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Individual tree properties from ALS data as input to habitat analysis in boreal forest

Eva Lindberg [1,2], Jean-Michel Roberge [3], Therese Johansson [3], Markus Hollaus [2], Johan Holmgren [1] and Joakim Hjältén [3]

[1] Department of Forest Resource Management, Swedish University of Agricultural Sciences, Umeå, Sweden

[2] Department of Geodesy and Geoinformation, TU Wien, Vienna, Austria

[3] Department of Wildlife, Fish, and Environmental Studies, Swedish University of Agricultural Sciences, Umeå, Sweden

Presented in SilviLaser 2015, La Grande Motte, France, 28 – 30 September 2015

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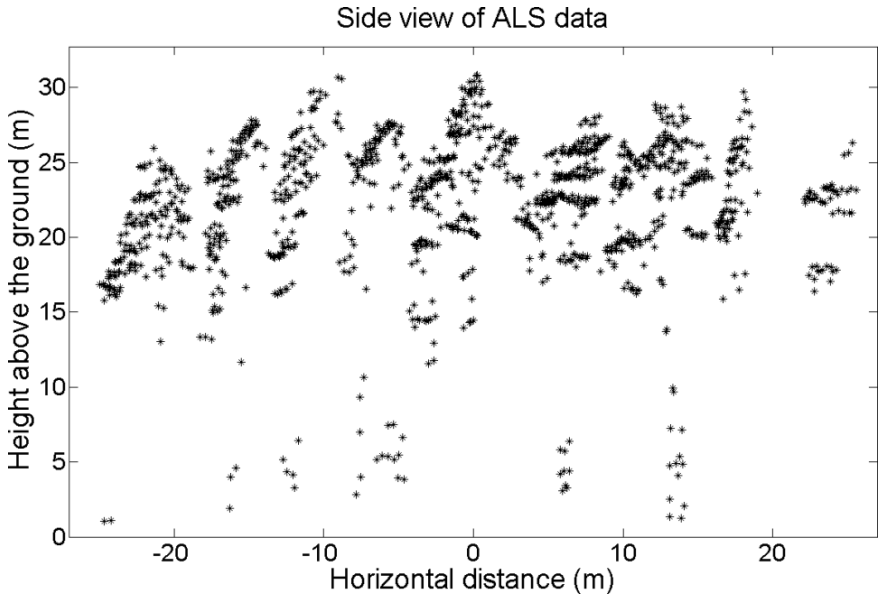
Introduction

Management of forests for biodiversity conservation

- Requires knowledge about habitat needs of forest-dwelling species

- Important habitat factors include
  - local stand conditions: forest structure, tree species
  - amount and distribution of suitable micro-habitats

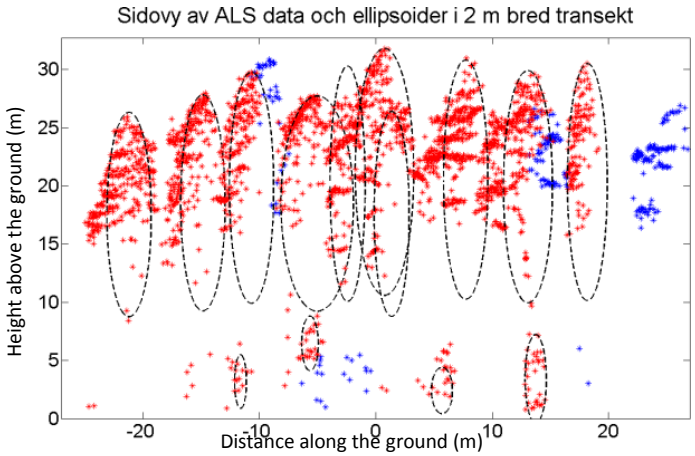
- Information at both scales can be derived from remotely sensed data



Detailed analysis of forest canopy from ALS data

- Until now, habitat studies including ALS data have mostly used area-based analysis where features are extracted as statistics from the ALS data in raster cells, typically with size in the order of 100-400 m^2.

- However, more detailed information about objects and structures can be derived from the ALS data. With dense ALS data (>5 returns/m^2), individual tree crowns (ITC) can be delineated from the data.



Objectives

- Evaluate if detailed analysis of the forest canopy from ALS data can improve our ability to detect habitat characteristics important for biodiversity of forest-dwelling birds and beetles.

Research questions

- Does information derived from individual tree crowns contribute additionally to habitat analysis compared to area-based information only?
  - estimation of the height distribution
  - information for tree species classification

- Which individual tree crown-based variables contribute most to our ability to predict the biodiversity pattern for birds and beetles and what tree properties do they represent?

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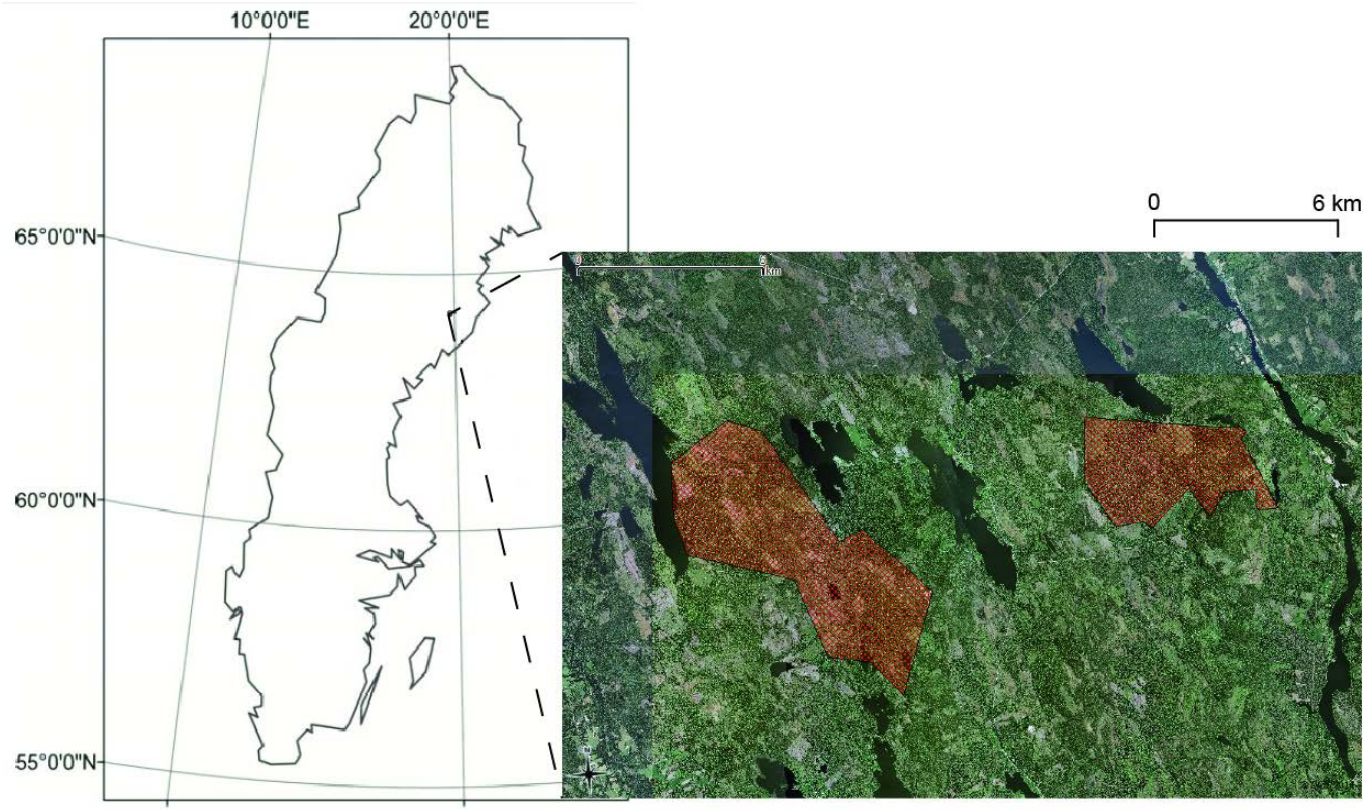
Material and methods

Study area

- Forest landscape in the middle boreal zone in northern Sweden
- Coniferous-dominated forest: Scots pine and Norway spruce



Field data

- Mature, middle-aged and young forest stands

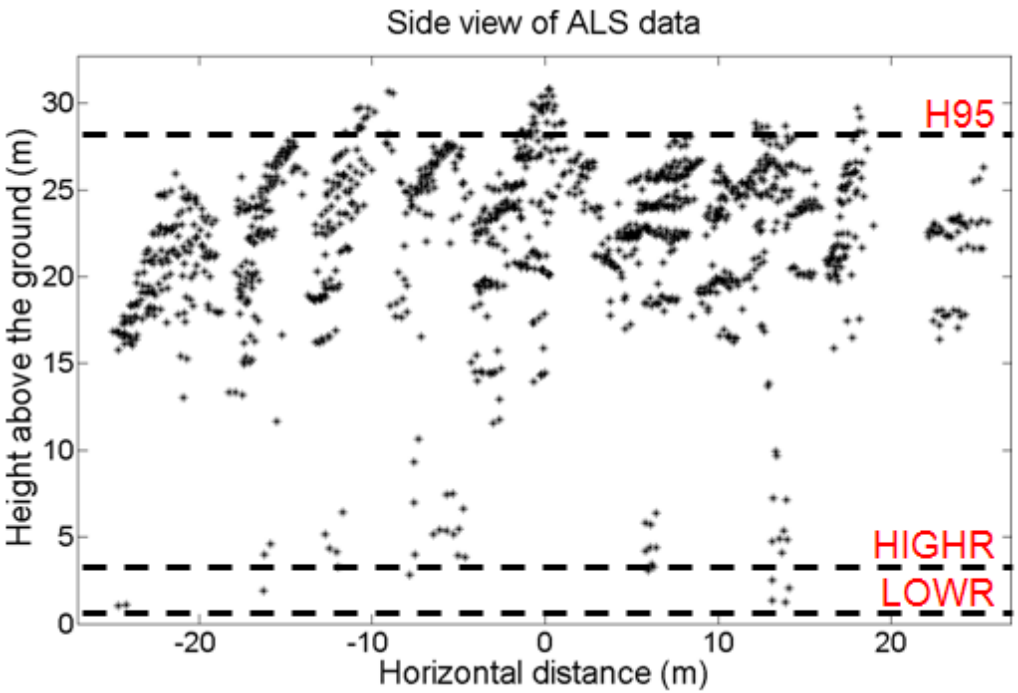
- Biodiversity data
  - birds surveyed using fixed-radius point counts (60 stands)
  - flying beetles captured using flight interception traps (42 stands)
  - ground-dwelling (Epigaeic) beetles captured using pitfall traps (42 stands)

- Abundance and species richness in each species group

Remotely sensed data

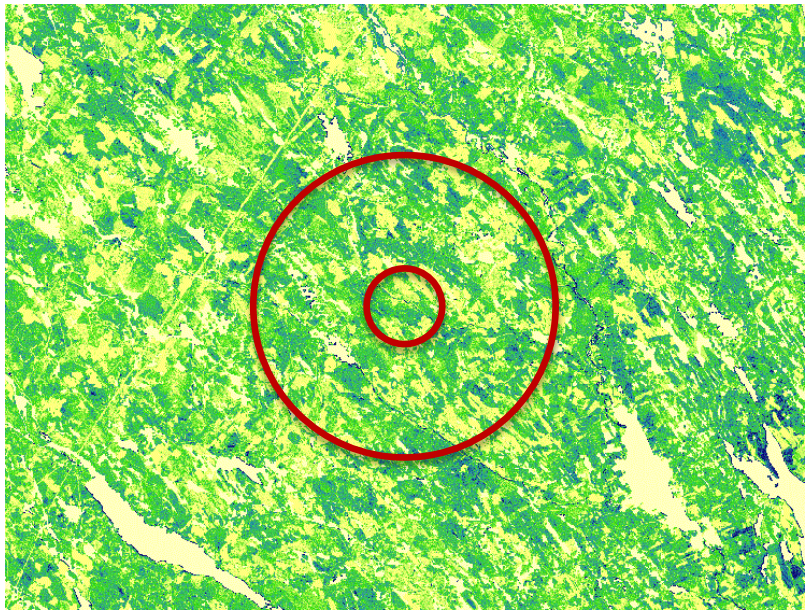
Airborne laser scanning data

- density of returns 5 m^{-2}
- area-based metrics describing the height and density of the vegetation in raster cells
- individual tree crown-based metrics describing the properties of tree crowns delineated from the ALS data



Remotely sensed data

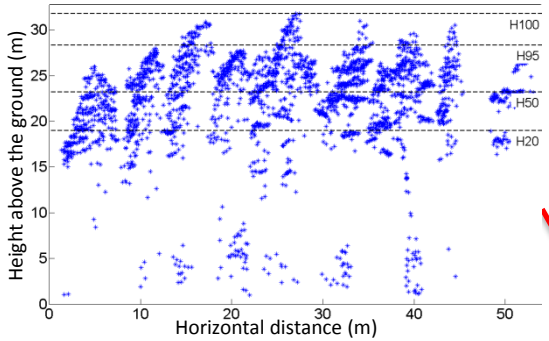
Variables describing forest conditions were derived in circles with 50 m radius



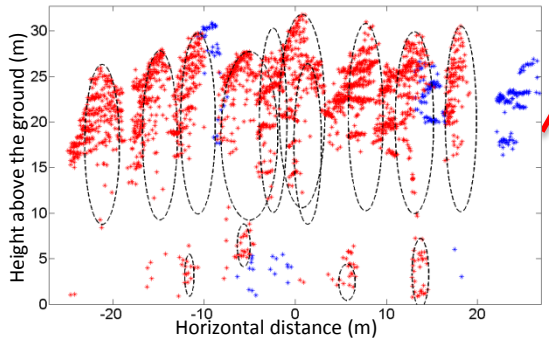
Overview

- Use variables derived from ALS data in regression models

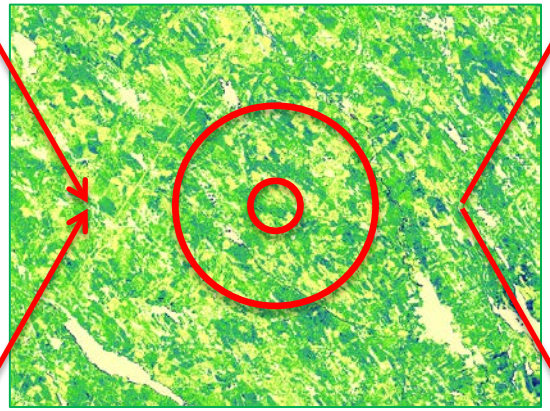
Area-based



ITC-based



Regression models



Bird abundance and species richness

Beetle abundance and species richness

Delineation of individual tree crowns from ALS data

- Segmentation of a correlation surface model followed by ellipsoidal tree model clustering of the ALS data in 3D.

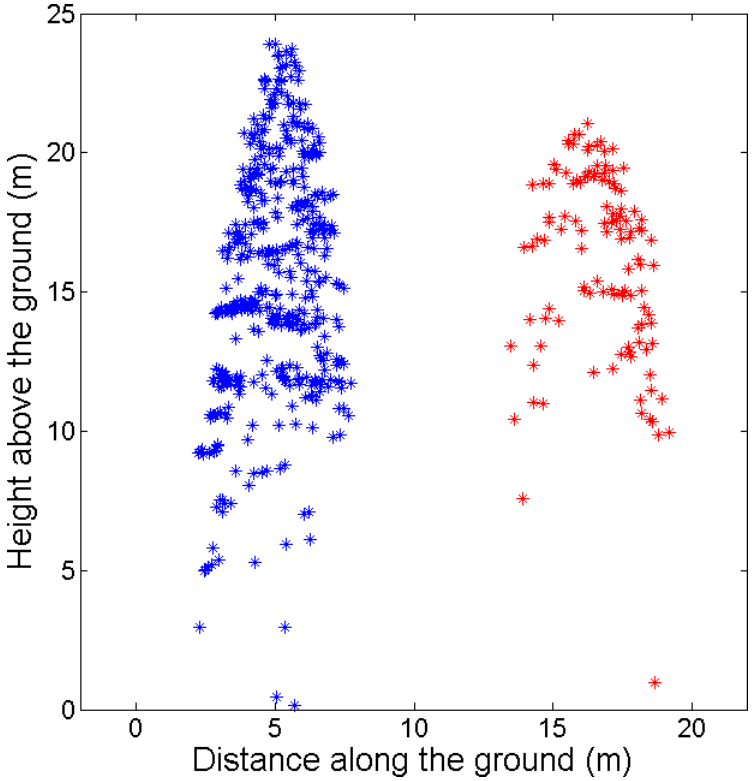
- The aim of the segmentation step is to establish one segment for each tree in the topmost canopy layer.

- The aim of the clustering step is to establish one cluster for each tree in the topmost canopy layer as well as one cluster for each tree below.
  - The algorithm is based on k-means clustering using ellipsoidal tree crown models.
  - Two categories of clusters are defined: Fixed clusters corresponding to trees already identified by segmentation of the CS and additional flexible clusters corresponding to trees below the topmost canopy layer.

Variables derived from individual tree crowns

- The proportions of the clusters depend on the tree species and other characteristics of the trees

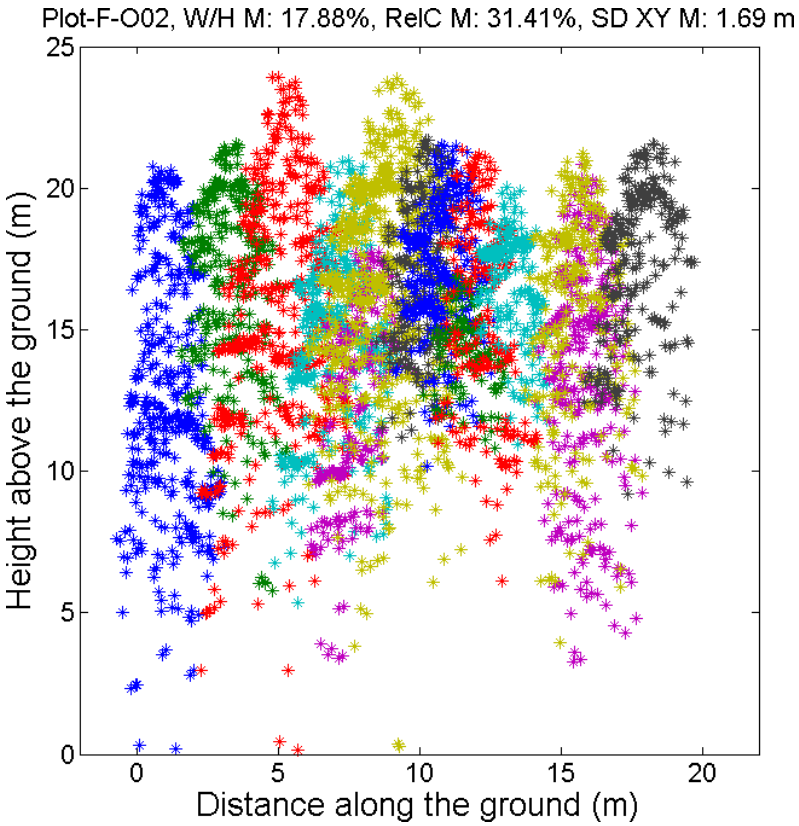
Spruce
H= 23.9 m
Horiz=2.32 m
Rel Horiz=21.0%
RelVert=38.4%

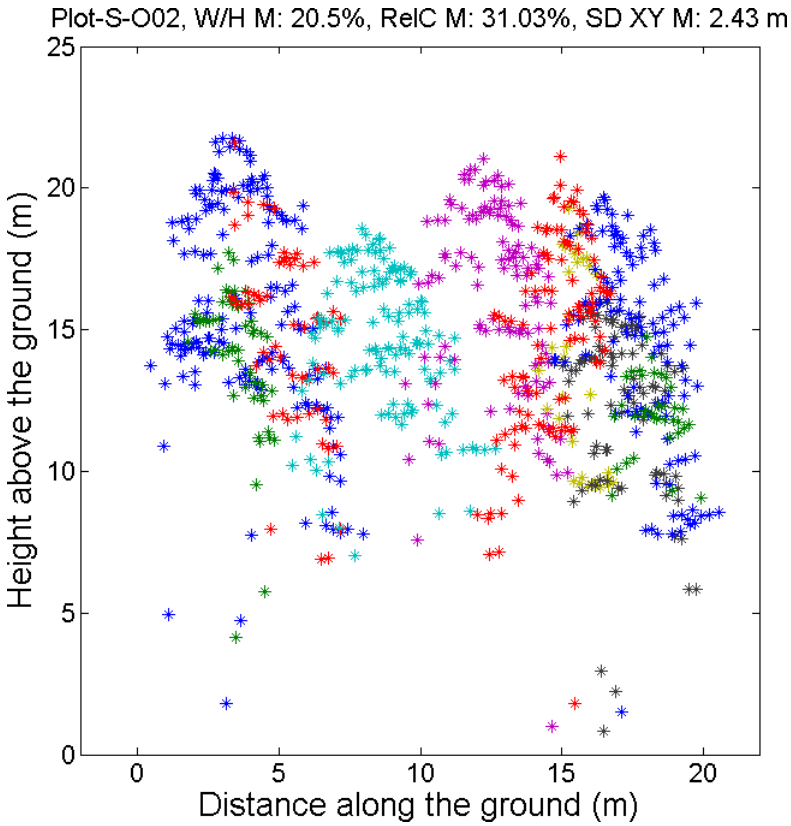


Pine
H= 21.1 m
Horiz= 2.71 m
Rel Horiz= 23.0 %
RelVert= 33.0 %

Variables derived from individual tree crowns

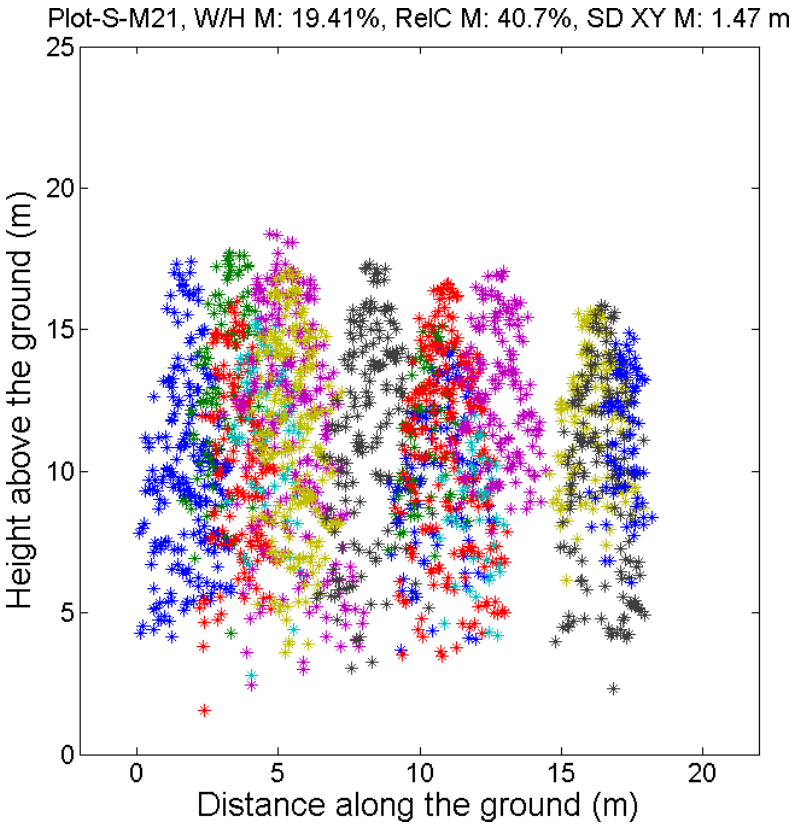
- ITC delineated from ALS data in old-grown forest. Spruce-dominated forest to the left, pine-dominated forest to the right (10 m wide and 20 m long transects).

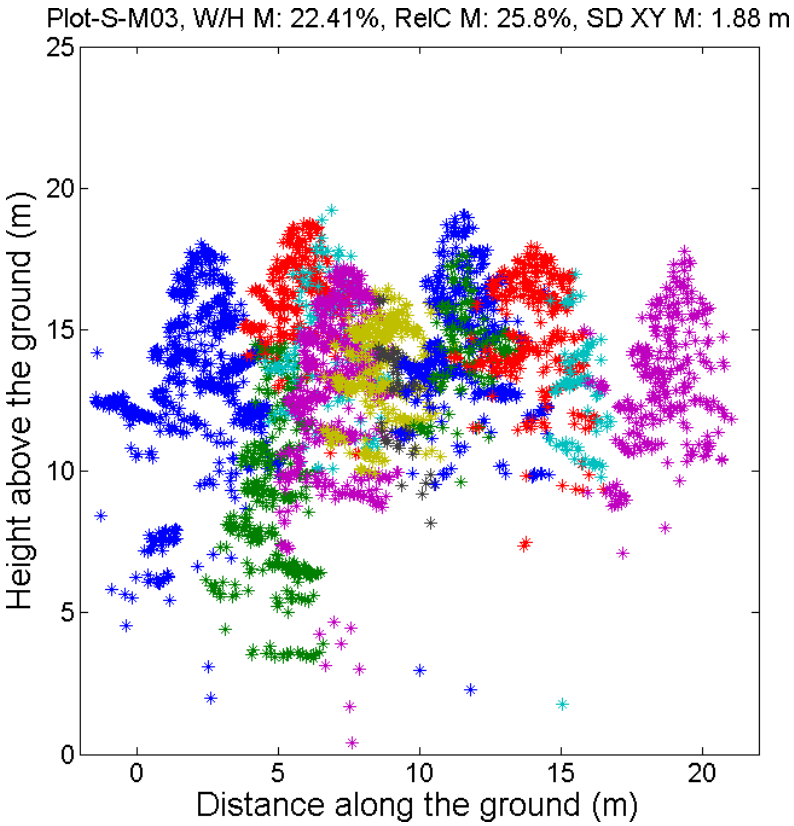




Variables derived from individual tree crowns

- ITC delineated from ALS data in middle-aged forest. Spruce-dominated forest to the left, pine-dominated forest to the right (10 m wide and 20 m long transects).





Regression models

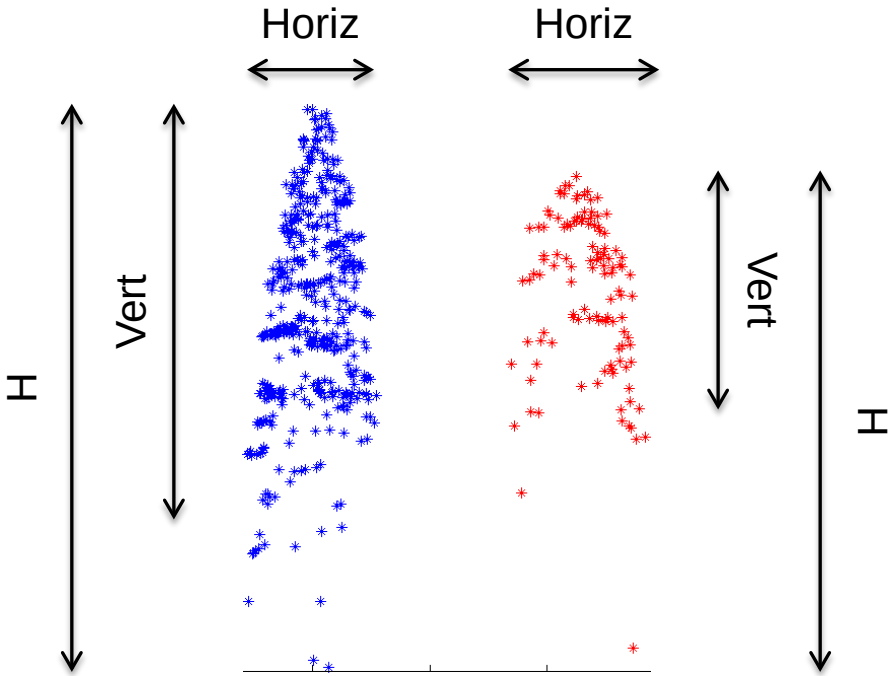
- Abundance and species richness as response

- Explanatory variables from ALS data
  - Only explanatory variables with correlation ≤ 0.6 in the same model

- Area-based variables
  - ALS_MaxH: maximum height in a raster with 1.0 m cells
  - ALS_ShanH: Shannon's diversity index for height with 10.0 m cells
  - ALS_LowVeg: fraction of returns 0.5-3.0 m above ground with 10.0 m cells

Regression models

- Individual tree crown-based variables
  - ITC_Horiz: mean value of horizontal crown width
  - ITC_RelHoriz_SD: standard deviation of horizontal crown width divided by height
  - ITC_RelVert_SD: standard deviation of vertical crown length divided by height
  - ITC_NumTotal: total number of individual tree crown clusters



Regression models

- Explanatory variables for the final models are selected based on the Akaike information criterion corrected for finite sample sizes (AICc)

The procedure considers all possible combinations of explanatory variables and selects the combination with minimum AICc.

- The sum of the AICc model weights are calculated for each explanatory variable over all models

The result is a value for each explanatory variable indicating its importance in the models

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Results and discussion

Individual tree crown-based or area-based?

- Comparison of explanatory power (adjusted R^2) and AICc

	Area-based		**ITC+area-based**	
	Adjusted R^2	AICc	Adjusted R^2	AICc
Bird abundance	0.42	33.6	0.48	29.8
Bird species richness	0.41	29.6	0.48	24.9
Flying beetle abundance	0.44	37.7	0.65	23.6
Flying beetle species richness	0.41	8.2	0.54	1.3
Epigaeic beetle abundance	0.53	73.9	0.60	73.3
Epigaeic beetle species richness	0.53	34.9	0.66	25.2

Importance of variables: Bird

- Explanatory variables with sum of AICc model weights > 0.6

Abundance		**Species richness**	
Explanatory variables	Sum of weights	Explanatory variables	Sum of weights
ALS_LowVeg	0.982 (+)	ALS_LowVeg	0.975 (+)
ITC_RelHoriz_SD	0.929 (-)	ITC_RelHoriz_SD	0.952 (-)
ITC_RelVert_SD	0.619 (+)	ITC_RelVert_SD	0.617 (+)

Importance of variables: Flying beetle

- Explanatory variables with sum of AICc model weights > 0.6

Abundance		**Species richness**	
Explanatory variables	Sum of weights	Explanatory variables	Sum of weights
ALS_MaxH	0.999 (+)	ALS_MaxH	0.961 (+)
ITC_Horiz	0.998 (-)	ITC_Horiz	0.938 (-)

Importance of variables: Epigaeic beetle

- Explanatory variables with sum of AICc model weights > 0.6

Abundance		**Species richness**	
Explanatory variables	Sum of weights	Explanatory variables	Sum of weights
ALS_MaxH	0.892 (+)	ALS_MaxH	0.843 (+)
		ITC_Horiz	0.855 (-)

Importance of variables

- What do the explanatory variables represent?

- Area-based variables:

+ ALS_LowVeg (birds)	Low vegetation
+ ALS_MaxH (flying and epigaeic beetles)	Tree height

- Individual tree crown-based variables:

+ ITC_RelVert_SD (birds)	Variation in relative vertical crown length
- ITC_RelHoriz_SD (birds)	Variation in relative horizontal crown width
- ITC_Horiz (flying and epigaeic beetles)	Mean horizontal crown width

Conclusions

- The individual tree crown variables improved the models and provided information on additional forest characteristics important for biodiversity

- Most important area-based variables: low vegetation (+) and tree height (+)
- Low vegetation is difficult to delineate as individual objects

- Most important individual tree crown-based variables: mean crown width (-), variation in relative crown width (-) and variation in relative vertical crown length (+)
- Consistent with the amount of pine having a negative relationship
- Tree species is difficult to estimate with area-based analysis

Thank you for your attention!

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