Estimation of tree volume at sample plot level using terrestrial laser scanning technology

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What is the volume of a tree ?

Is the amount of wood accumulated in trees [m^3], can be scaled up to [m^3 /ha] to characterize entire stands.

Why is information about tree volume important ?

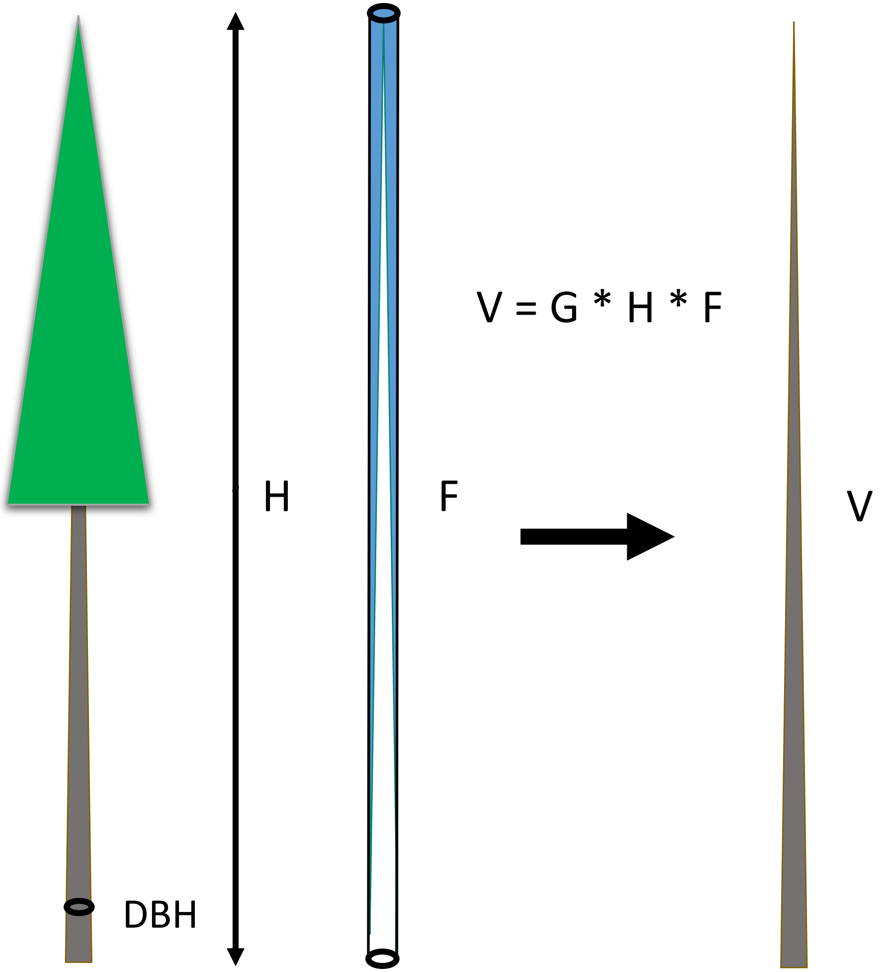
With accurate information on forest resources, foresters can:

- manage forests in a sustainable way,
- plan silvicultural and management activities,
- estimate economic income

How to measure tree volume ?

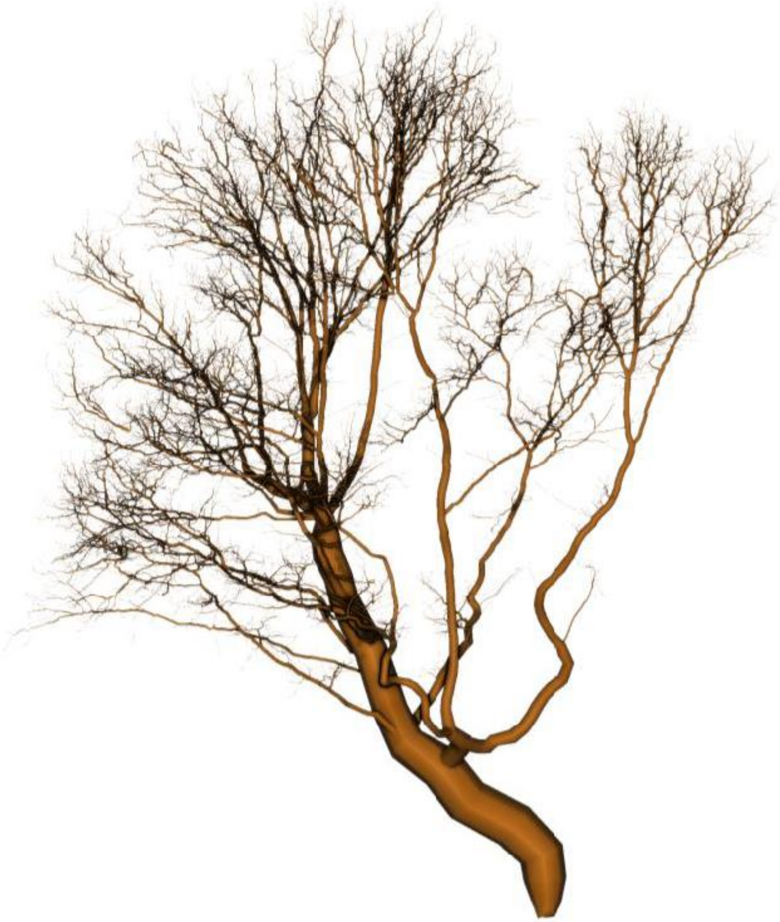
Characteristic difficult to measure directly by using conventional instruments

- For standing trees using allometric formulas based on DBH and tree height
- Field work is time-consuming and expensive



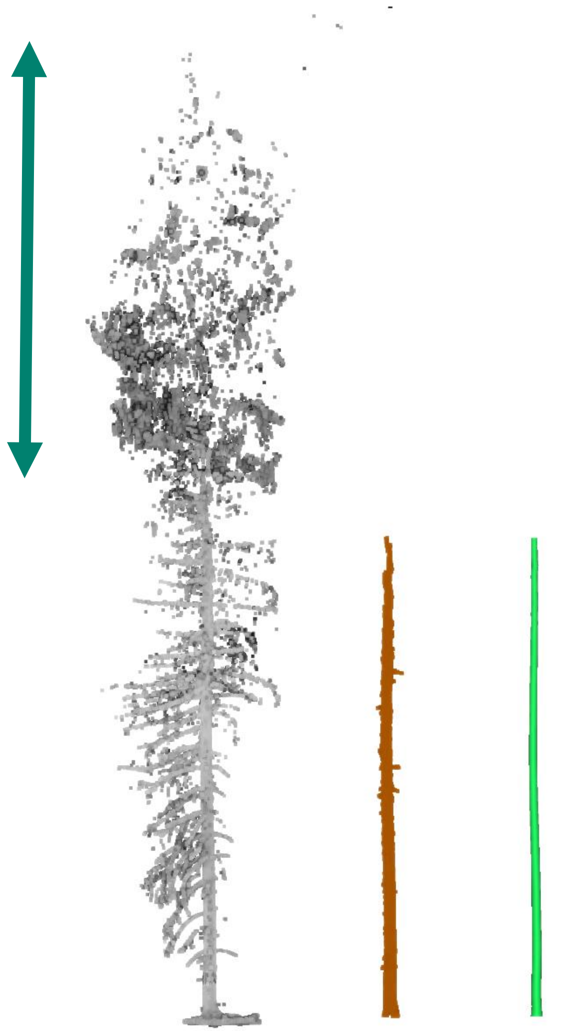
Terrestrial Laser Scanning (TLS)

Direct measurement of tree volume - Quantitative Structure Model (QSM)



- high-quality data needed
- high-end laser scanning devices are necessery
- multiple TLS positions during data acqusition are necessery

Limitation of TLS technology in tree surveys



- In operational data acquisition, the TLS point cloud for the upper parts of trees is sometimes too sparse to be able to reconstruct the shape of the stem and upper parts of canopy.

- According to some studies it is possible to map stems to an average of 55-66% of the relative height of trees (Liang et al., 2014, 2018; Saarinen et al., 2017)

Scientific objective of the study

Development of a tree height-independent approach for estimating the total merchantable tree volume that can be applied to terrestrial laser scanner data.

The method assumes that neither information about the tree height nor about the structure of the upper parts of the tree is required for the estimation of the tree volume.

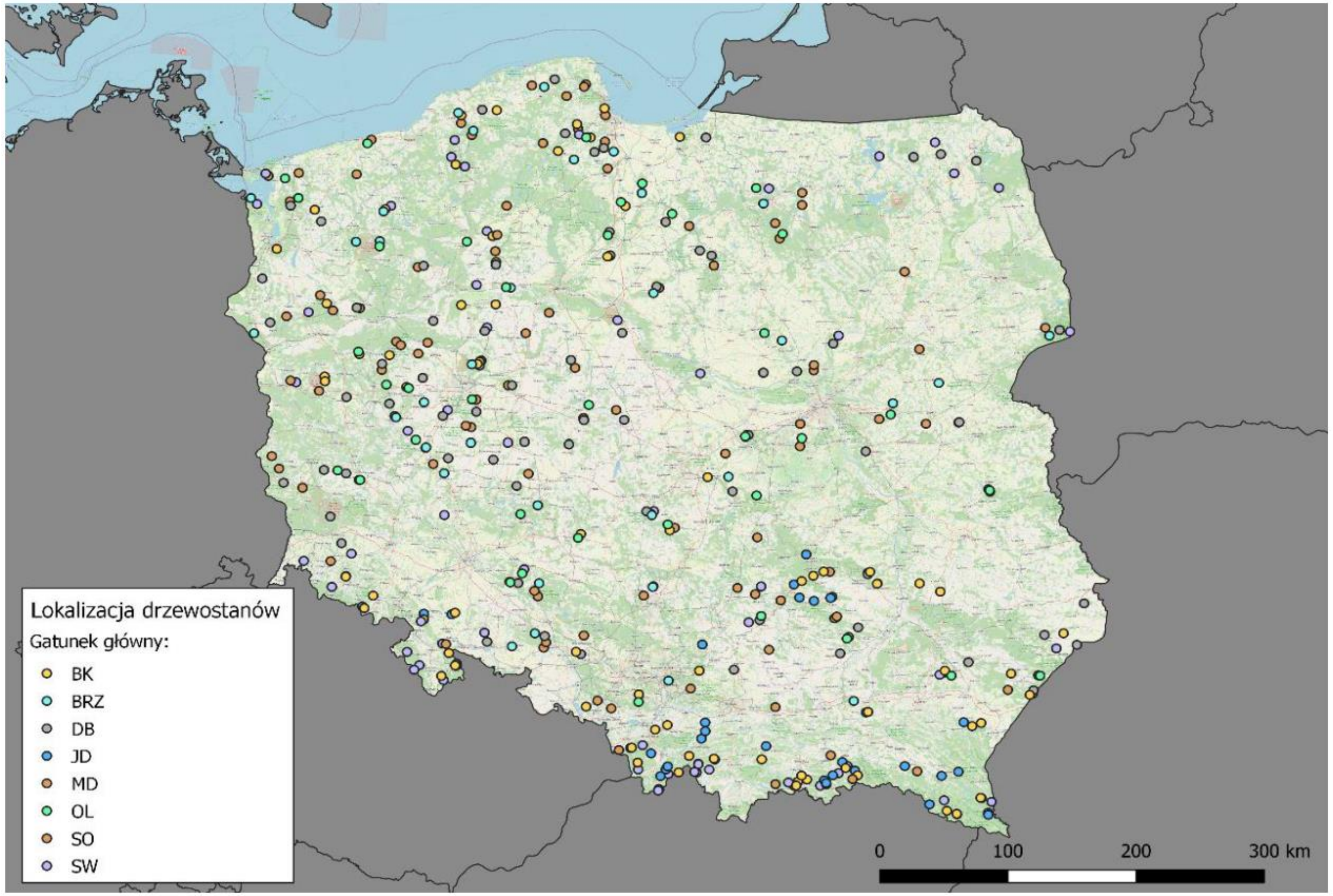
The method only uses information about the lower part of the stem, i.e. the part that is most visible to the TLS scanner.

Secondary objectives:

- compare the estimation results of the developed method to the method currently used in practice (method using conventional measurements – DBH, H)
- check which part of the stem has to be mapped in order to obtain better results than the conventional method
- test the method at sample plot level in different stratification groups

Methods

Individual tree dataset (development of method)



Field data

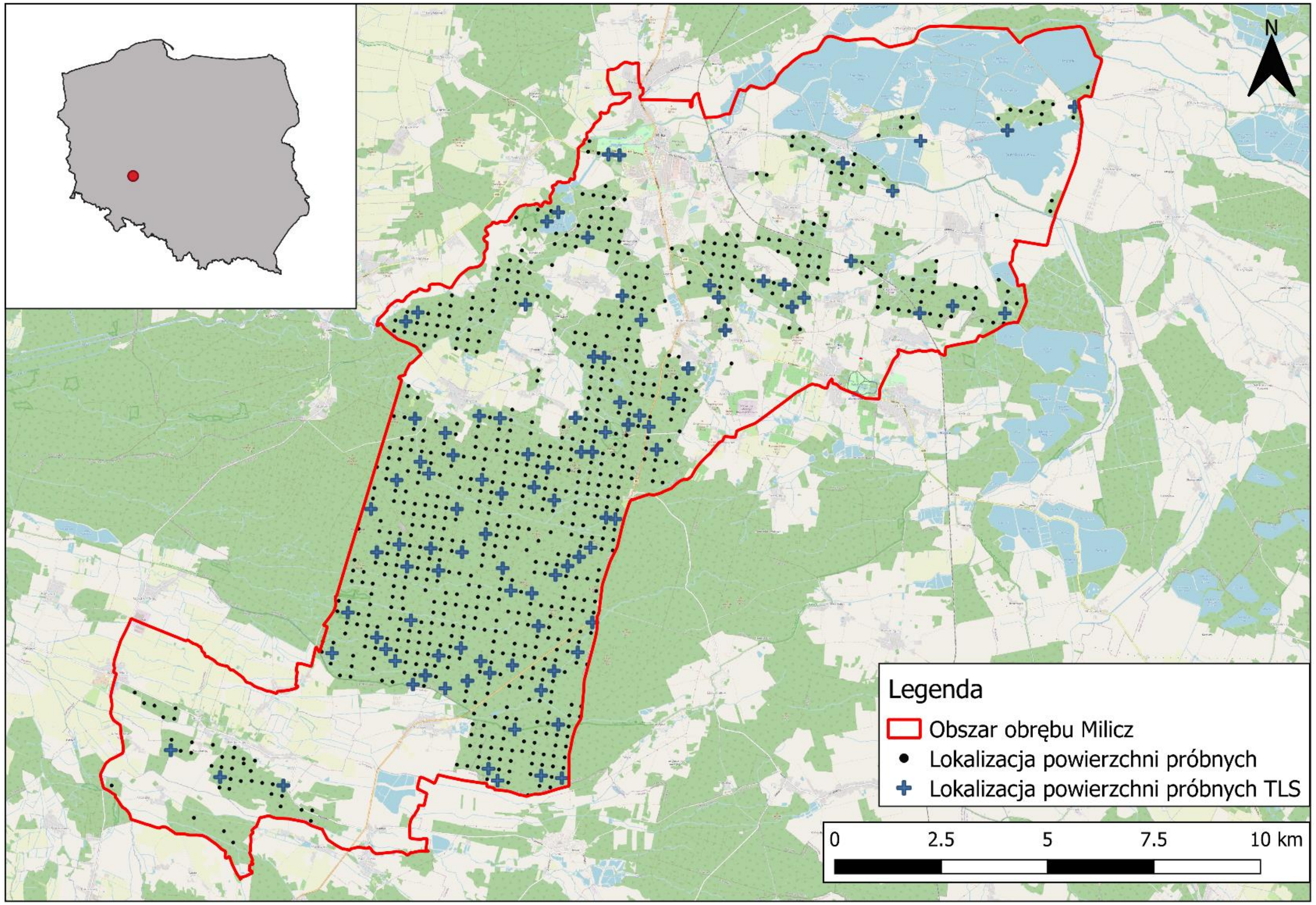
- 2983 trees
- *8 species*
- *Sectional measurments*
- *V_{REF} (sections)*
- *V_{ALLOM} (DBH, H allometrics)*

TLS data

- 263 trees
- *Multi-Scan Approach*
- *3 positions per tree*

Methods

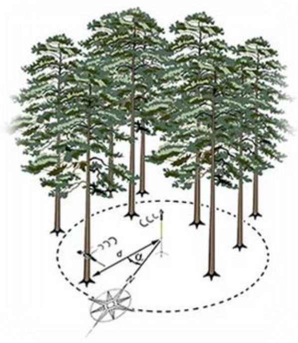
Sample plot dataset (method verification)



Field data

100 sample plots

- *radius 12,62 m*
- *DBH, H, species, position …*
- ***V_{ALLOM} (DBH, H allometrics)***



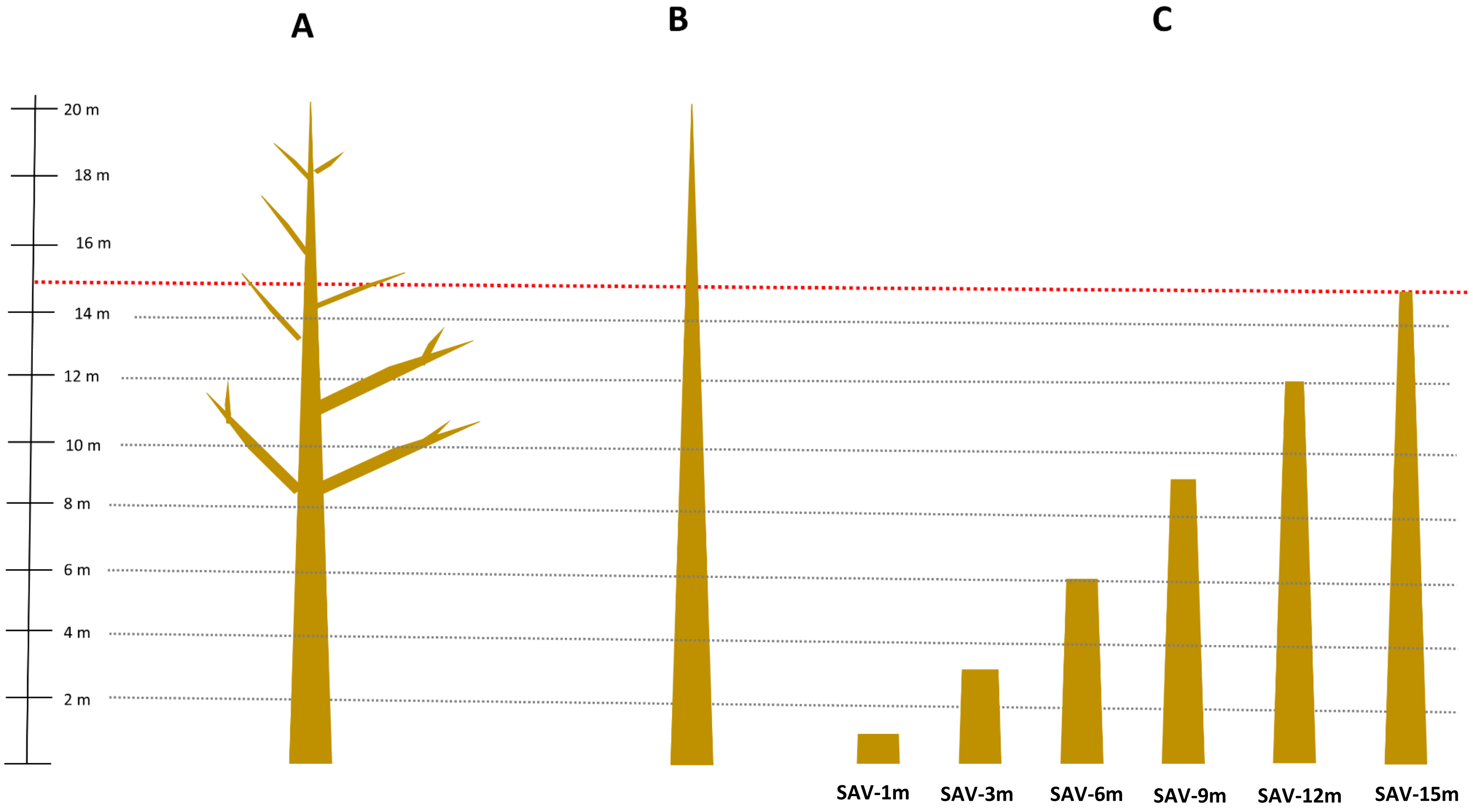
TLS data

100 sample plots

- *Multi-Scan TLS*
- *4 positions per sample plot*

REMOTE sensing based assesment of woody BIOMASS and carbon storage in FORESTS

Stem Accumulated Volume (SAV)



New predictor of total tree volume – Stem Accumulated Volume (SAV).

i.e.
SAV-3m – stem volume up to 3 metres

Stem Accumulated Volume Models (SM)

General SM equation:

$$y = ax^b$$

where:
y – total merchantable volume;
a,b – model coefficients ;
x – Stem Accumulated Volume (SAV) value

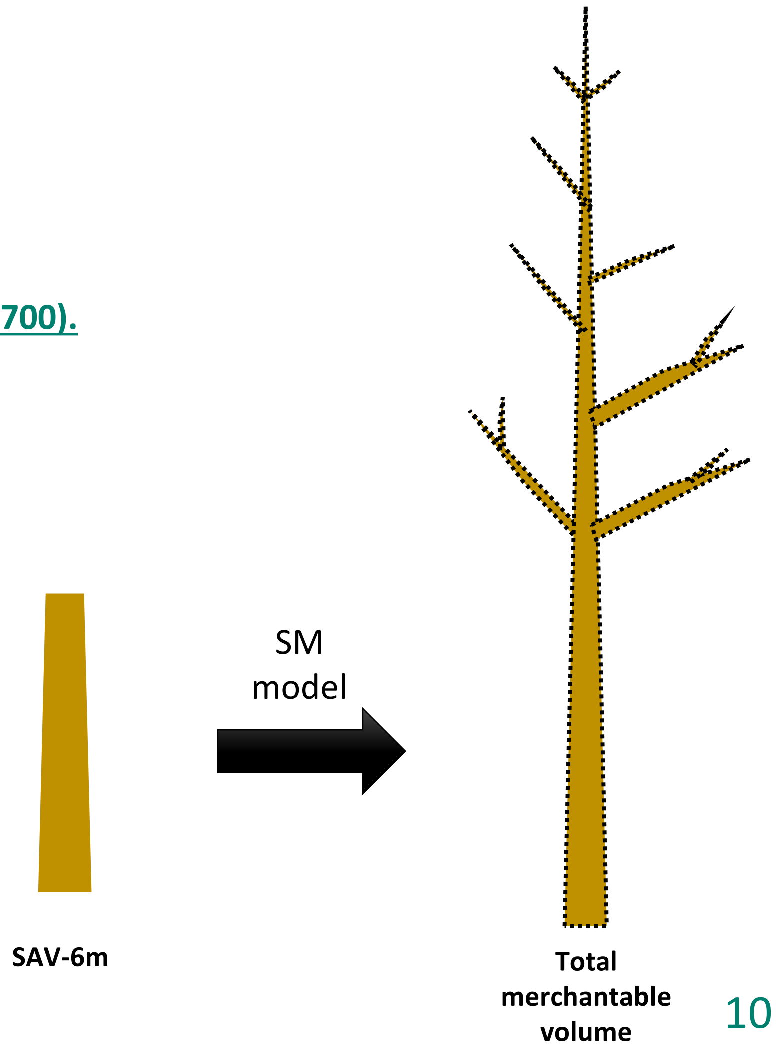
The MMS models were built from sectional destructive measurments data of the individual trees dataset (n~2700).

Trees with TLS data were not used in the process of building the models (indpendent verictaion dataset).

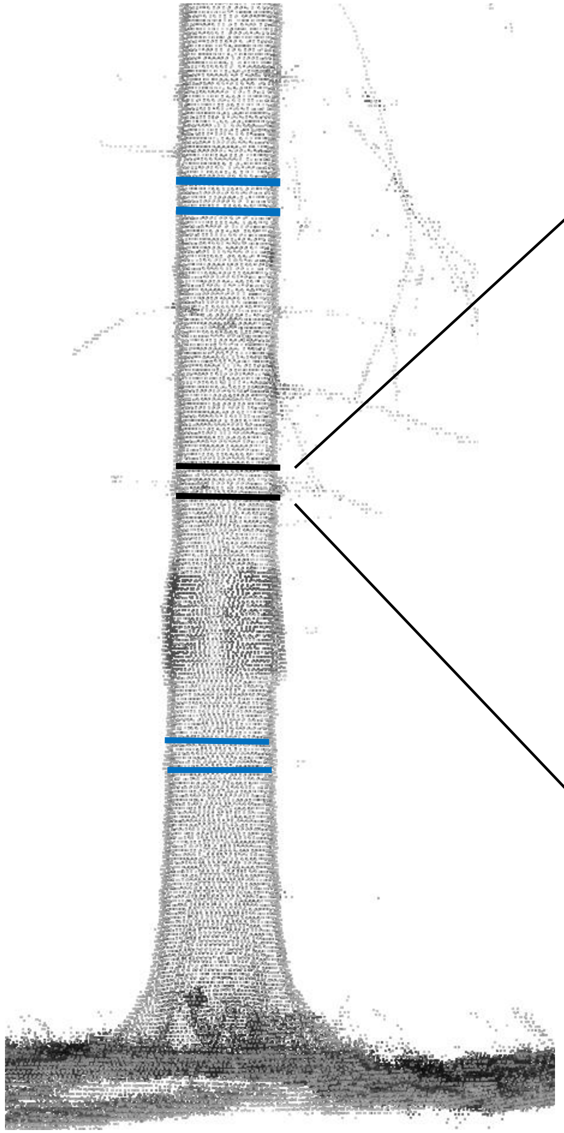
The MMS models use SMPs from 1 to 15 m, which can be determined from sectional survey data or TLS.

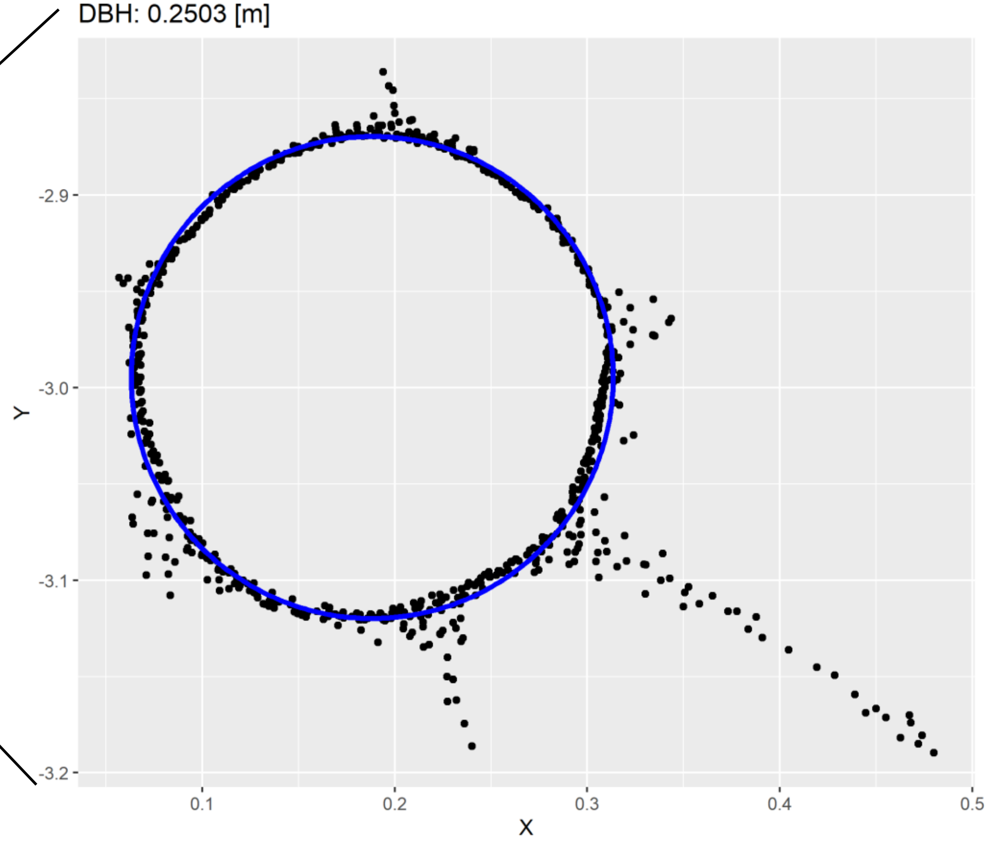
The models were prepared in three variants:

1. **SM-WS**: **without** the use of **species** information;
2. **SM-GRP**: including information on tree **species group** (coniferous/ deciduous);
3. **SM-SPC**: including **individual species** information (Pine, Spruce, Larch, Fir, Oak, Beech, Birch, Alder).



TLS data processing



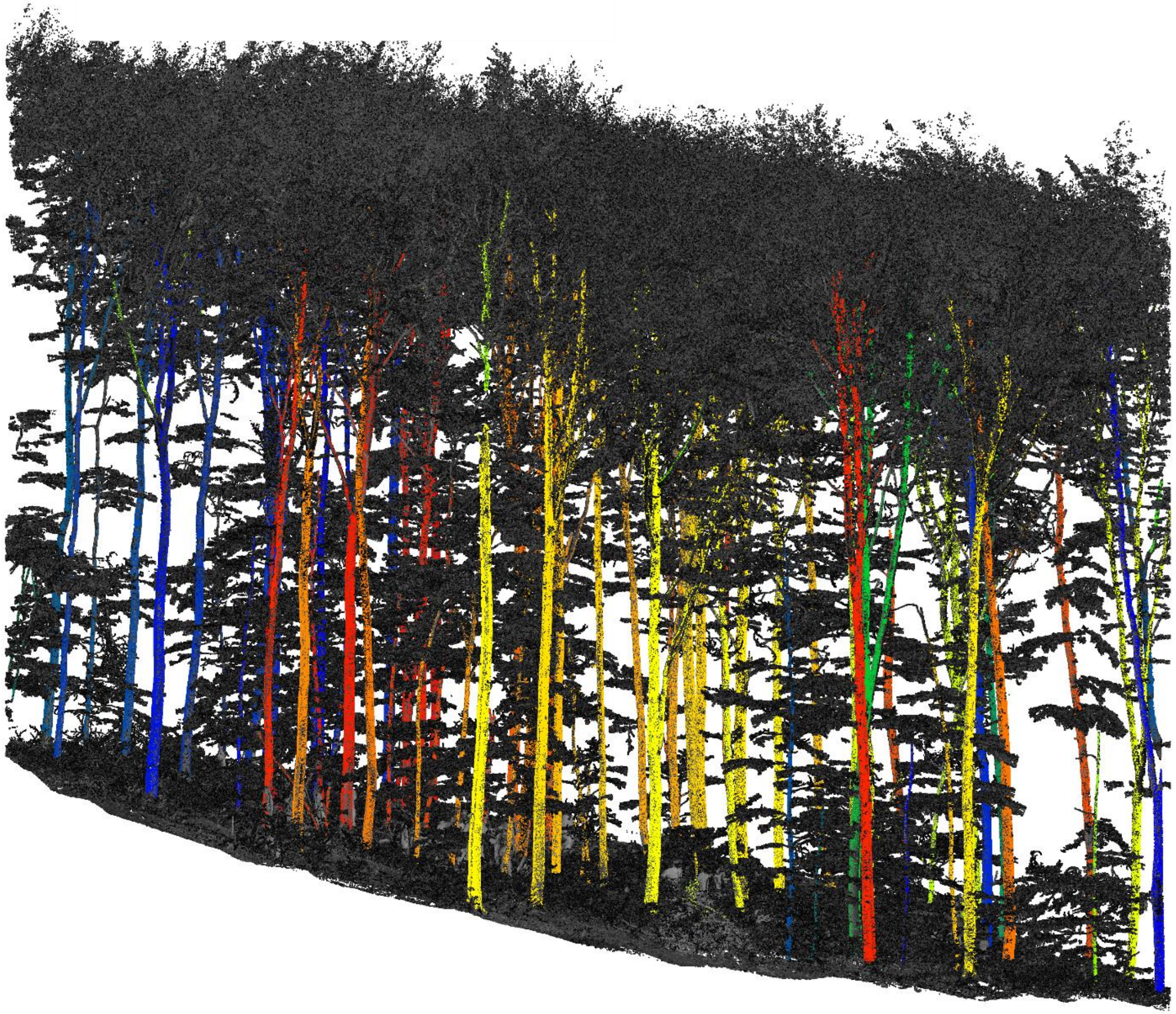


„Virtual" measurments of tree taper curve and Stem Accumulated Volume (SAV_{TLS}) calucaltion

Methods

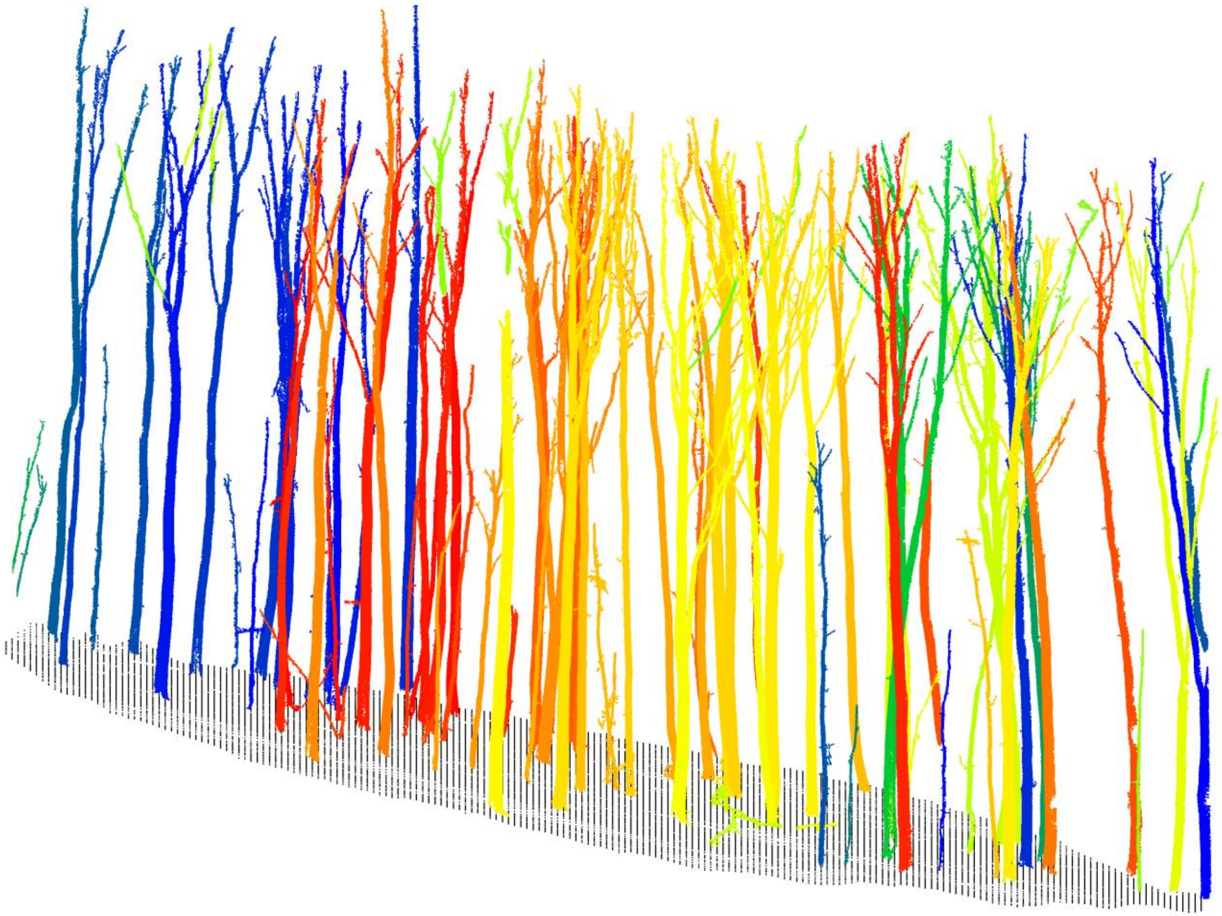
TLS data processing

TLS data processing



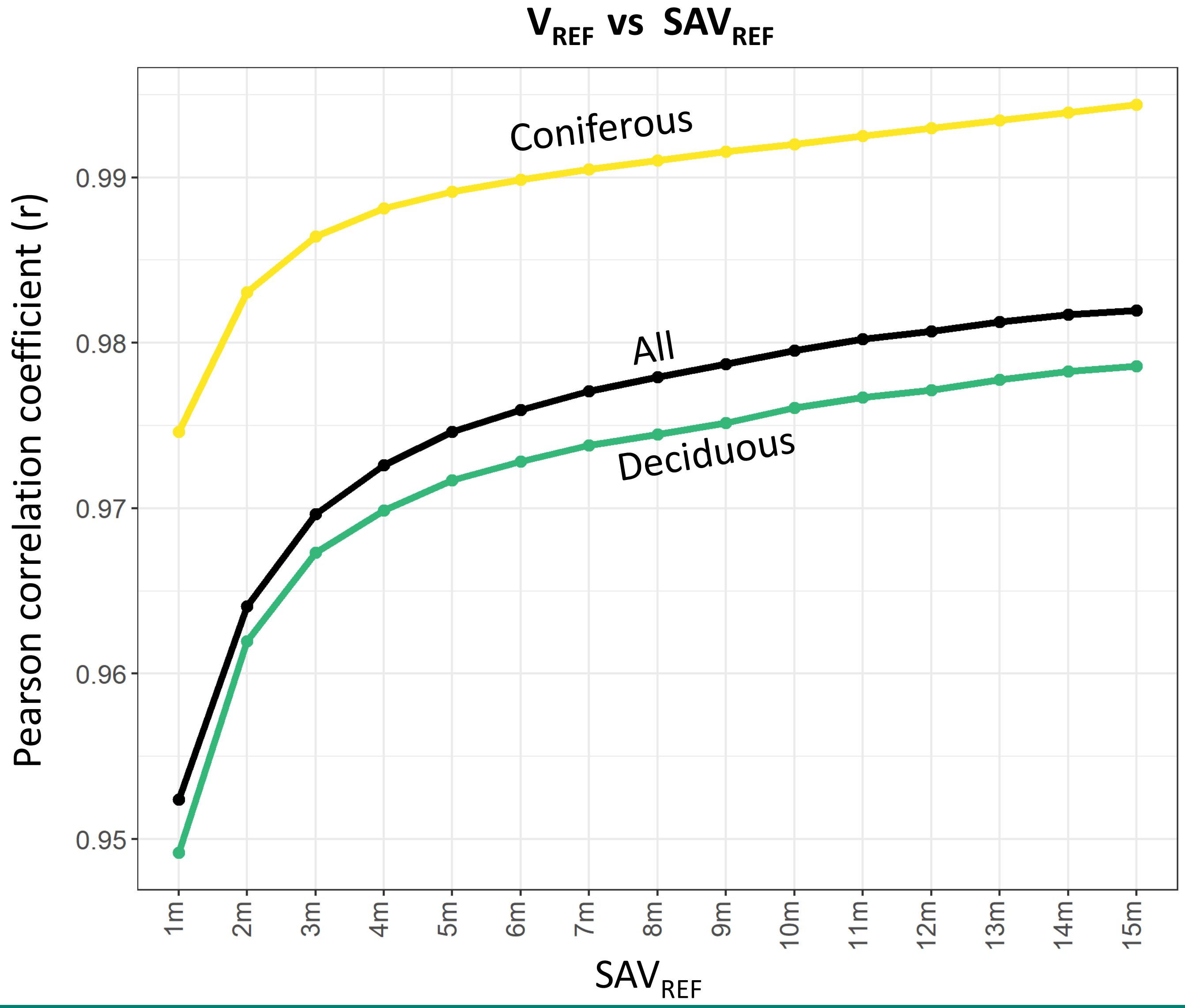
Methods

TLS data processing



Selected results

Individual tree level



Correlation between
Stem Accumulated Volume
and
Total Merchantable Volume
(destructive measurements)

r = 0,94 – 0,99

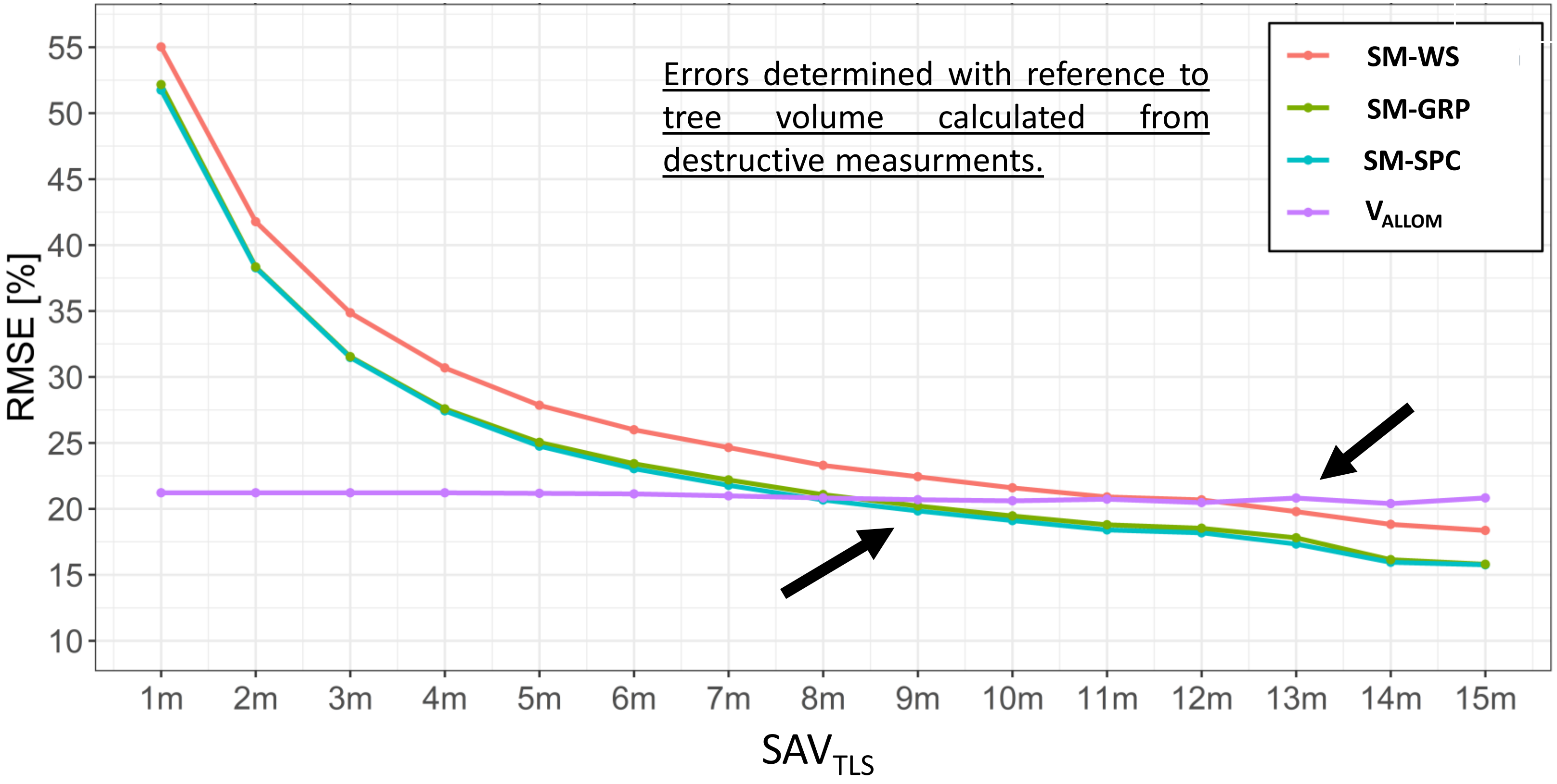
Higher SAV = Higher Correlation

Coniferous > Deciduous

Individual tree level

Independent validation dataset (N=263)
SM on TLS data
V_{ALLOM} on traditional field data

RMSE for predictions of tree volume



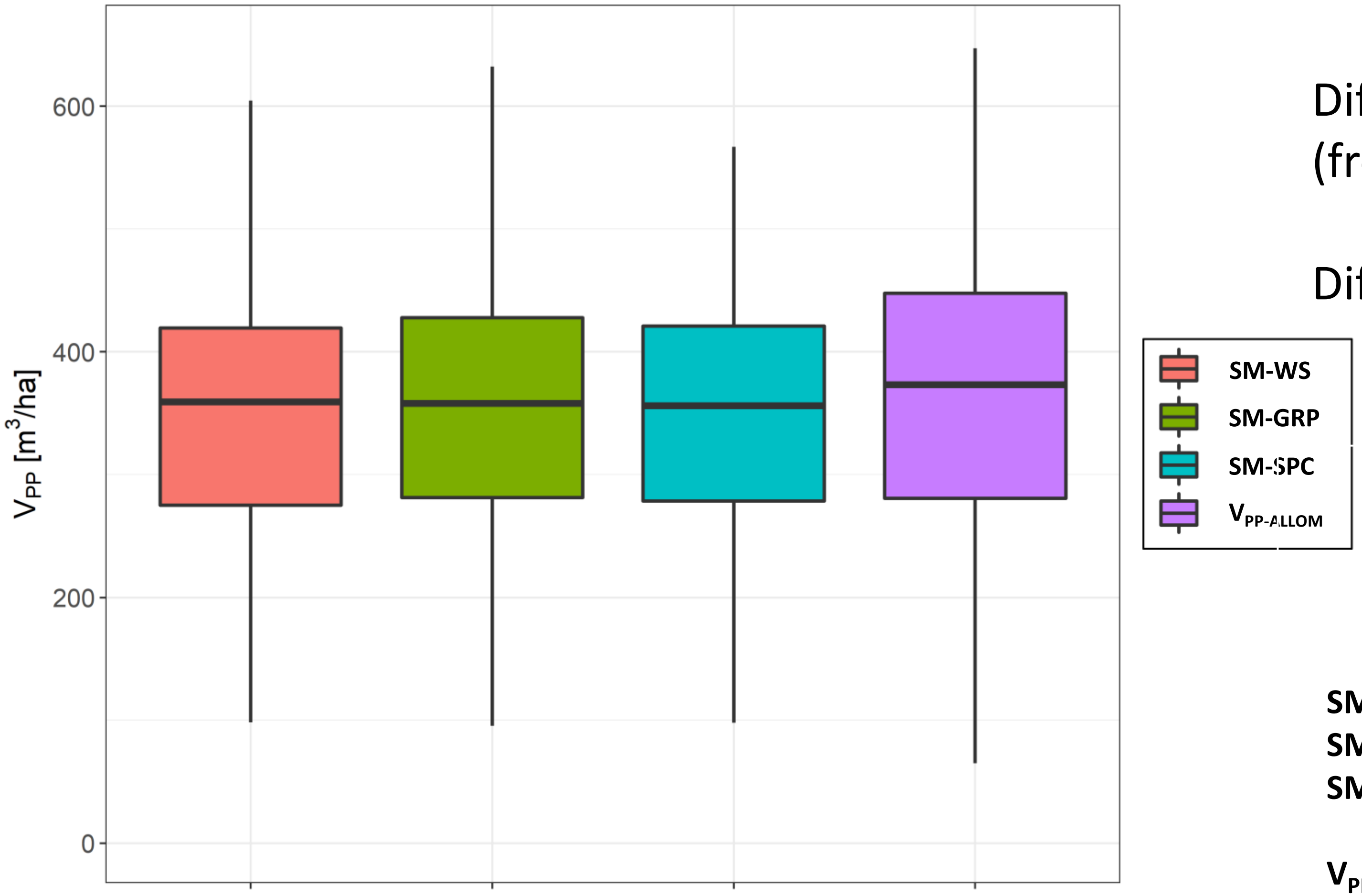
RMSE
SM : 55% to 15,7%
V_{ALLOM} : 21 %

SM-WS – SAV model without species information
SM-GRP – SAV model with species group information
SM-SPC – SAV model with individual species information

V_{ALLOM} = Allometrics (DBH, H) – traditional method

Sample plot level

GSV estimates
All sample plots (N=100)



Growing Stock Volume [m^3/ha]

Difference between SM and $V_{PP-ALLOM}$ ~7% (from -30 to -23 m^3/ha)

Differences not statistically significant

SM on TLS data
$V_{PP-ALLOM}$ on traditional field data

SM-WS – SAV model without species information
SM-GRP – SAV model with species group information
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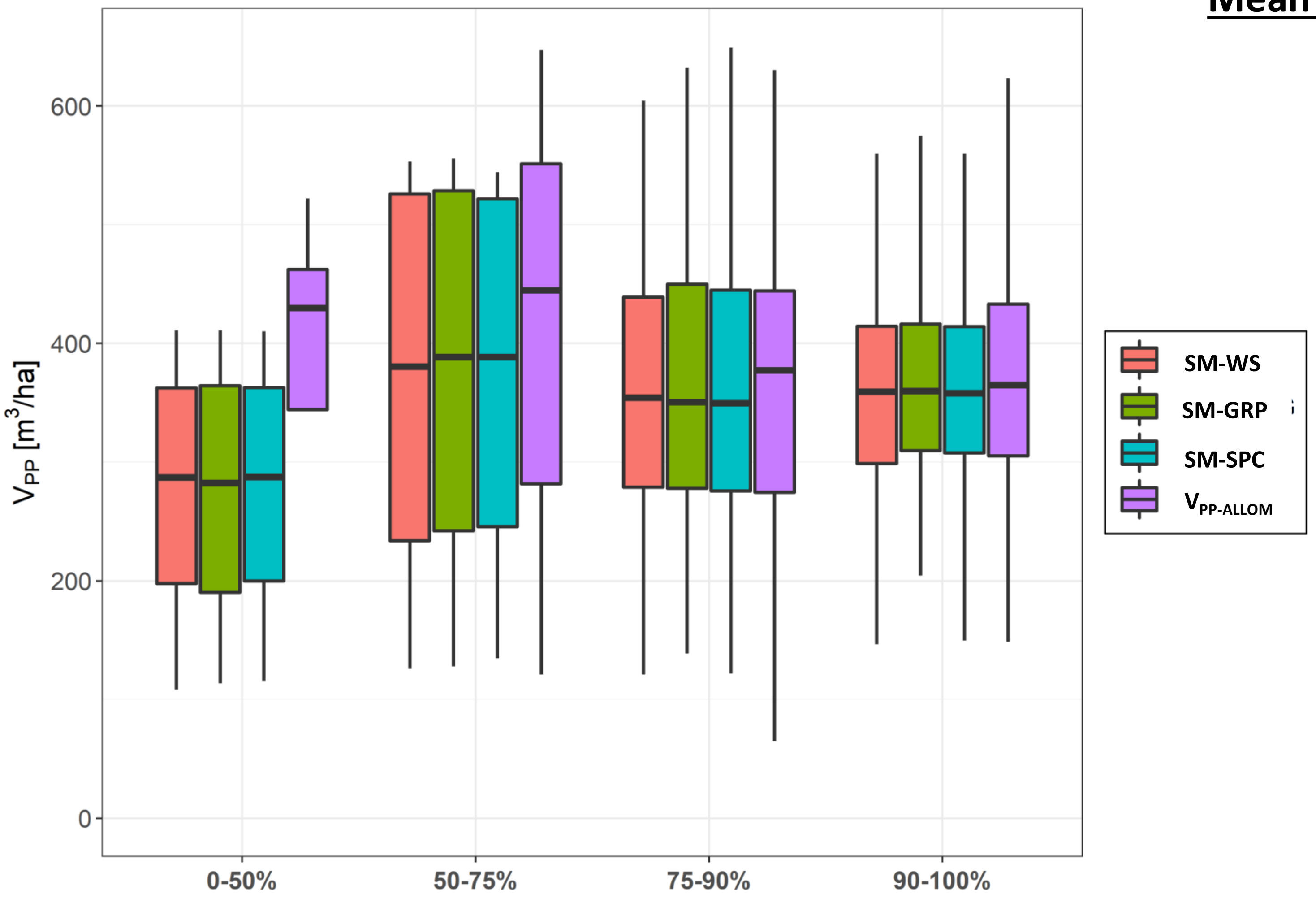
$V_{PP-ALLOM}$ = Allometrics (DBH, H) – traditional method

Selected results

Sample plot level

GSV estimates
Tree detection rate



Mean accuracy of tree detection for whole dataset: 88%

Tree Detection rate	GSV difference on medians
0-50 %	142-147 m^3/ha (33-34%)
50-75 %	56-64 m^3/ha (13-14%)
75-90 %	37-47 m^3/ha (9-12%)
90-100 %	8-12 m^3/ha (2-3%)

SM-WS – SAV model without species information
SM-GRP – SAV model with species group information
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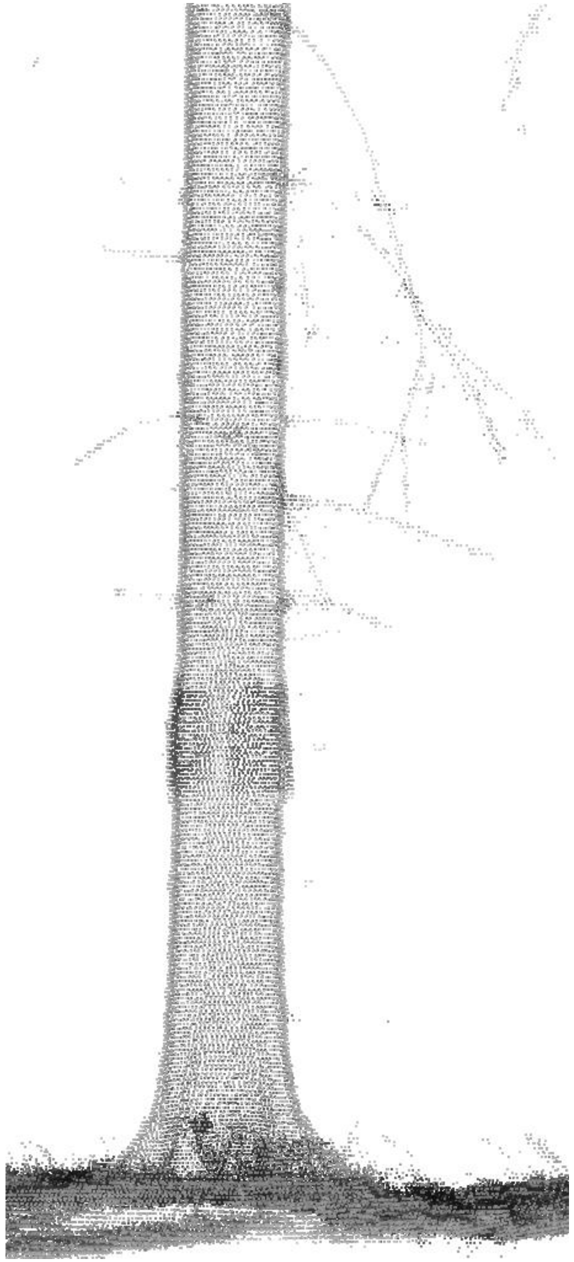
$V_{PP-ALLOM}$ = Allometrics (DBH, H) – traditional method

Most important outcomes

- The Stem Acummulated Volume (SAV) is strongly correlated with the total merchantable volume of the trees and can be used as a predictor of this feature.

- With a mapped stem up to a height of 8-10 metres, it is possible to determine the volume of trees at an equivalent level to the traditional method. When stems are mapped higher than 10 metres, more accurate tree volume determination can be expected.

- It is possible to determine the growing stock volume at the sample plot with a precision comparable to the traditional method, assuming that all trees are detected and their trunks measured to a height of at least 8-10 metres.



Thanks for attention.

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