrics are calculated in sample plots or raster cells with typical size 10x10 m
- A prediction model is formulated between the stand attributes and the metrics
- However, the tree species may be mixed in a plot with for example 10 m radius
- Use a smaller area to get more homogenous tree species?



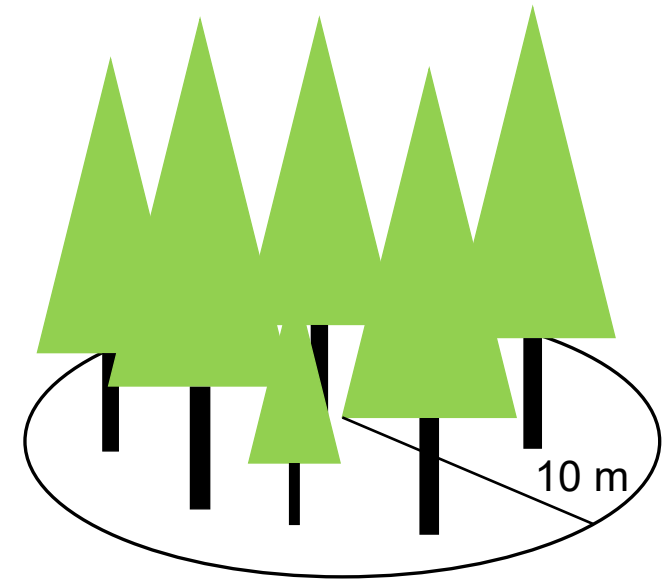
Alternative to individual trees – mini raster

- A new variety of area-based analysis of LiDAR data
- Classify dominant tree species for raster cells with size 0.5x0.5 m using a moving window approach
- The features in each raster cell are derived in a circle with radius 5 m
- Features from LiDAR intensity in different wavelengths
- The resulting raster can be aggregated for areas of interest

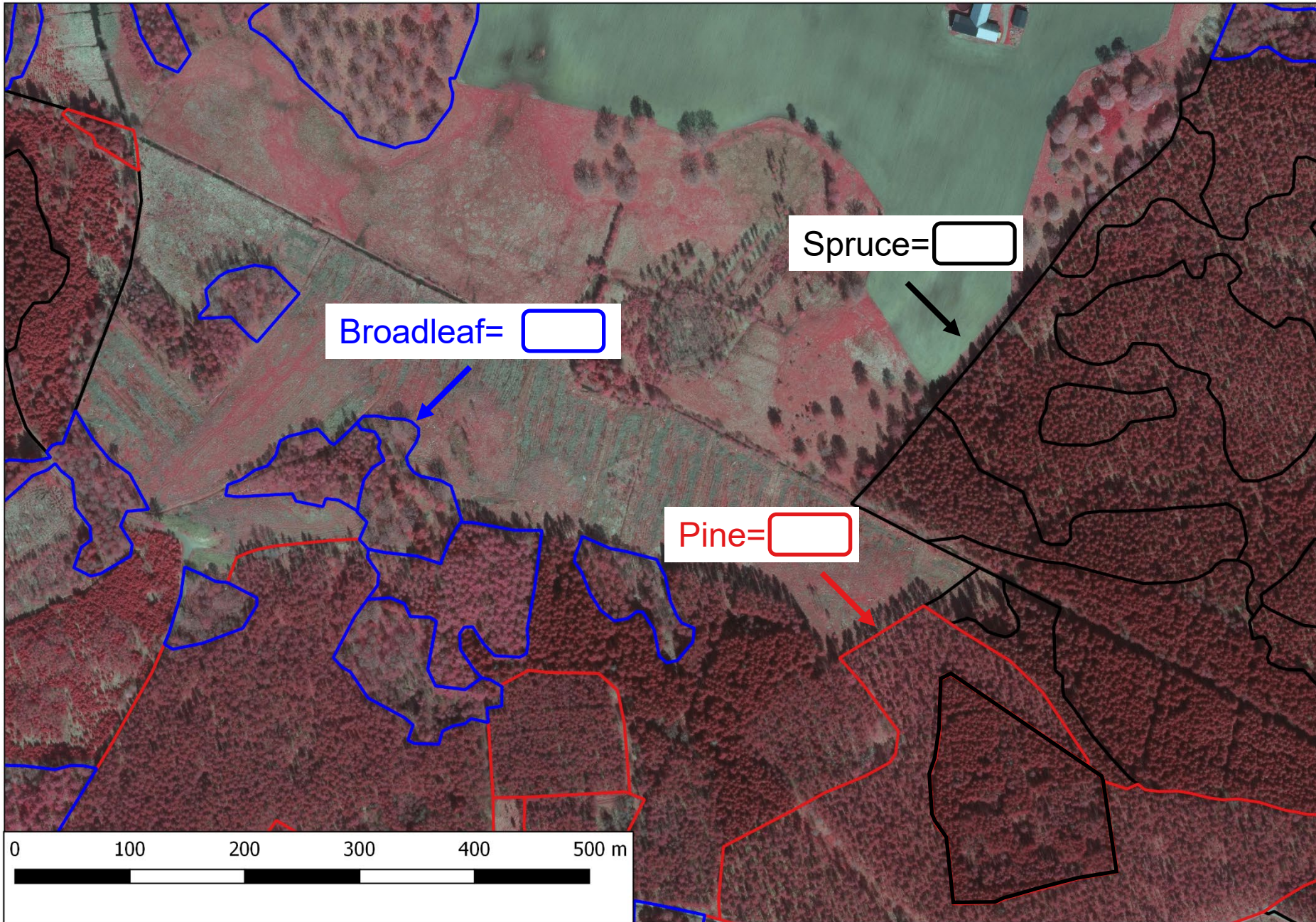


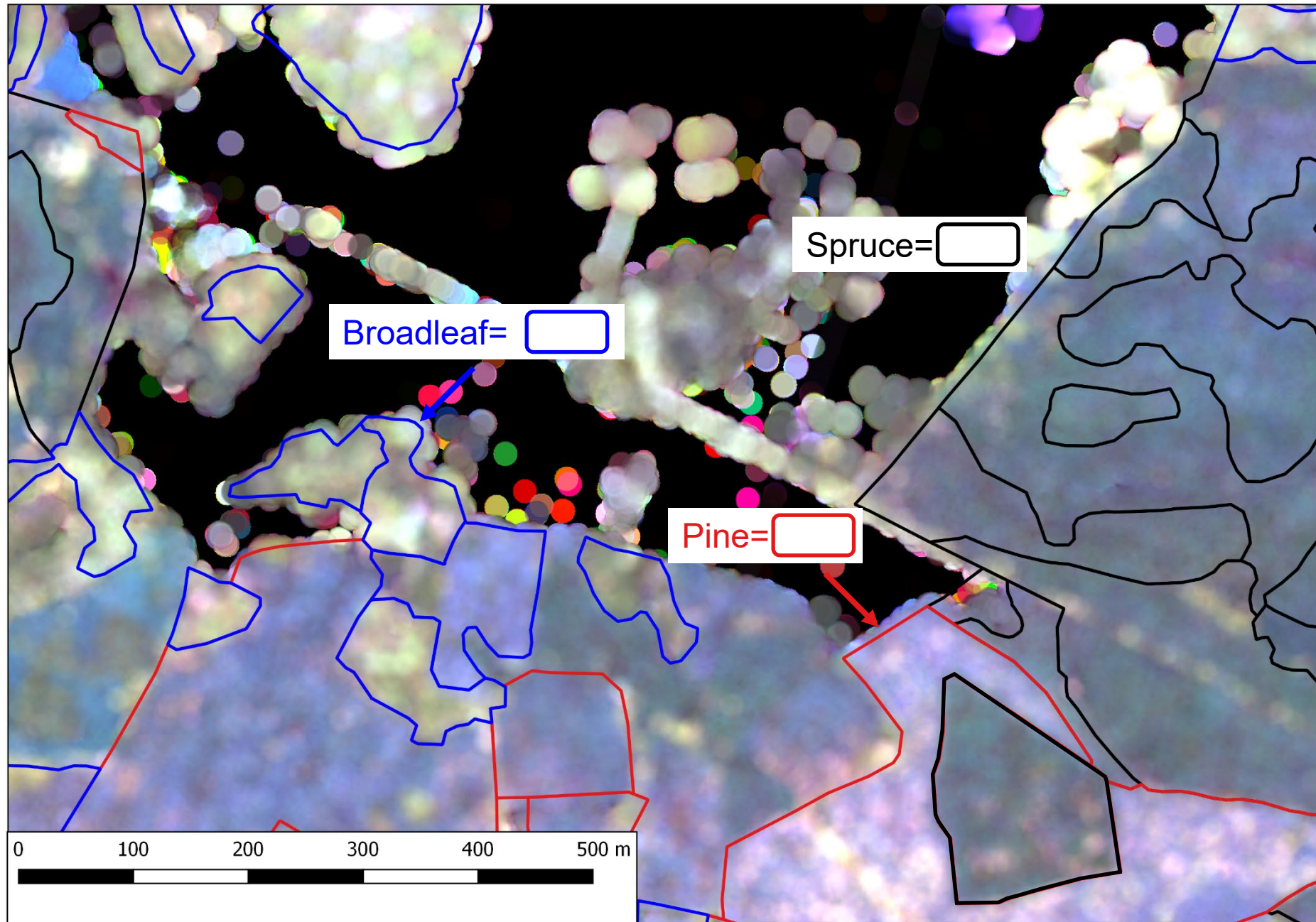
Alternative to individual trees – mini raster

- Data collected in 2016 in southwest Sweden
- Airborne laser scanning with Optech Titan X
- Field inventory of 331 sample plots
- Select plots with mature forest only
- Dominant tree species based on basal area:
Pine, spruce, and broadleaf species

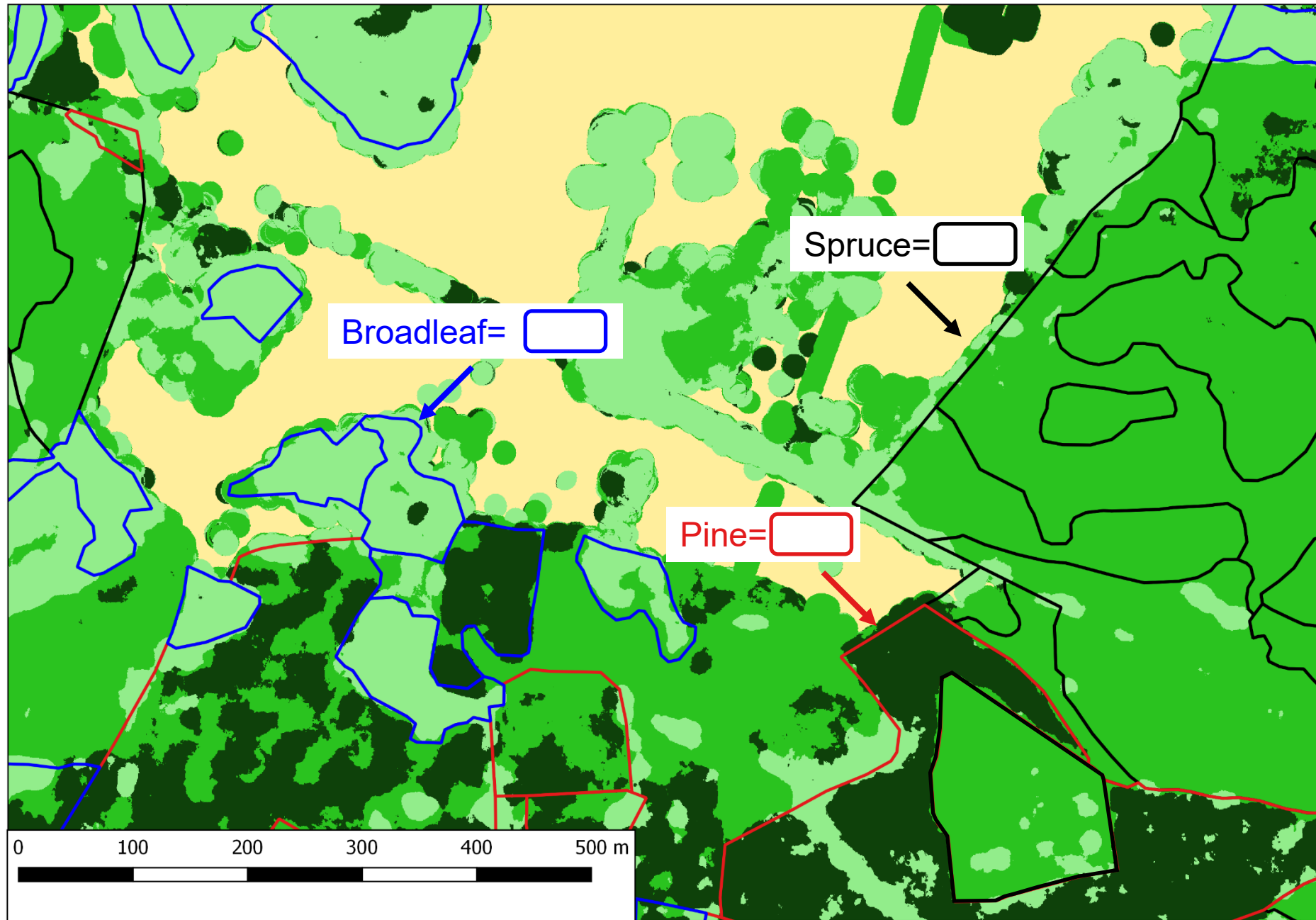


Aerial image





Classified raster from MS-LiDAR Pine=  Spruce=  Broadleaf= 



Alternative to individual trees – mini raster

- Confusion matrix, tree species composition evaluated in sample plots
- Conventional area-based analysis, classification at plot level

	Pine	Spruce	Broad-leaf	Mixed	UA
Pine	19	0	0	5	79%
Spruce	2	84	2	25	74%
Broad-leaf	0	0	13	11	54%
Mixed	1	5	8	11	44%
PA	86%	94%	57%	21%	68%



Alternative to individual trees – mini raster

- Confusion matrix, tree species composition evaluated in sample plots
- New mini raster method

	Pine	Spruce	Broad-leaf	Mixed	UA
Pine	17	0	0	3	85%
Spruce	2	86	2	16	81%
Broad-leaf	0	0	15	11	58%
Mixed	3	3	6	22	65%
PA	77%	97%	65%	42%	75%



Alternative to individual trees – mini raster

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Conclusions

- Multispectral LiDAR improves classification of tree species compared to monospectral LiDAR
- In particular the intensity in several wavelengths is important
- Part of the improvement comes from structural features – higher point density, possibly better spatial distribution of points
- More accurate species classification resulted in higher accuracy for volume estimation



Thank you!

- Questions?
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