Predicting forest structural variables using Sentinel-2 and airborne laser scanning data in boreal forest

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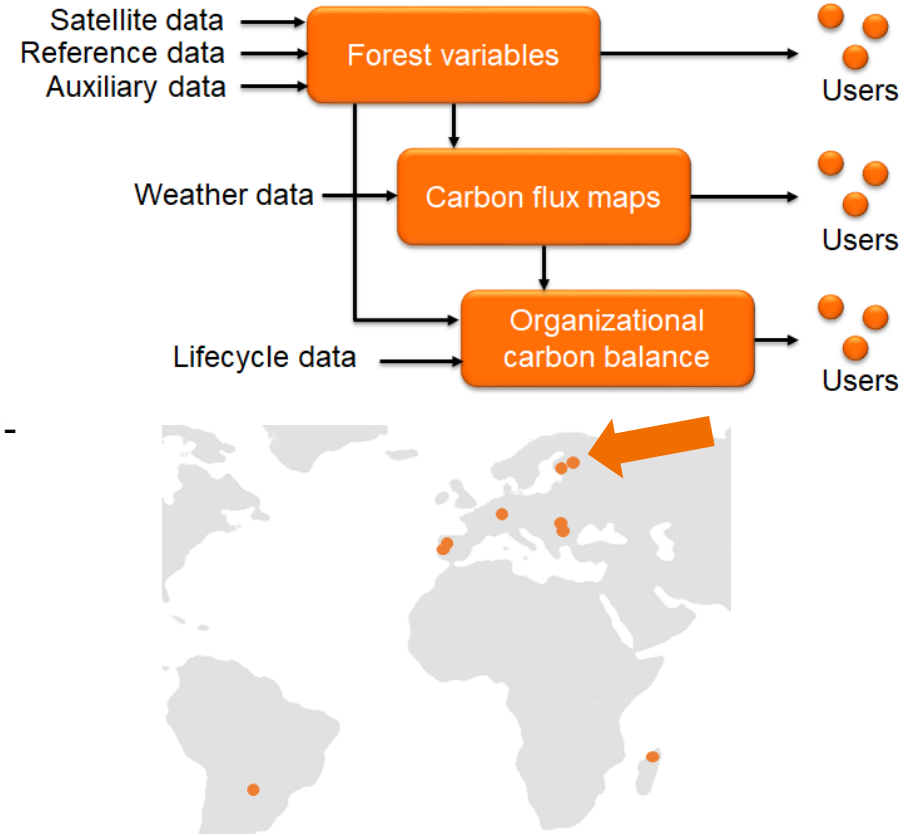
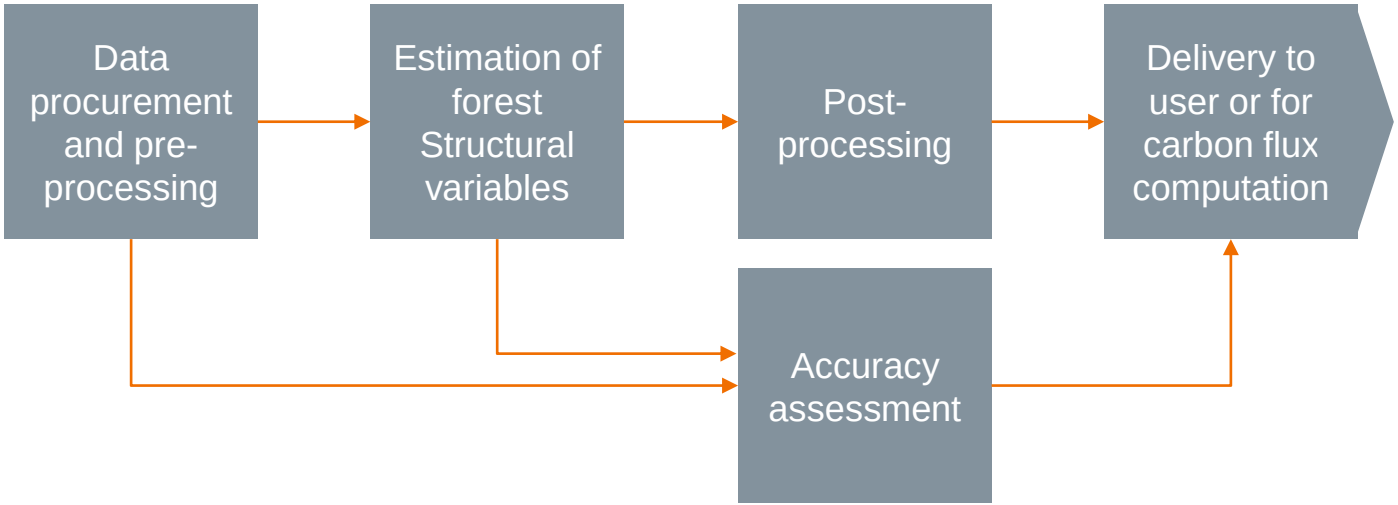
Background and objective

- Forest Flux innovation action project
- Services for high-resolution maps of forest structural variables, forest carbon fluxes, storage, and their development over time
- Main EO data source Copernicus Sentinel-2
- In pilot site in Finland separate study with airborne laser scanning (ALS) data: Would adding ALS data improve accuracy of Sentinel-2 based estimation of forest structural variables?



Forest Flux H2020 Innovation Action project of the European Union, Grant Agreement No. 821860, 2018-2021

Overview of the approach



Forest variables: basal area, stem volume, tree height, tree diameter, stem number, tree species proportions, site type

Whole chain from data pre-processing to post-processing and accuracy assessment implemented on Forestry Thematic Exploitation Platform (Forestry TEP)

forestry tep

https://f-tep.com/

Study area and data

- Study area in North Karelia, Finland, area 2916 km^2
- Copernicus Sentinel-2 MSI image acquired 14.6.2019
- Airborne laser scanning data from National Land Survey of Finland from year 2019
- Sample plot data of Finnish Forest Centre measured in 2019

T35VNL

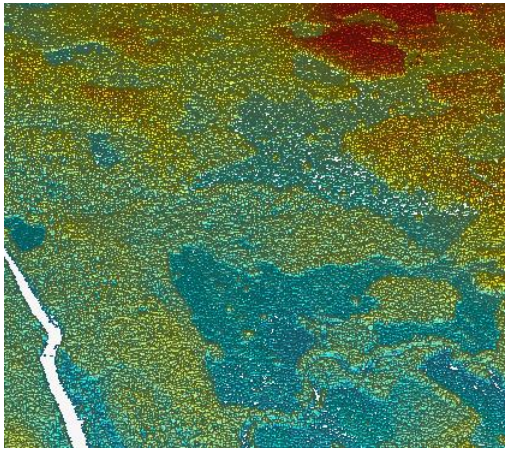
https://www.metsakeskus.fi/en/open-forest-and-nature-information
https://www.maanmittauslaitos.fi/en/maps-and-spatial-data/expert-users/product-descriptions/laser-scanning-data

EO data and pre-processing

- ALS data: density 0.5 points/m^2, 324 tiles of 3 km x 3 km
- Pre-processing in Forestry TEP using service based on lidR R-library
- ALS features: 95th percentile of height, maximum height, average height, standard deviation, kurtosis and skewness of height distribution

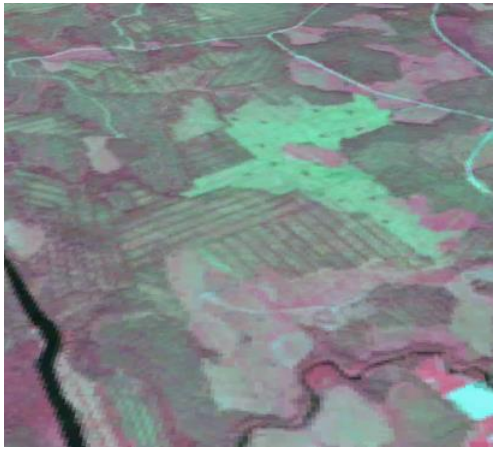
- Sentinel-2 Level 2A
- Bands used: B2, B3, B4, B5, B8, B11 and B12

Area ~1.5 km x 3 km



ALS point cloud

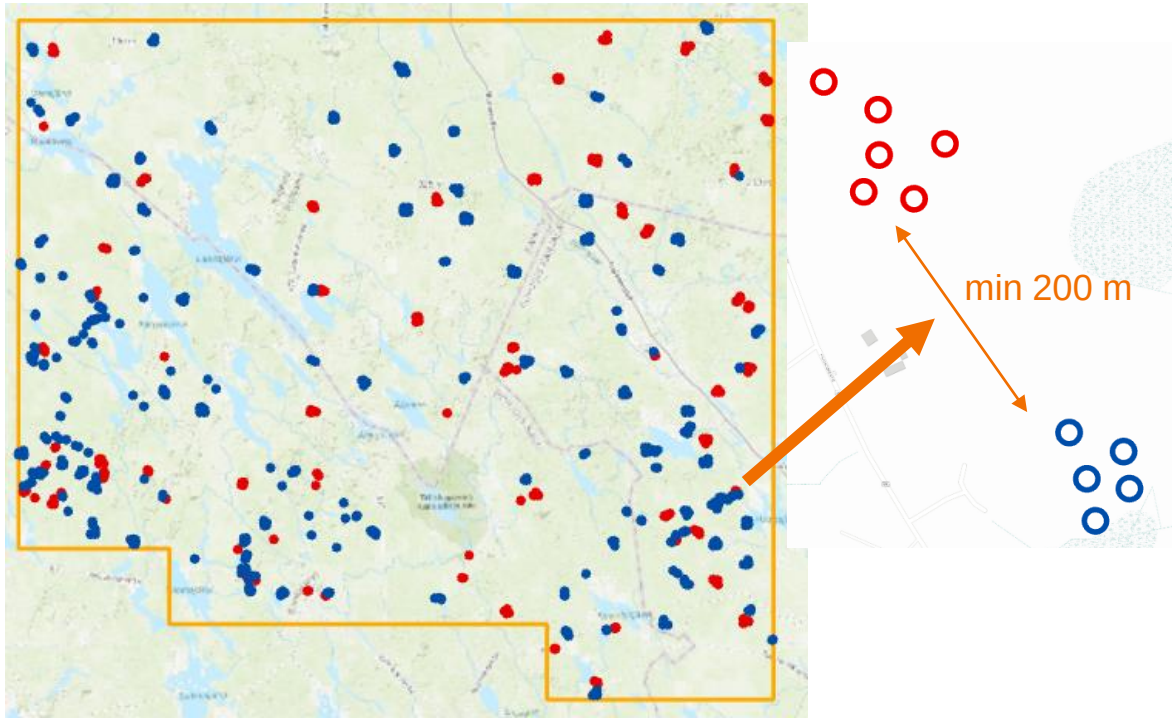
ALS feature average height



Sentinel-2 false color composite

Reference data

- 853 sample plots
- Circular plots with radius 9 m and 12.6 m
- Random division to training and test sets
  - Stratification based on stem volume
  - Minimum distance between training and test plots 200 m
  - 597 training plots (blue dots)
  - 256 test plots (red dots)

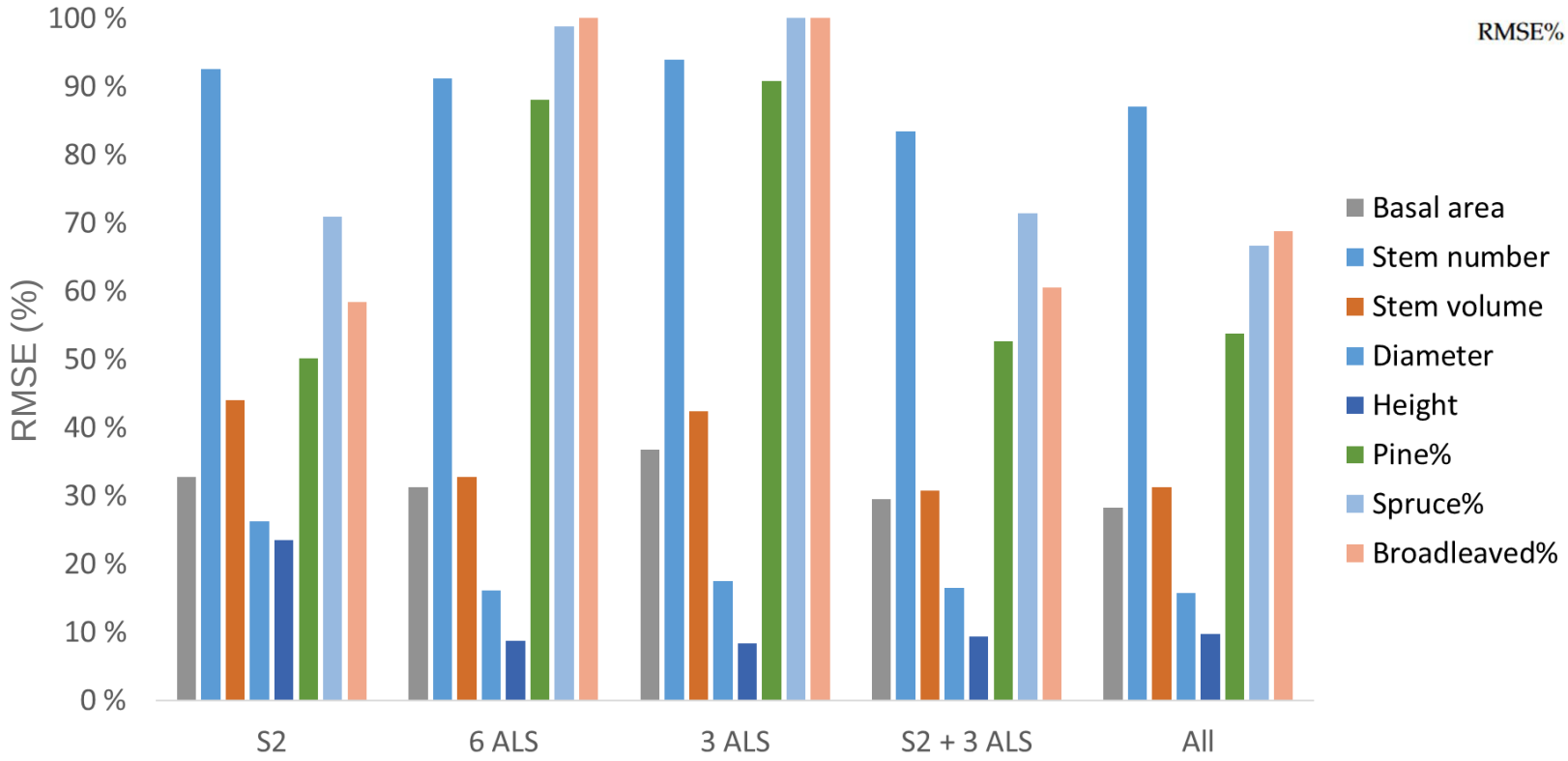


Accuracy assessment results

Relative root mean square error (RMSE) of the estimates

$$\mathrm{RMSE} = \sqrt{\frac{\sum_i (y_i - \hat{y}_i)^2}{n}}$$

$$\mathrm{RMSE\%} = \frac{RMSE}{\bar{y}}$$

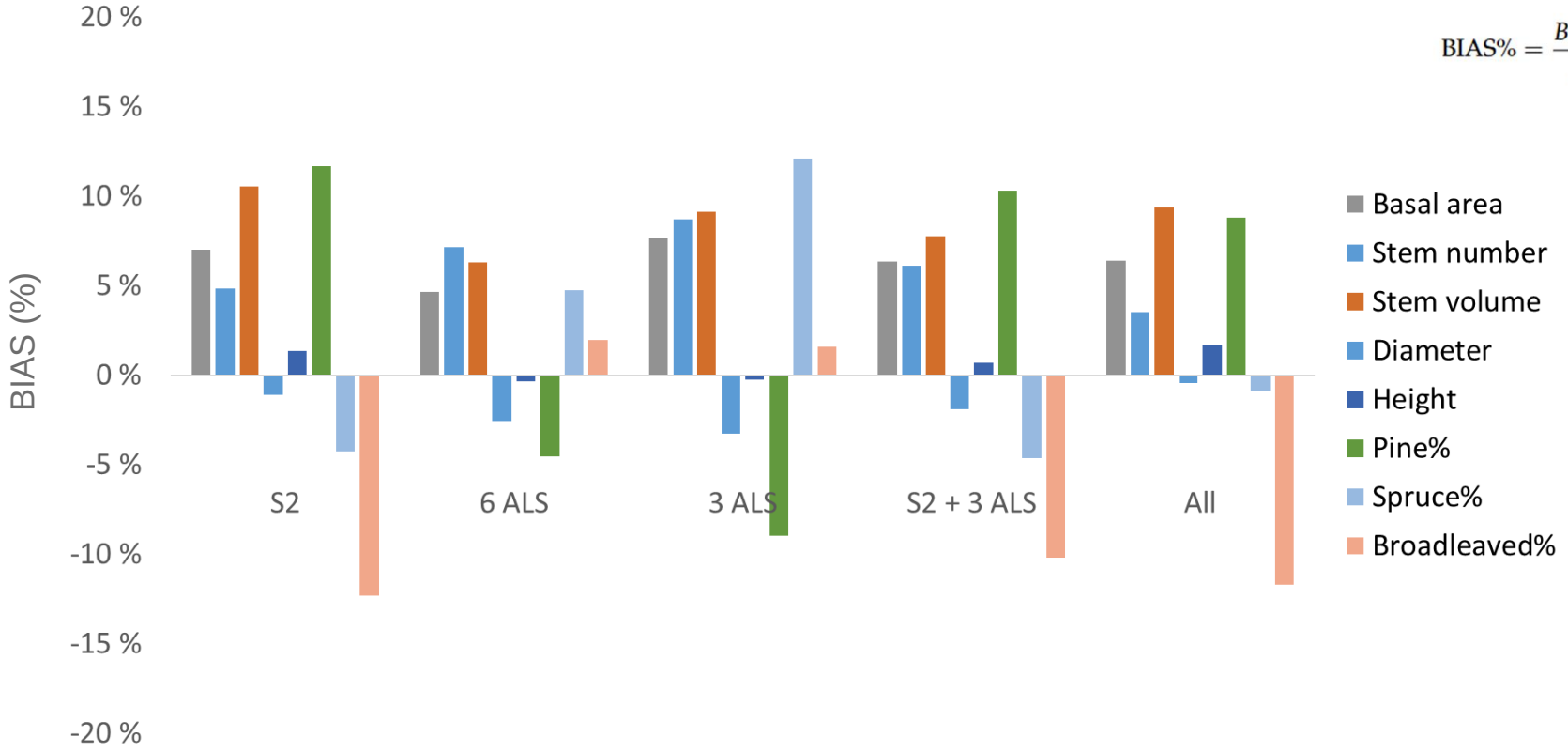


Accuracy assessment results

Relative bias of the estimates

$$\mathrm{BIAS} = \frac{\sum_i (\hat{y}_i - y_i)}{n}$$

$$\mathrm{BIAS\%} = \frac{BIAS}{\bar{y}}$$



Accuracy assessment results

Tree species and site type classification

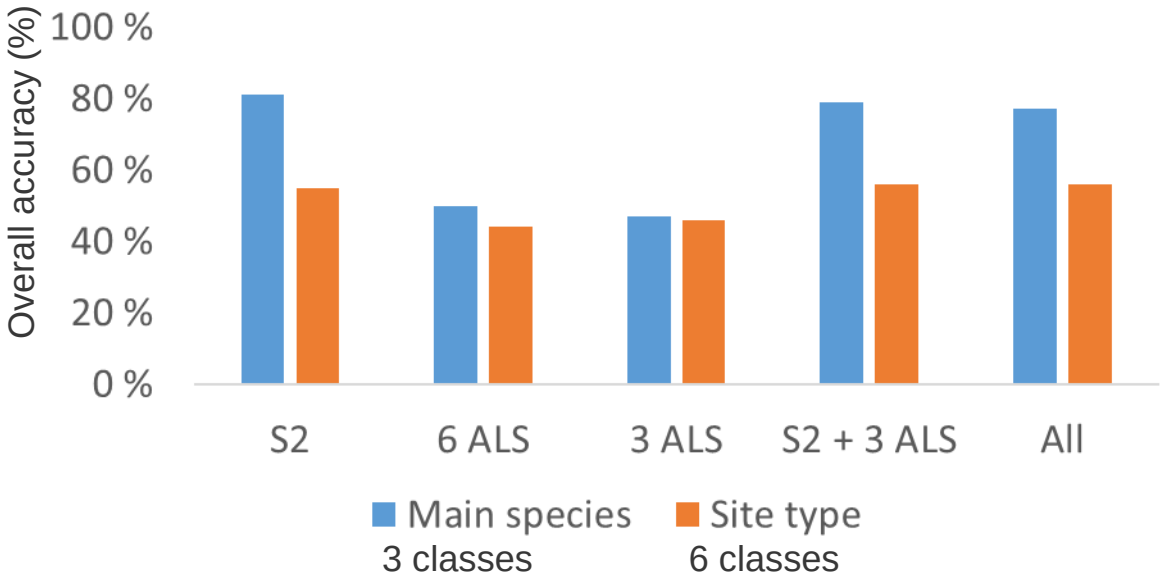
Confusion matrix of main species

Classification \ Reference	Pine	Spruce	BL	UA
Pine	100	14	8	82%
Spruce	9	43	10	69%
BL	3	5	38	83%
PA	89%	69%	68 %	N=230

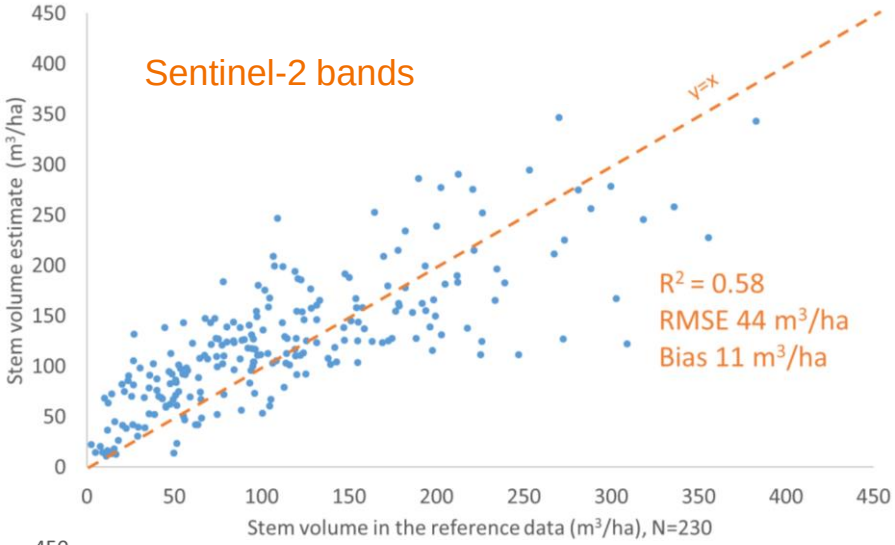
Overall accuracy 79%

PA = producer's accuracy
UA = user's accuracy

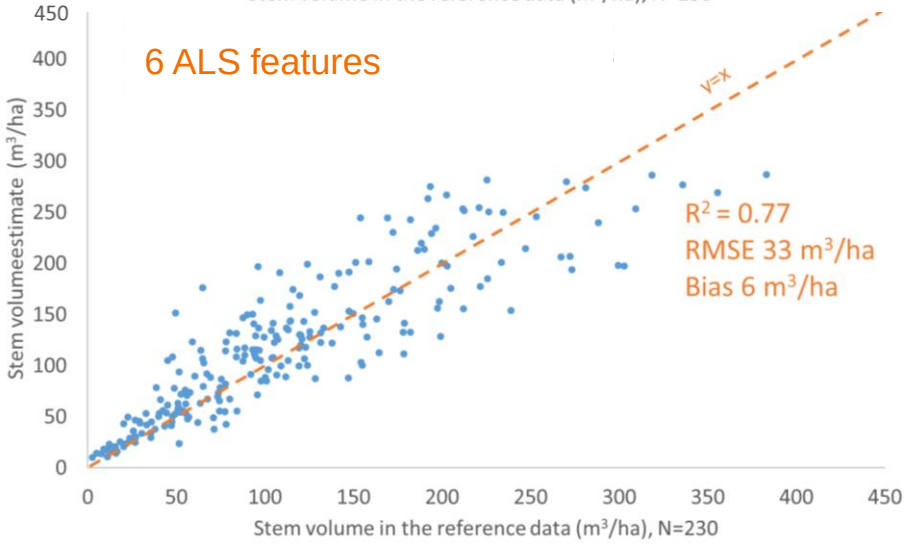
Overall accuracies of main tree species and site type



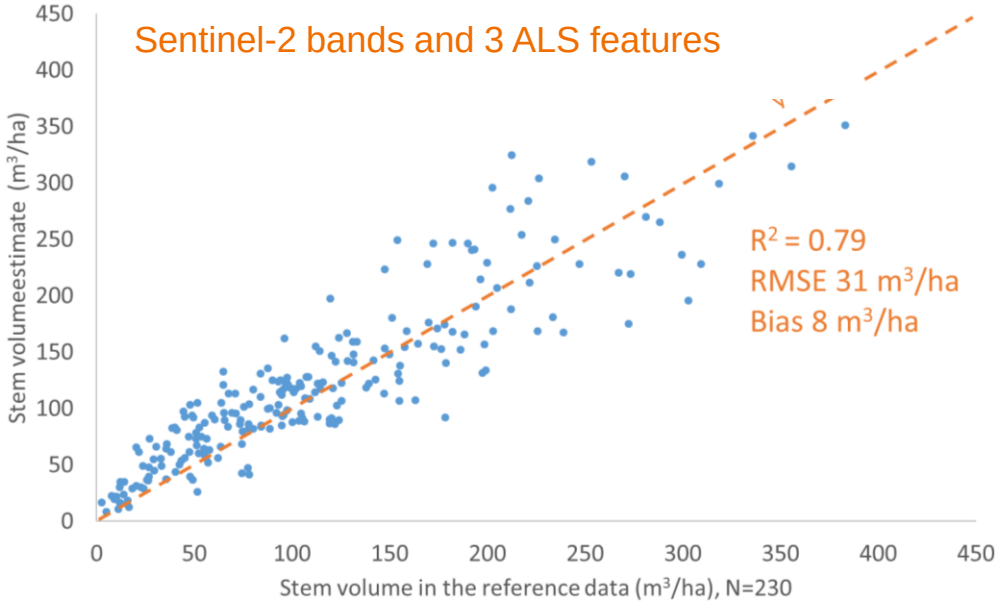
Sentinel-2 bands



6 ALS features



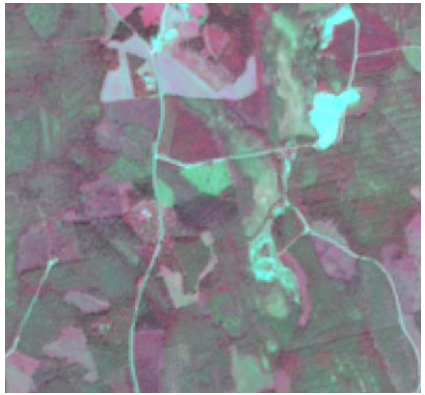
Sentinel-2 bands and 3 ALS features

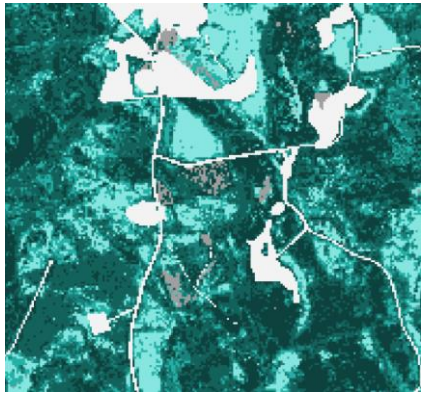


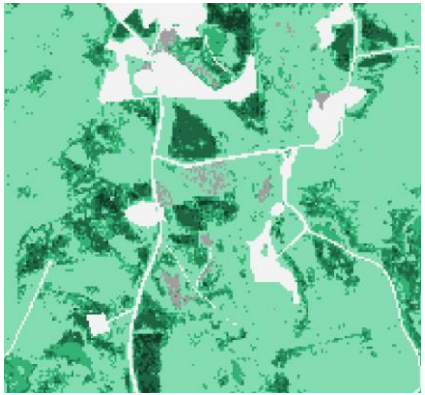
Coefficient of determination: $R^2 = 1 - \frac{SS_{res}}{SS_{tot}} = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \bar{y}_i)^2}$

Map examples

Feature set Sentinel-2 and 3 ALS



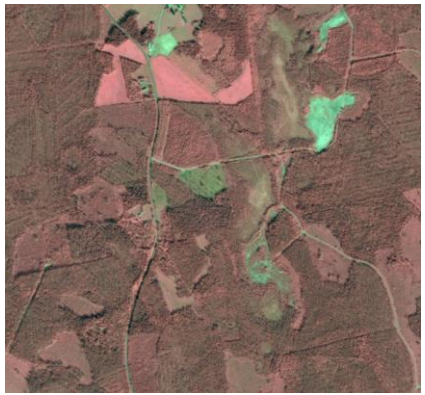


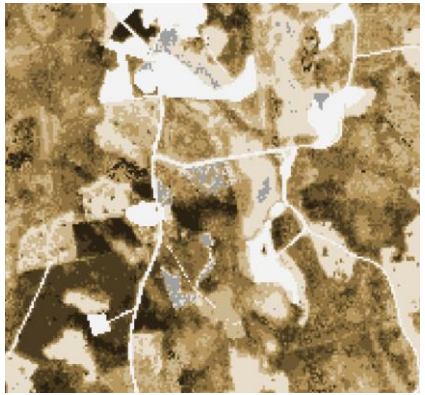


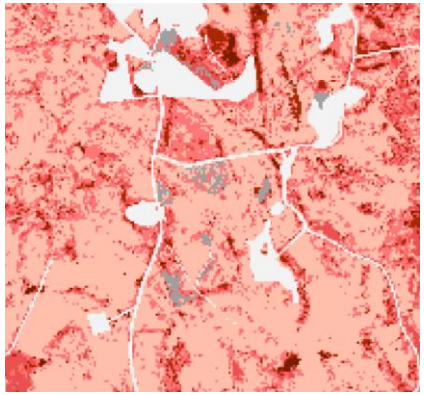
Proportion of pine
No data
Non-forest
0-20%
21-40%
41-60%
61-80%
81-100%

Proportion of spruce
No data
Non-forest
0-20%
21-40%
41-60%
61-80%
81-100%

Sentinel-2 14.6.2019







Stem volume
No data
Non-forest
≤ 50 m³/ha
51-100 m³/ha
101-150 m³/ha
151-200 m³/ha
201-250 m³/ha
251-300 m³/ha
> 300 m³/ha

Proportion of broadleaved trees
No data
Non-forest
0-20%
21-40%
41-60%
61-80%
81-100%

Deimos 26.8.2019

Area size ~1.8 km by 1.8 km

Conclusions

- Combination of Sentinel-2 and ALS features for structural forest variable estimation provided better results than either of them alone
- ALS features improved accuracy in high-volume plots compared to exclusive Sentinel-2 estimation
- Similar results with Sentinel-2 only and three ALS features for volume
- Major improvement by combining Sentinel-2 and three ALS features
- With six ALS features similar results to Sentinel-2 and three ALS features for stem volume but tree species estimation results much poorer
- For site type no remarkable improvement from ALS features as compared to using only Sentinel-2

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https://www.forestflux.eu/