ESTIMATION OF TREE SIZE DISTRIBUTIONS BY COMBINING VERTICAL AND HORIZONTAL DISTRIBUTION OF LASER MEASUREMENTS WITH EXTRACTION OF INDIVIDUAL TREES

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Objectives:

- Evaluate the information content in a new tree detection algorithm and the semivariogram measure for estimation of stem diameter distributions
- Identification of additional variables that are efficient for the estimations
- Information sources are validated in the percentile method as well as in regression of Weibull parameters

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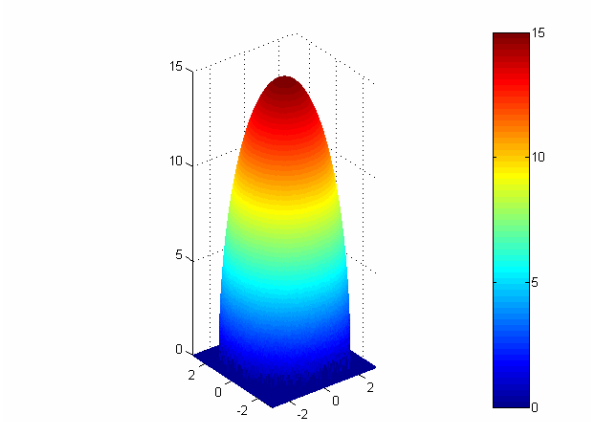
Tree detection – segmentation using templates

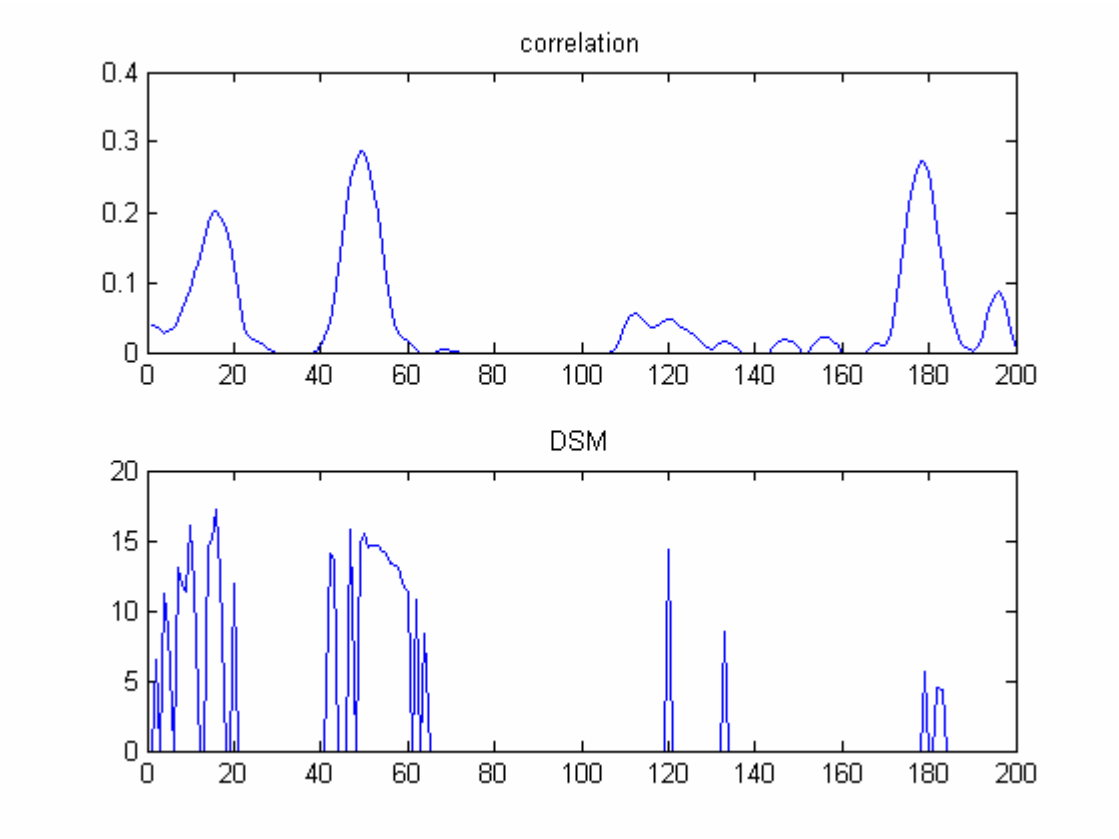
1. Create a digital surface model (DSM)
2. Create a correlation surface using templates
3. Segmentation using correlation surface and DSM
4. Calculate tree attributes

Generalized ellipsoid of revolution

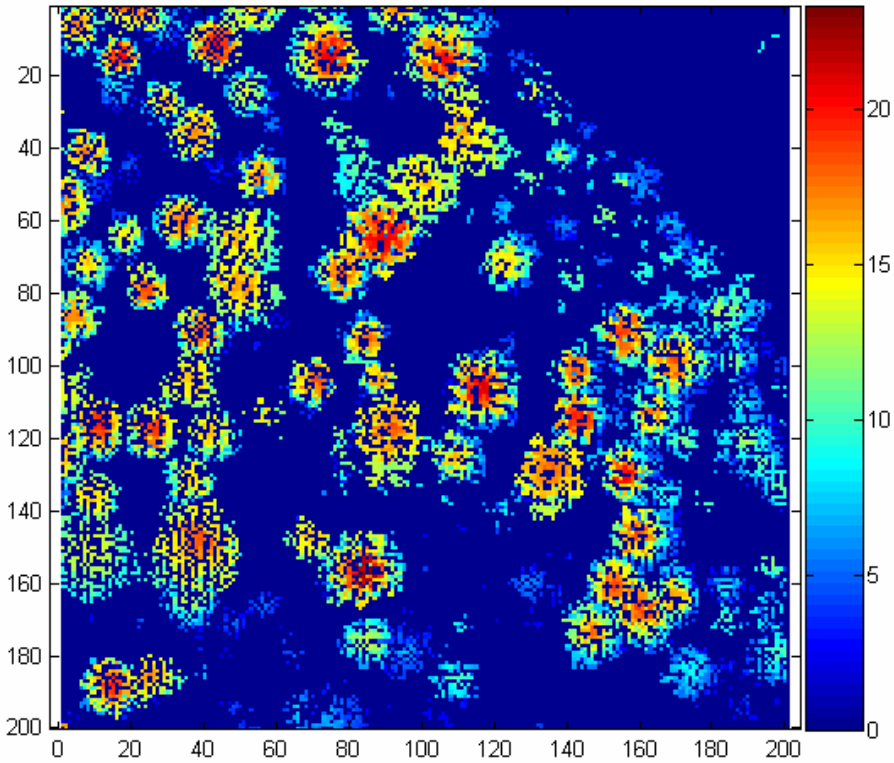


$$(z/a)^n + (r/b)^n = 1$$

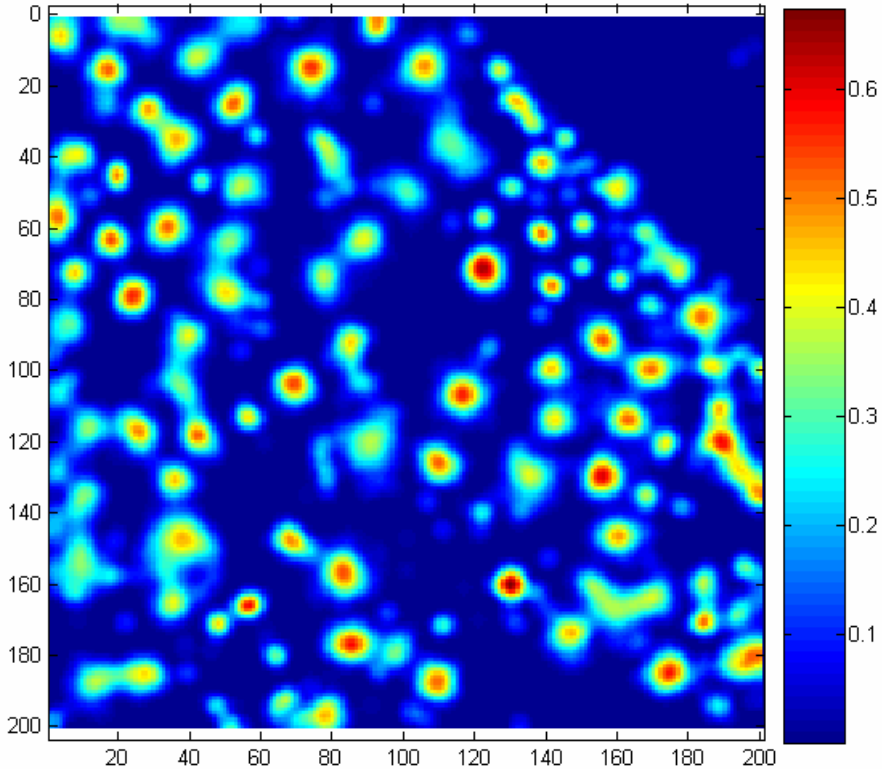
Profile of smoothed correlation surface and DSM [m]



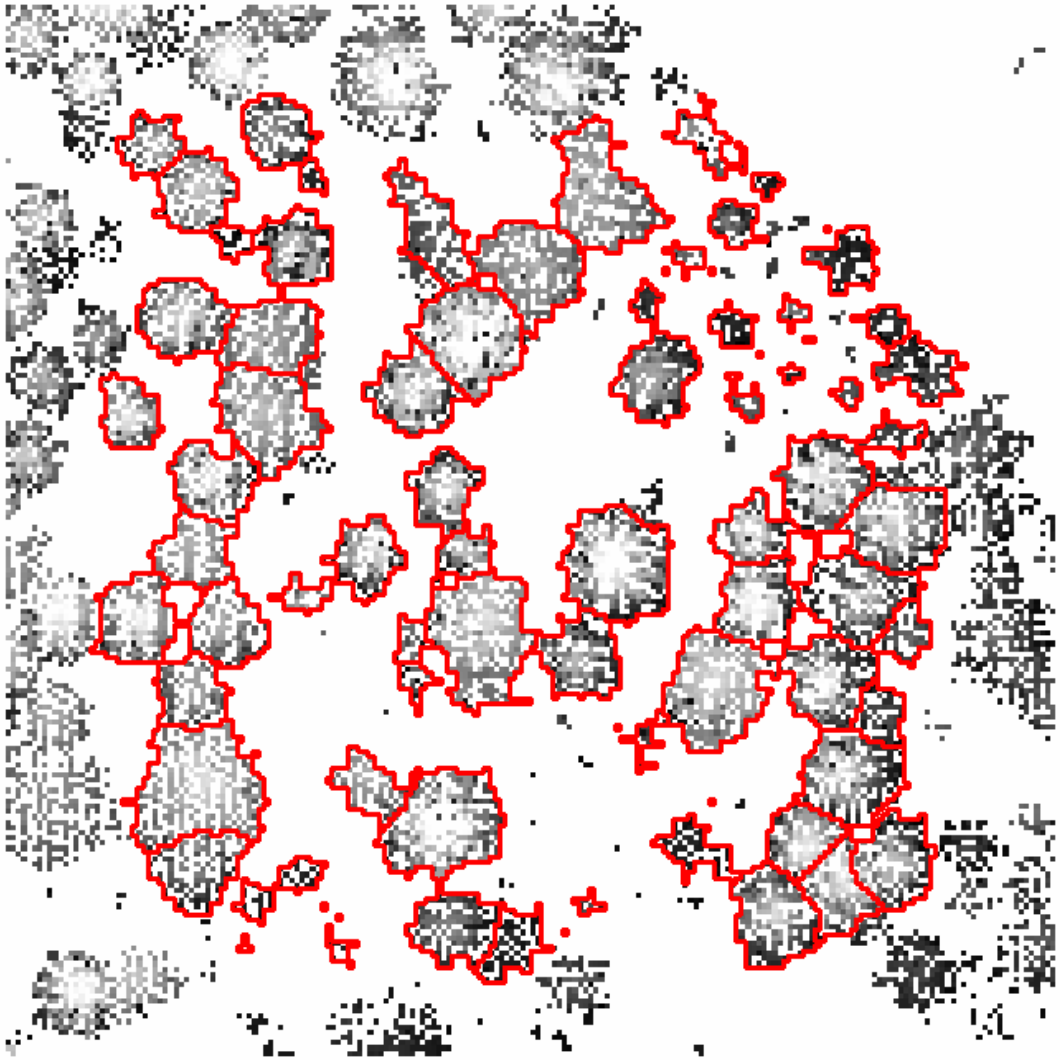
DSM [m] (0.25 m/pixel)



Smoothed correlation surface

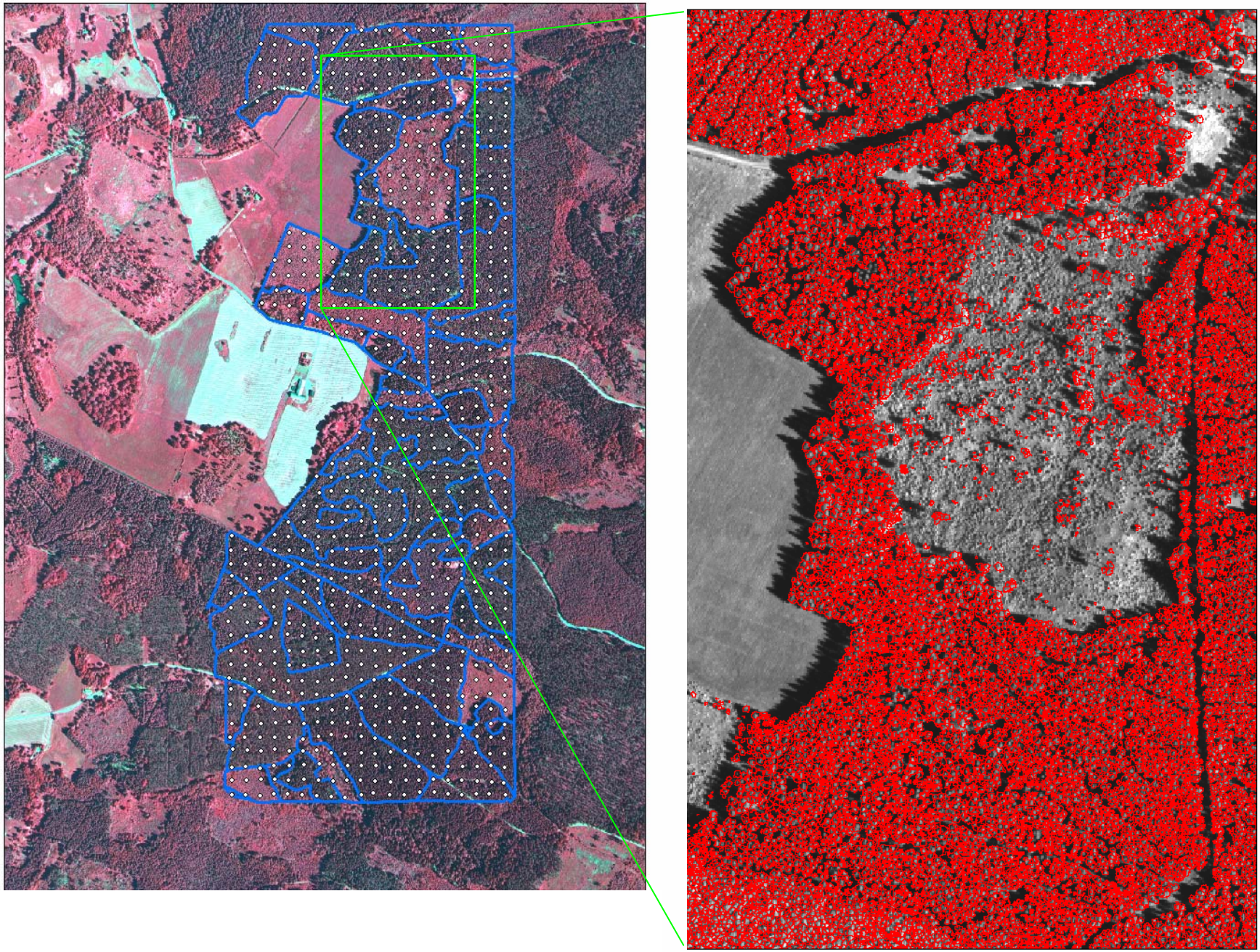


Crown segments with DSM [m] as background image



For each tree crown:

- Tree position
- Tree height
- Crown width
- Correlation value



MATERIAL:

- Test site south of Sweden (lat. 58°30'N, long. 13°40'E)
- Forest dominated by Scots pine and Norway spruce
- Field plots 10 m radius, grid with 40 spacing, 45 forest stands
- Average tree density 867 stems ha^{-1} (286-2475 stems ha^{-1})
- Average stem diameter 0.20 m (0.10-0.34 m)
- Average tree height was 16.9 m (8.3-26.5 m)
- Average density laser data 7 measurements m^{-2}

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Variables derived from laser data:

- Percentiles of laser canopy heights (raw heights)
- Percentiles of heights of detected trees (tree heights)
- Percentiles of laser measured crown size (tree height x crown width)
- The spatial ratio (Sr) was derived as $Sr = \theta s / (\theta n + \theta s)$, where θn = nugget, $\theta n + \theta s$ = sill
- Variance of laser canopy heights
- Mean of laser canopy heights
- Weibull scale and shape parameter of laser canopy heights (raw heights)
- Weibull scale and shape parameter of detected tree heights
- Weibull scale and shape parameter of laser measured crown size (tree height x crown width)

Statistical models:

- Seemingly Unrelated Regression (SURE)
- Regression of the Weibull parameters

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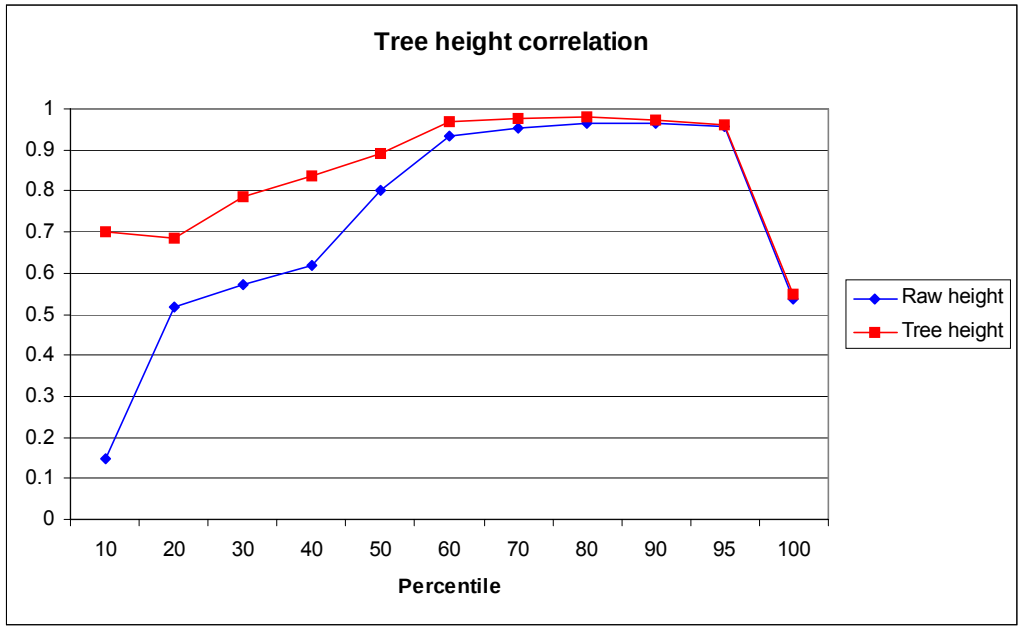
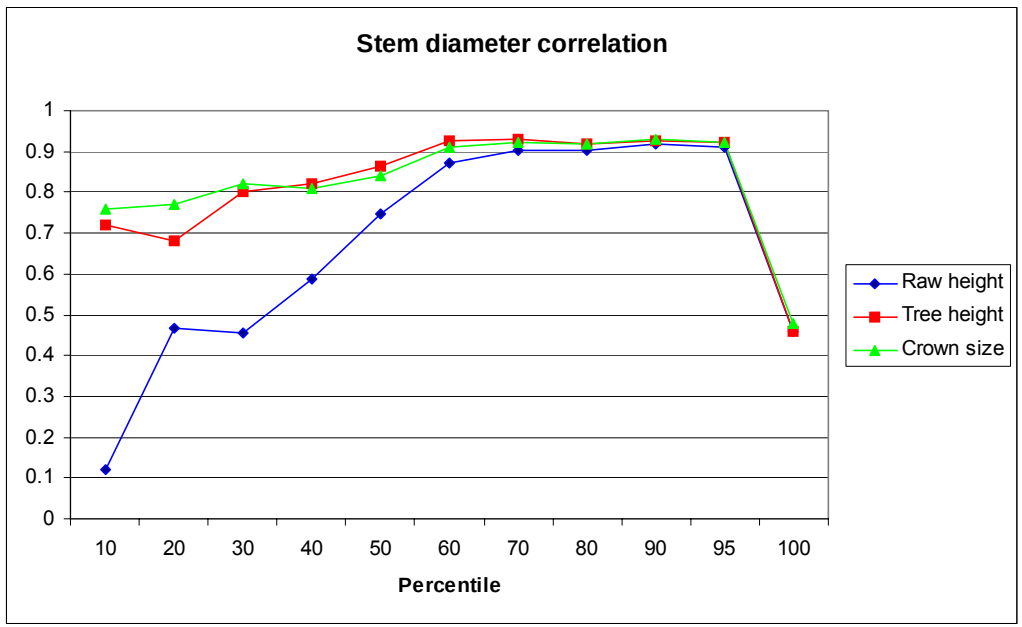
Correlation:

field measured and laser measured percentiles





Independent variables for estimation of stem diameter percentiles with the SURE model, R2 values, and error index, using measures from laser canopy heights (H) or from tree detection (T), or a combination

Independent variables	***R2***	***Error index***
Percentiles (H)	0.45	76
Percentiles (H), mean (H), variance (H)	0.65	168
Percentiles (H), variance (H), spatial ratio (H)	0.63	104
Percentiles (T)	0.50	63
Percentiles (T), variance (H)	0.60	88
Percentiles (T), spatial ratio (T)	0.55	131
Percentiles crown size (T)	0.54	59
Percentiles crown size (T), variance (H)	0.69	66
Percentiles crown size (T), variance (H), spatial ratio (H)	0.71	107

Independent variables for estimation of the shape and scale parameter of the Weibull distribution for describing the stem diameter distribution, R2 values, using measures from canopy heights (H) or from tree detection (T), or a combination

Independent variables	***Shape R2***	***Scale R2***
Mean (H), Variance (H)	-	0.87
Variance (H)	0.30	-
Shape (T), Scale (T)	-	0.86
Shape (T), Variance (H)	0.39	-
Shape Crown size (T), Variance (H)	0.47	-

Conclusions:

- Higher correlation between percentiles of stem diameter and percentiles of attributes of the detected trees compared with percentiles of canopy heights
- For estimation of stem diameter distributions using SURE, percentiles from the tree detection yielded higher R^2 values compared with using percentiles of the laser canopy heights
- Both with and without tree detection, the R^2 could be improved by adding additional variables, e.g., the variance of canopy heights and the spatial ratio (not the same for the error index)
- The best R^2 value for estimation of the scale parameter was obtained by using the mean and variance of laser canopy heights
- The best R^2 value for estimation of the shape parameter was obtained by using shape parameter from the crown size distribution together with the variance of the laser canopy heights

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Thank you for your attention!

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