Use R! for estimating forest parameters based on Airborne Laser Scanner Data

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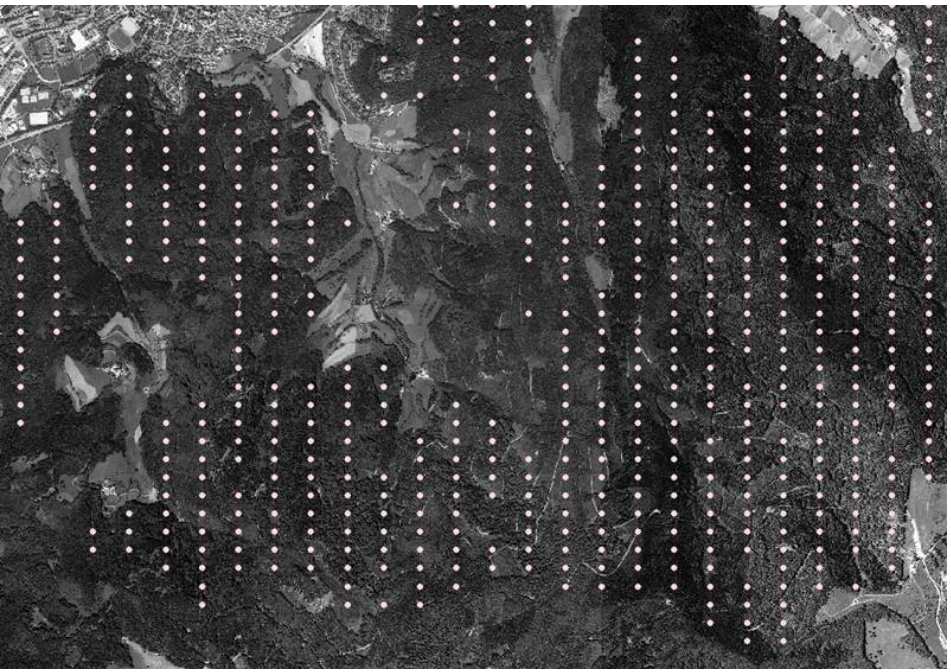
Inhalt

Sample Plot Inventory

- Forest inventory $\rightarrow$ statistical sound information on the enterprize-level (Stands are too small)



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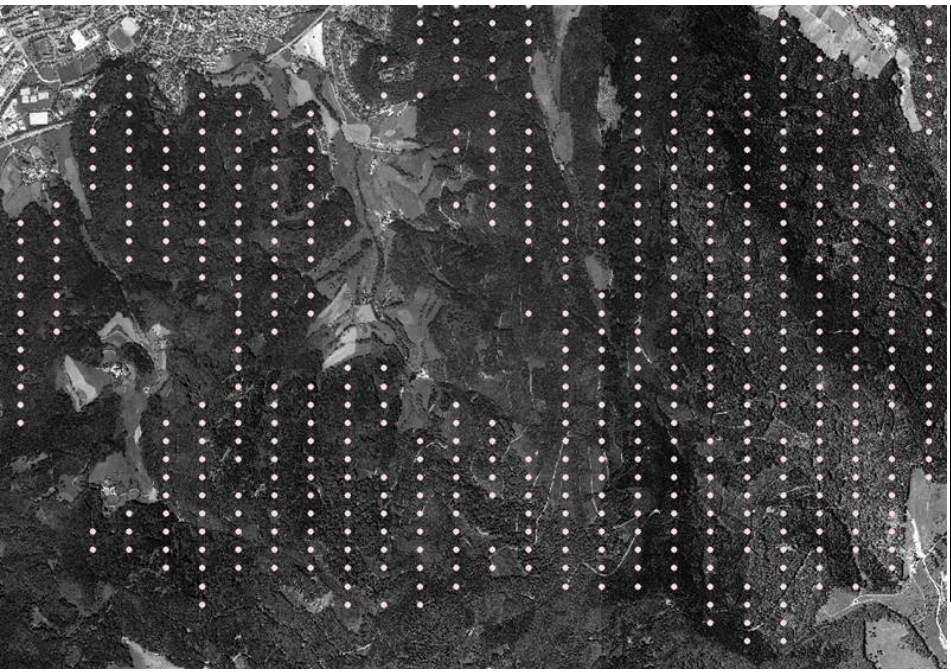

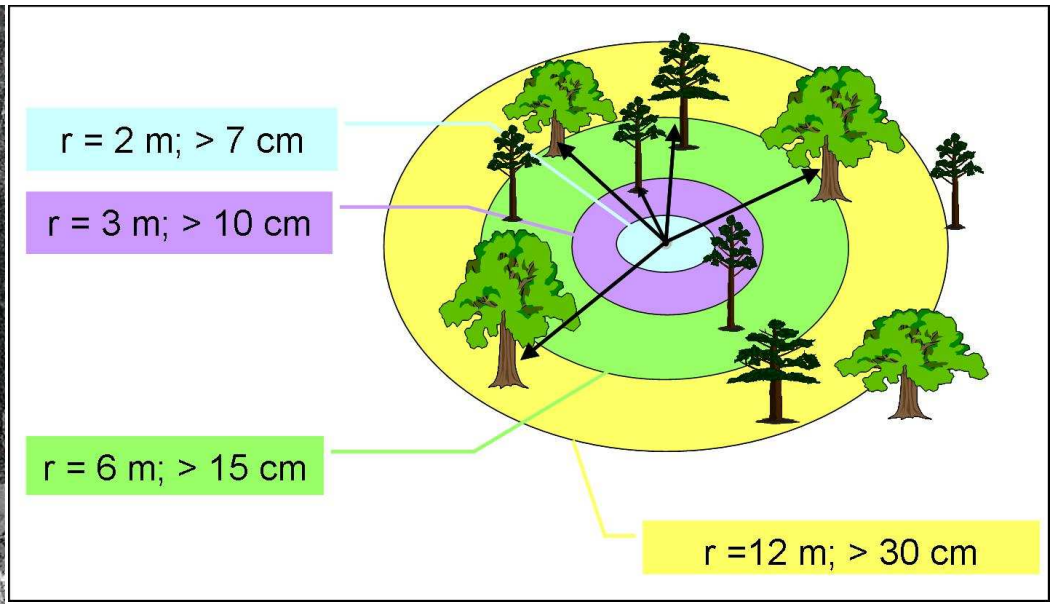

Motivation

- High costs
- Insufficient information on stand level
- Staff reduction
- Increased economical interest in timber products

$\Rightarrow$ Greater information-need on the stand level

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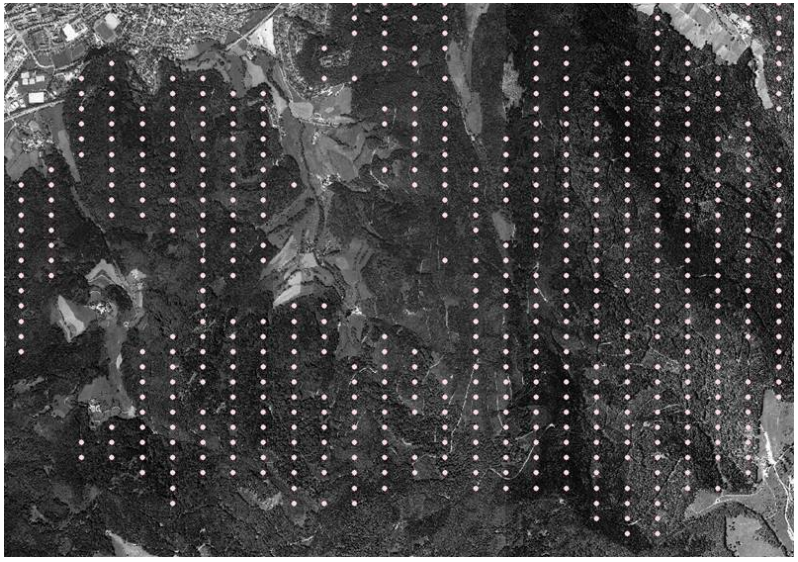
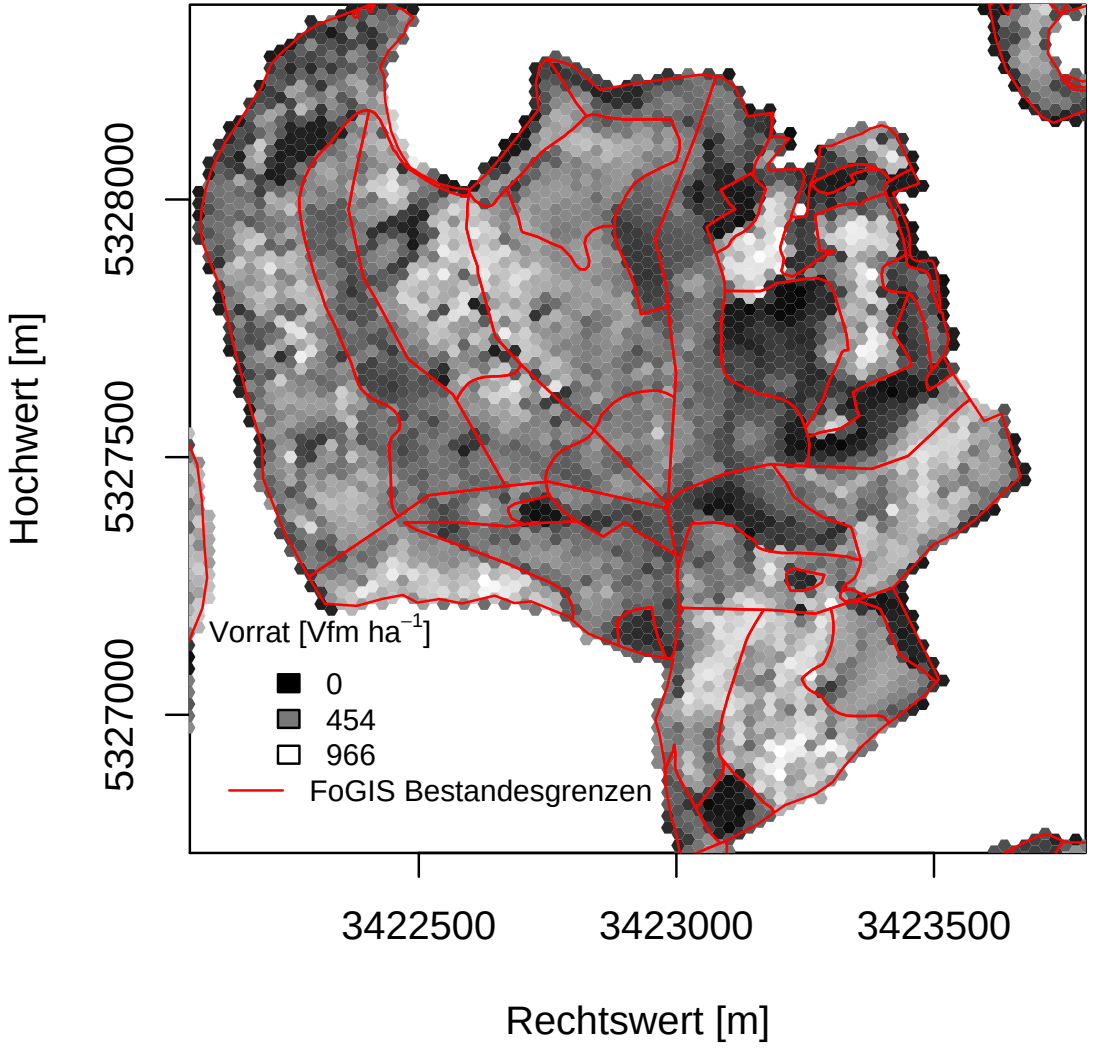
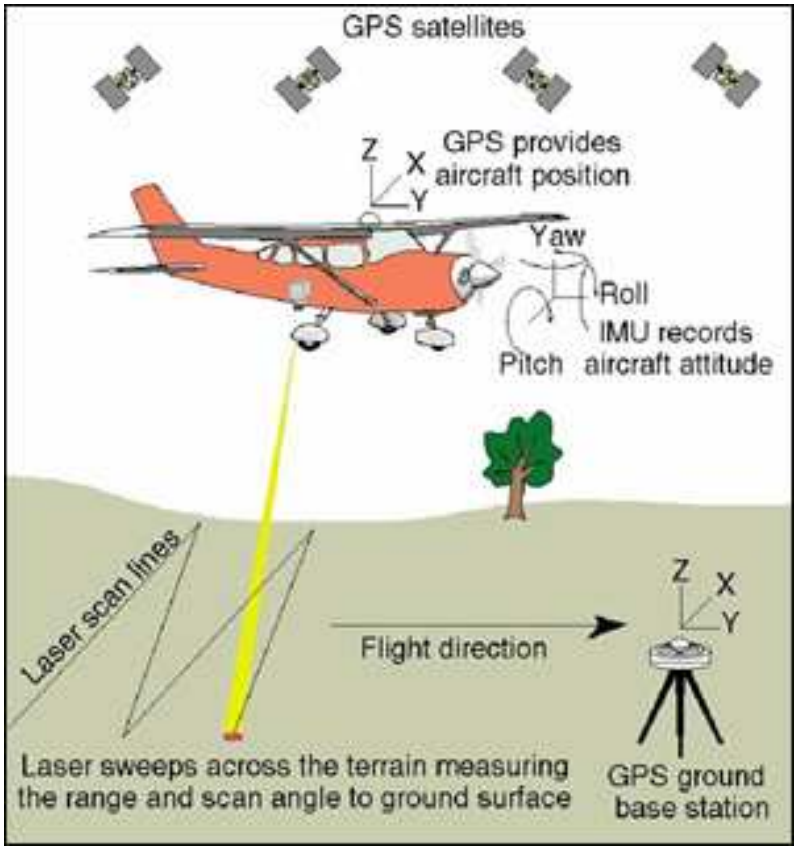
Aim $\Rightarrow$ Regionalization (small area estimation): From a point-wise to a wall-to-wall information





Airborne Laser Scanning



http://www.geokosmos.com/technologies/airbornscan.jpg

- Active remote sensing system
- Laser for distance measurement
- Pointcloud with XYZ-raw data

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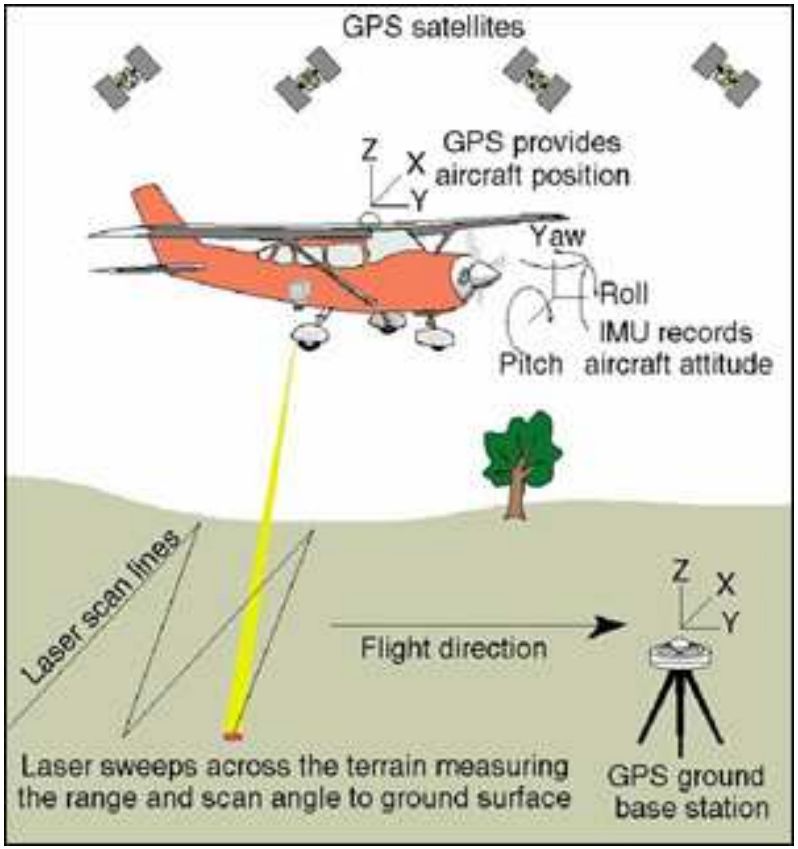

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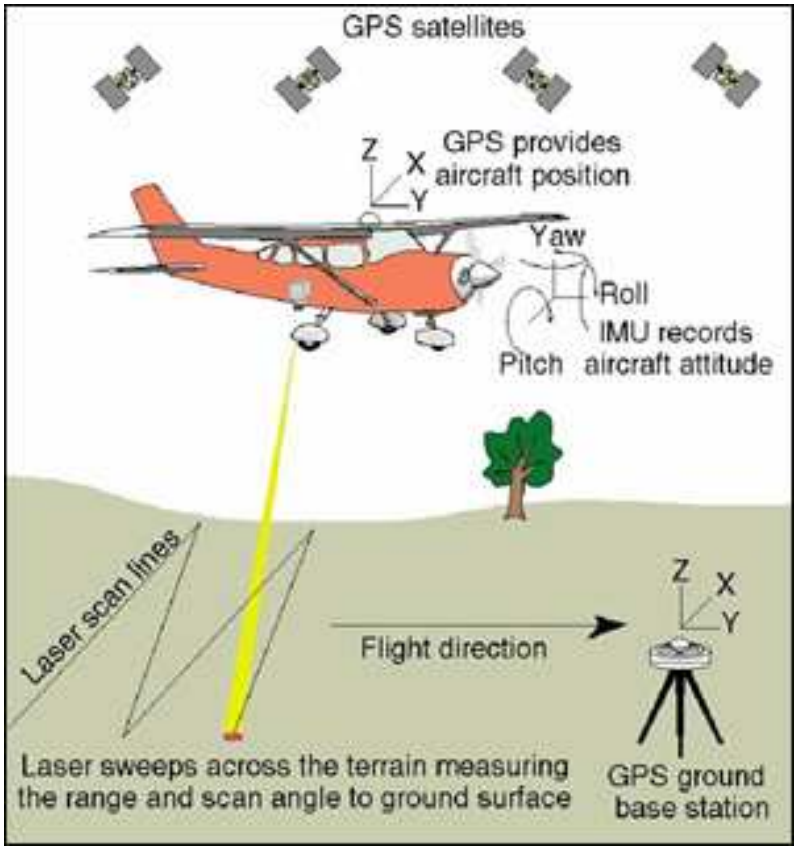

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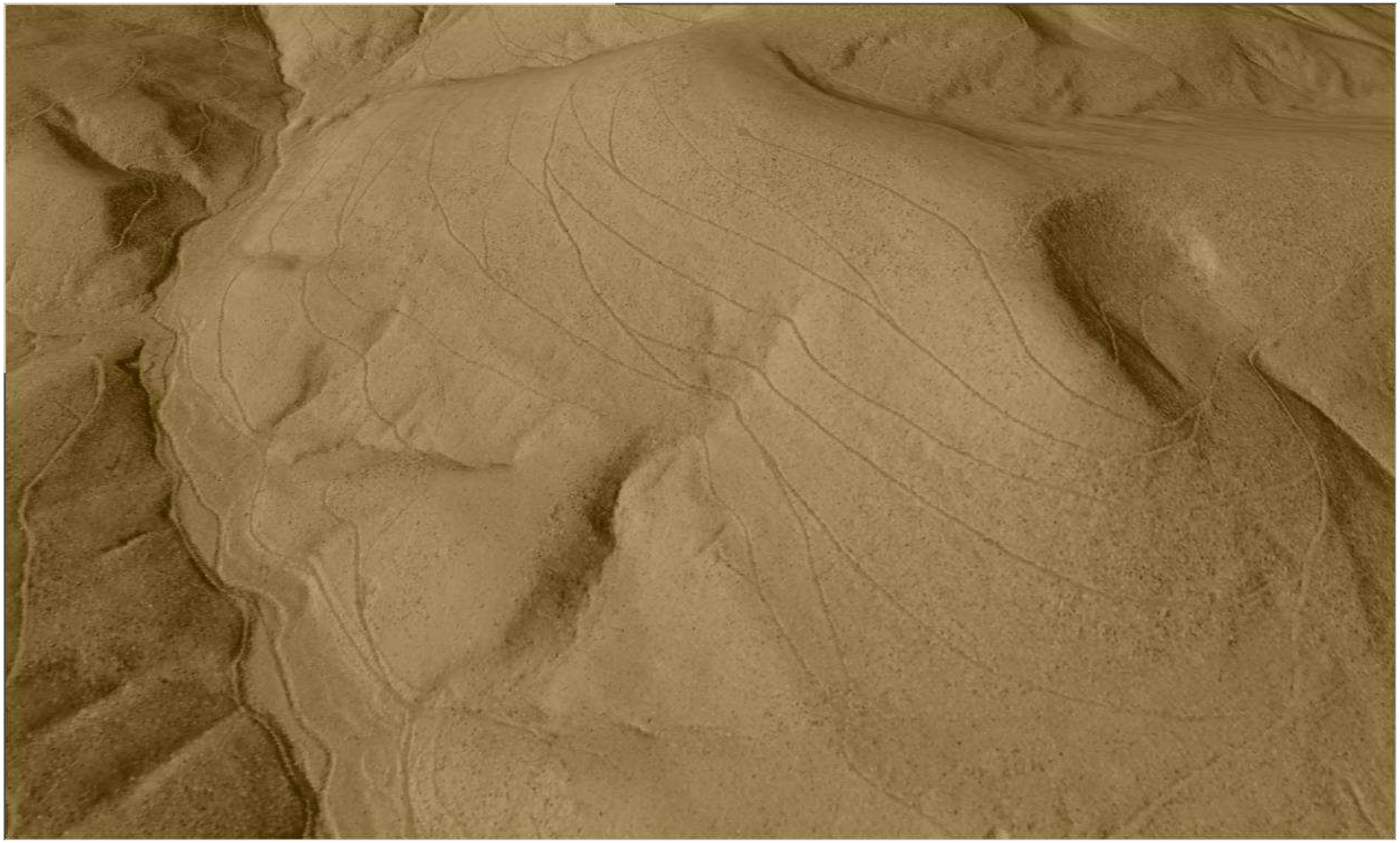
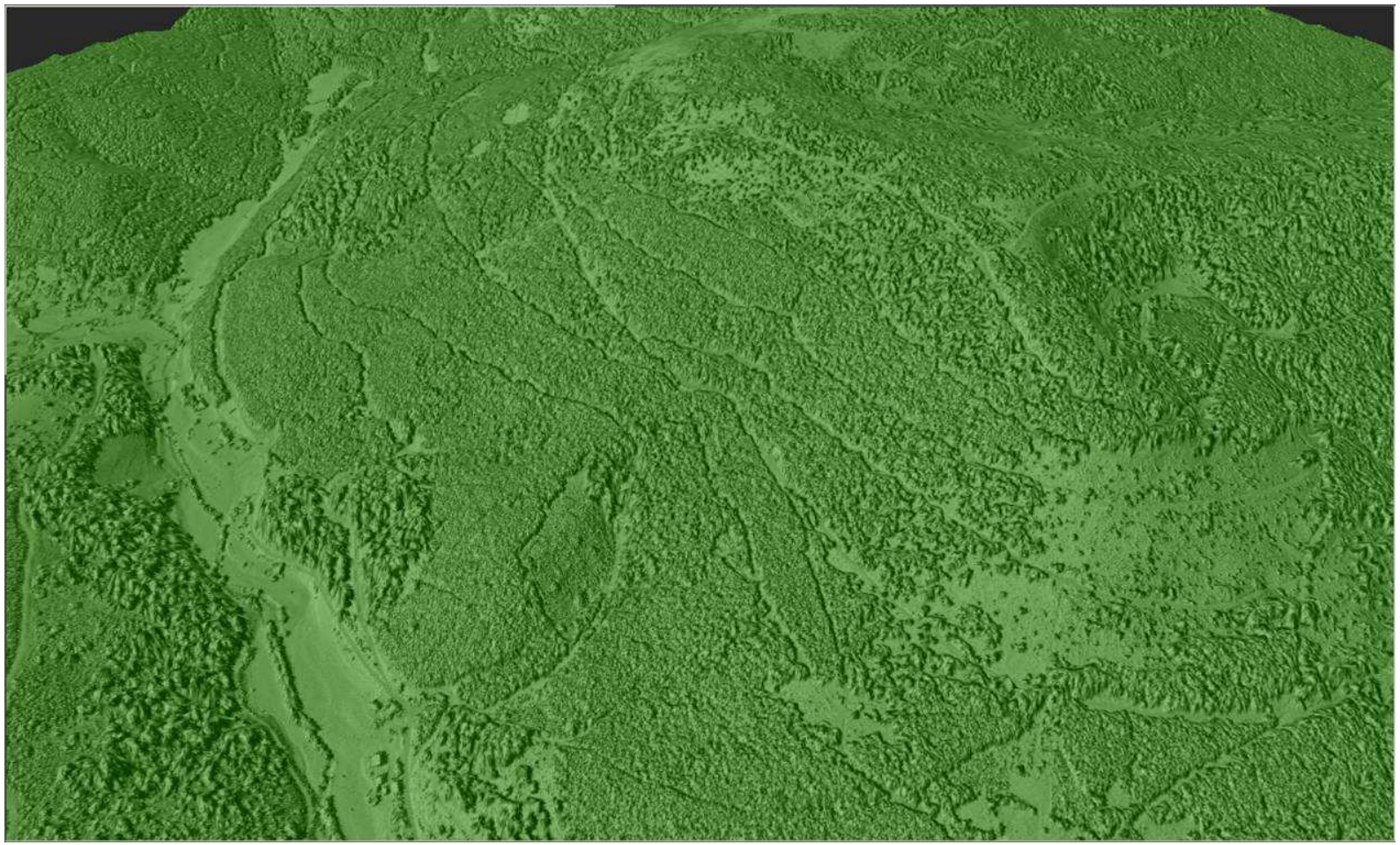
Digital Terrain Model



Software: TreesVis, FELIS Uni Freiburg

Digital Surface Model



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Area-based method

- Aggregation of laser data on sample plot level $\rightarrow$ metrics
- Statical relation between
  - Metrics
  - Sample plot attributes (volume, diameter distribution, tree height)

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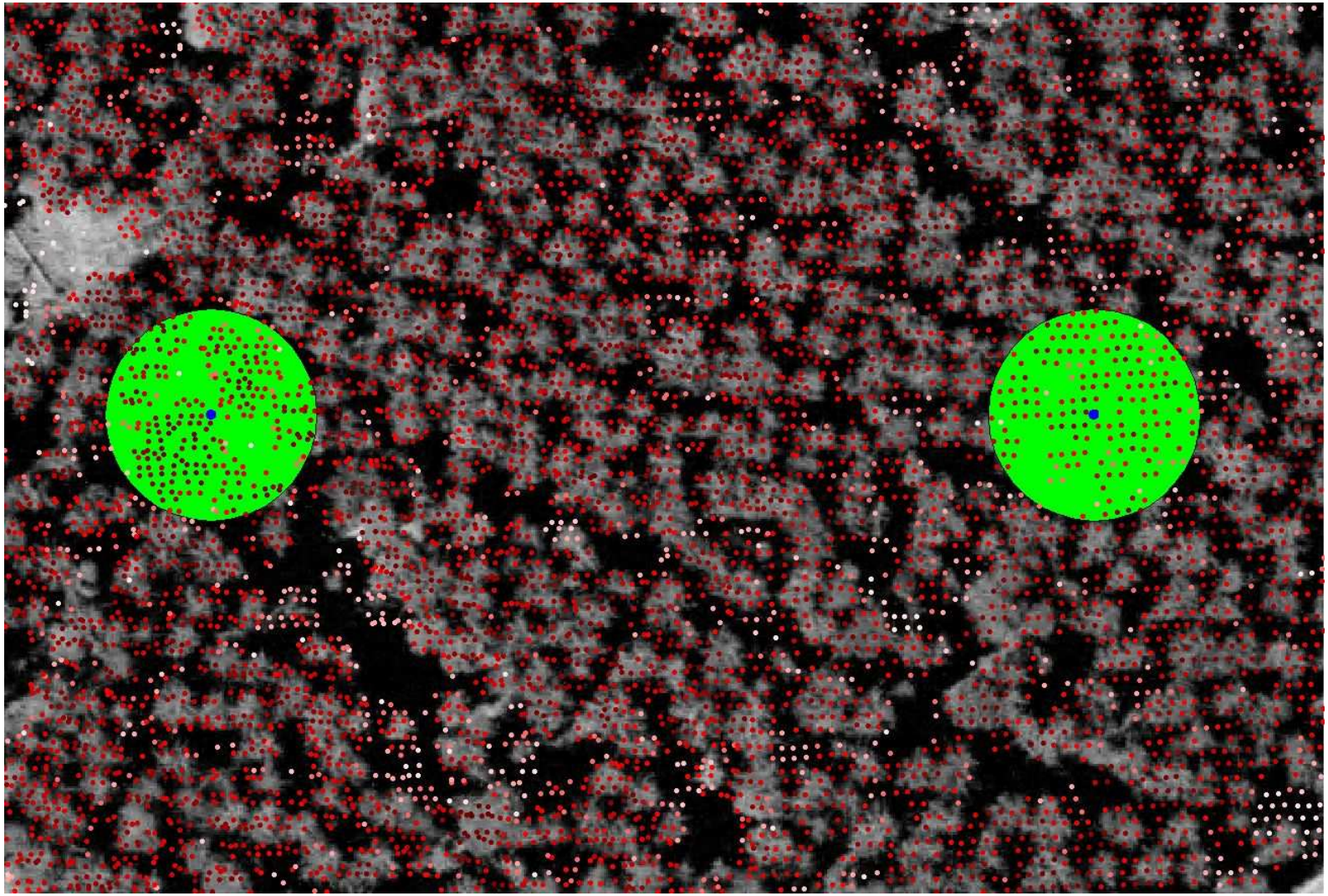
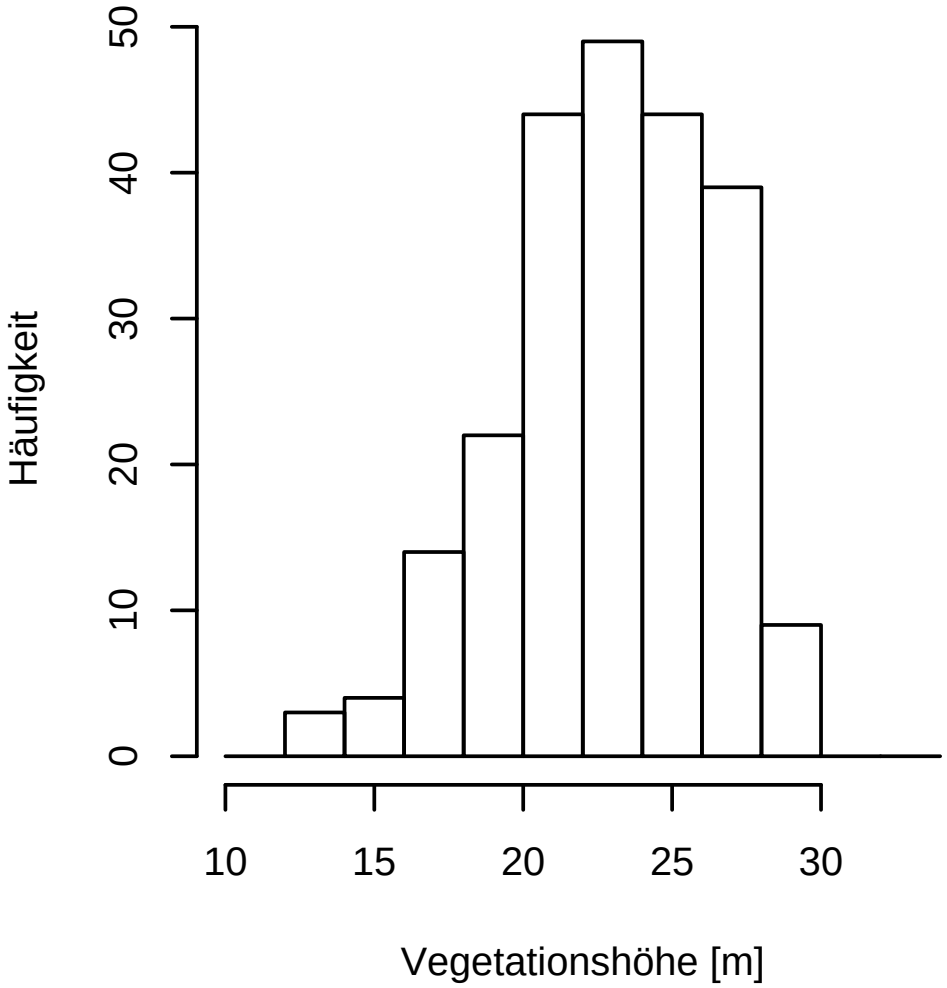
Computation of metrics



Computation of metrics - *basic R*



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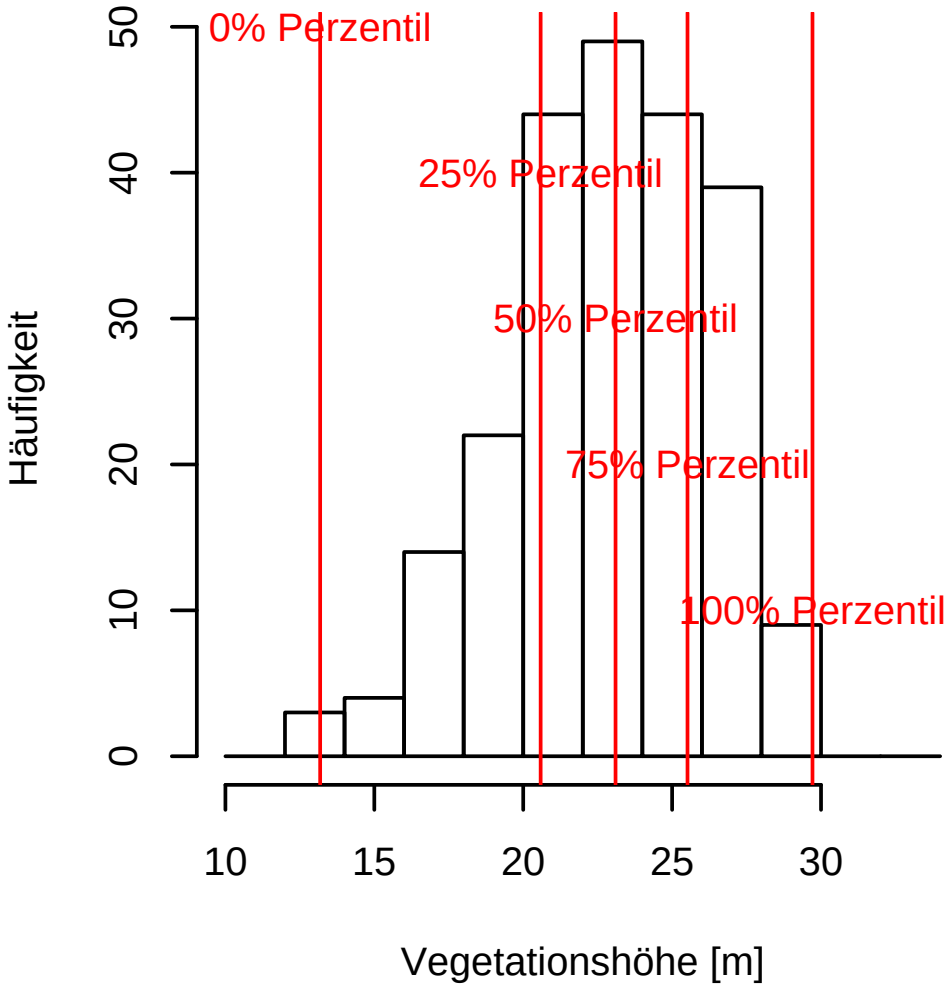

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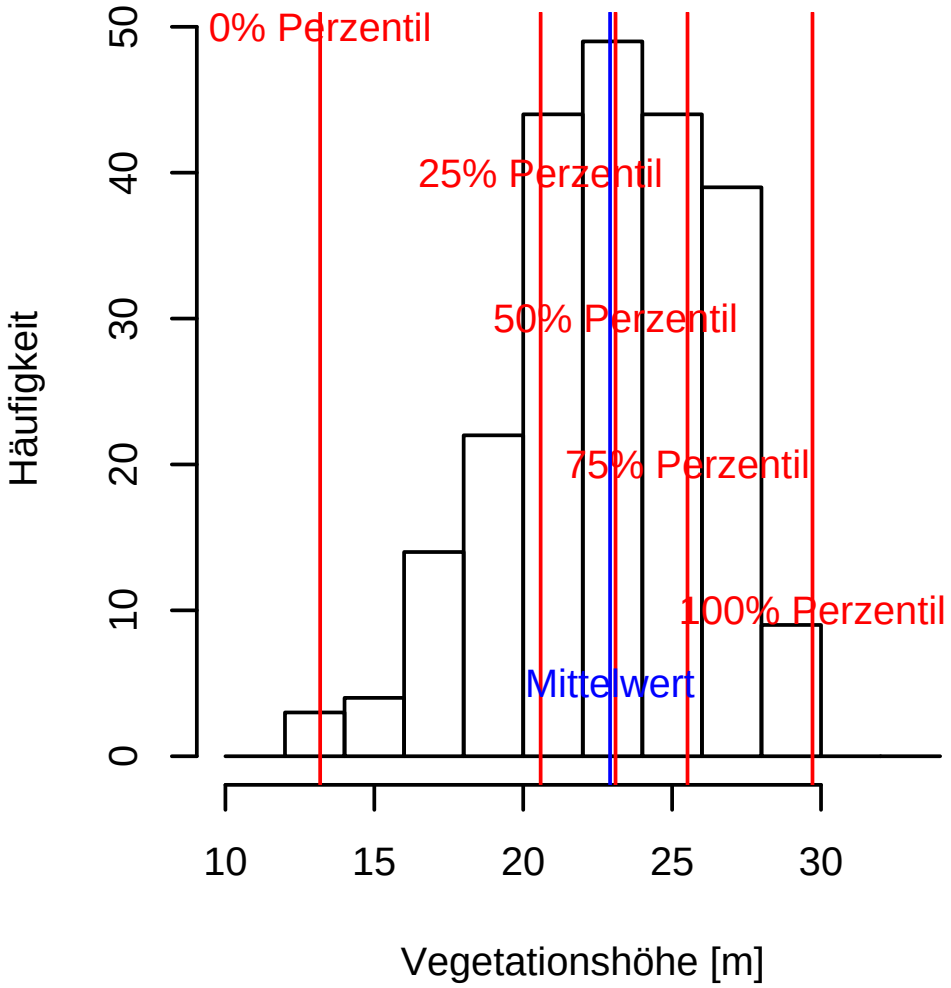

Other predictor variables - *ArcGIS*

- Crown cover
- Coniferous proportion

Hierarchical data structure

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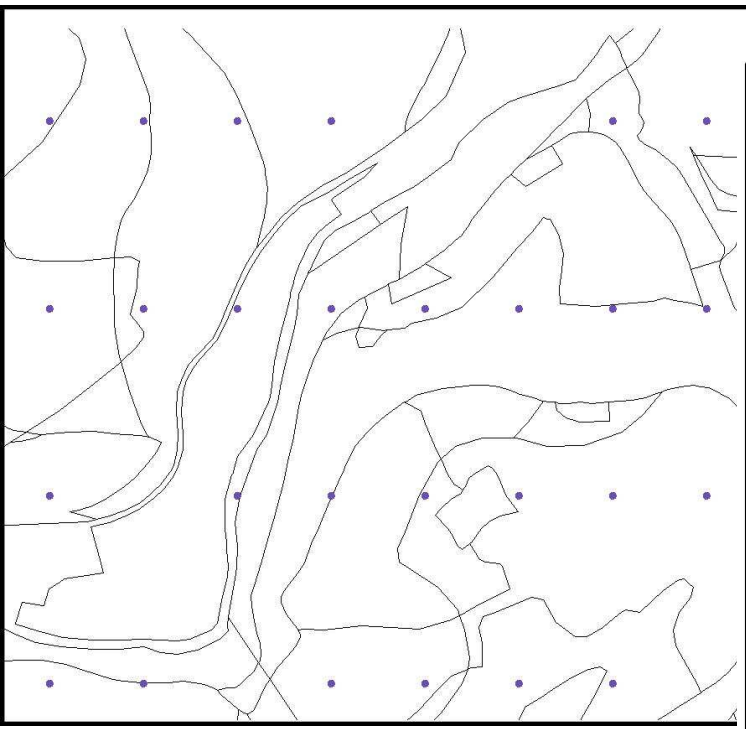
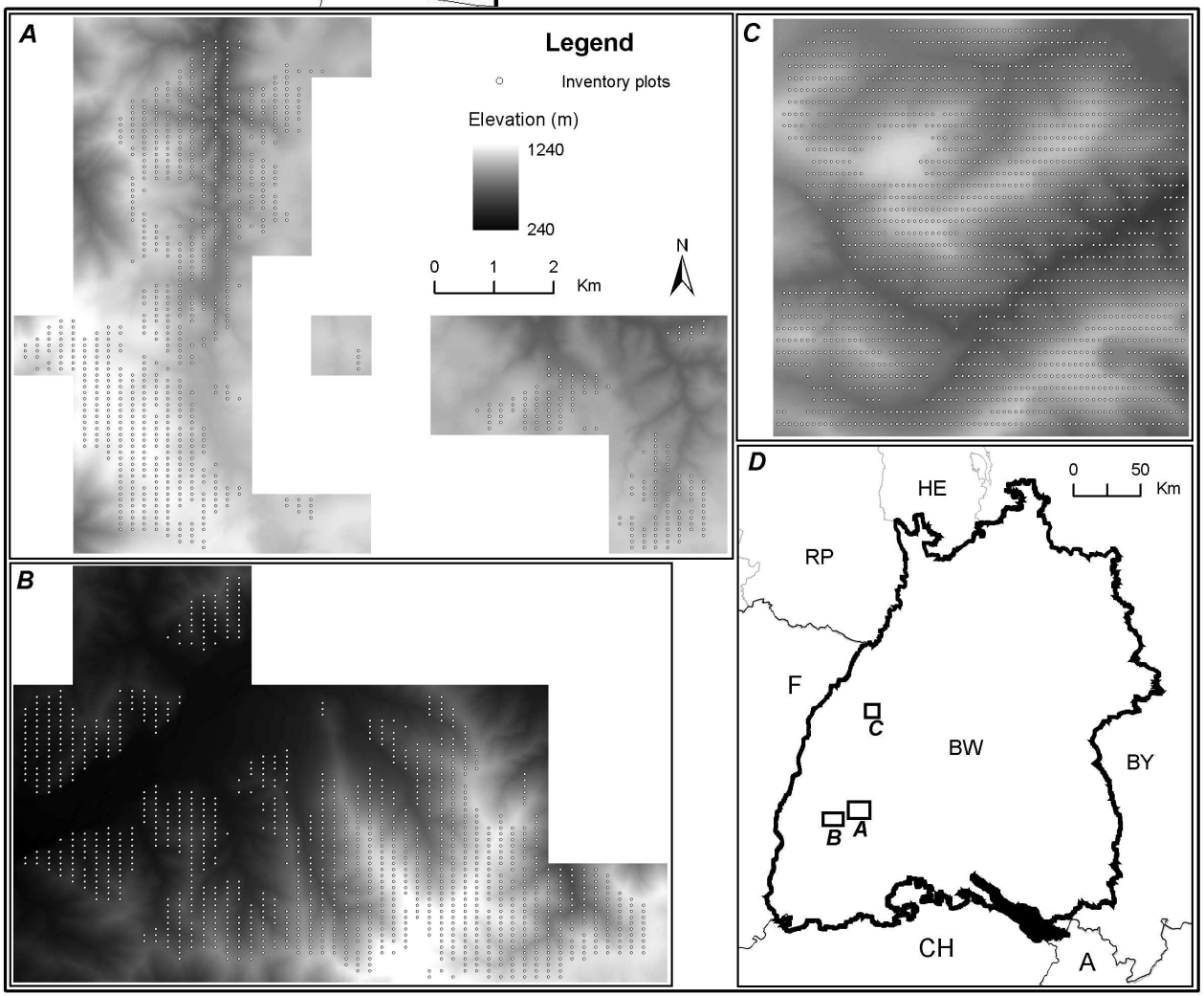




Linear mixed model - *lme*

$$\boldsymbol{y}_{ij} = \boldsymbol{X}_{ij}\beta + \boldsymbol{U}_{i,j}\gamma_i + \boldsymbol{U}_{ij}\gamma_{ij} + \varepsilon_{ij}$$

with

$$\gamma_i \sim \mathrm{N}(\mathbf{0}, \boldsymbol{D}_{(1)}), \quad \gamma_{ij} \sim \mathrm{N}(\mathbf{0}, \boldsymbol{D}_{(2)}), \quad \varepsilon_{ij} \sim \mathrm{N}(\mathbf{0}, \boldsymbol{\Sigma}_{ij})$$

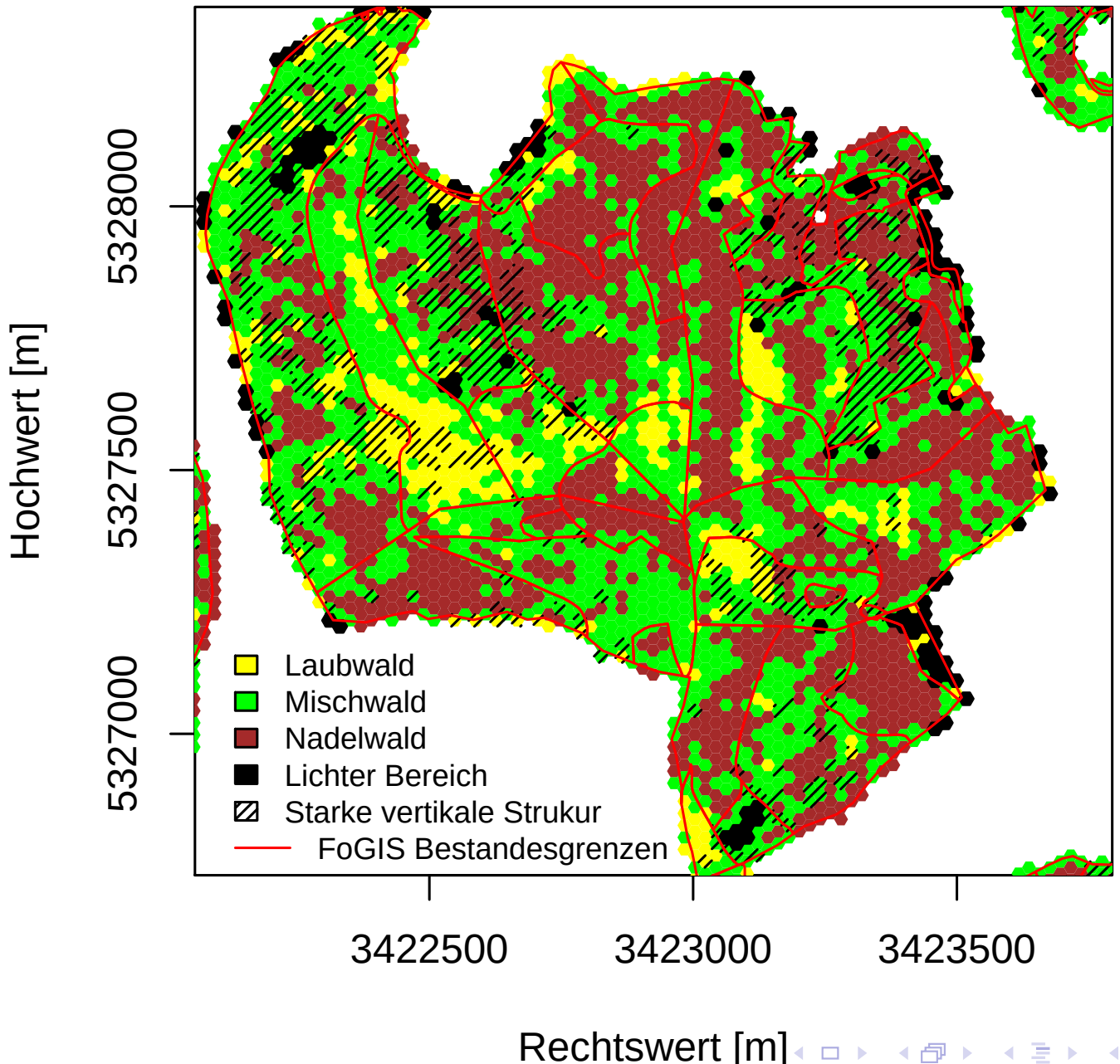
where

$$\boldsymbol{\Sigma}_{ij} = \begin{pmatrix} \sigma^2 \hat{y}_{ij1}^{2\delta} & \cdots & \mathrm{Kov}(\varepsilon_{ij1}, \varepsilon_{ijn_{ij}}) \\ \vdots & \ddots & \vdots \\ \mathrm{Kov}(\varepsilon_{ijn_{ij}}, \varepsilon_{ij1}) & \cdots & \sigma^2 \hat{y}_{ijn_{ij}}^{2\delta} \end{pmatrix}$$

and

$$\mathrm{Kov}(\varepsilon_{ijk}, \varepsilon_{ijk'}) = \exp(-s/\rho) \;\; \sigma\hat{y}_{ijk}^{\delta} \;\; \sigma\hat{y}_{ijk'}^{\delta}$$

Regionalization - *Maptools*



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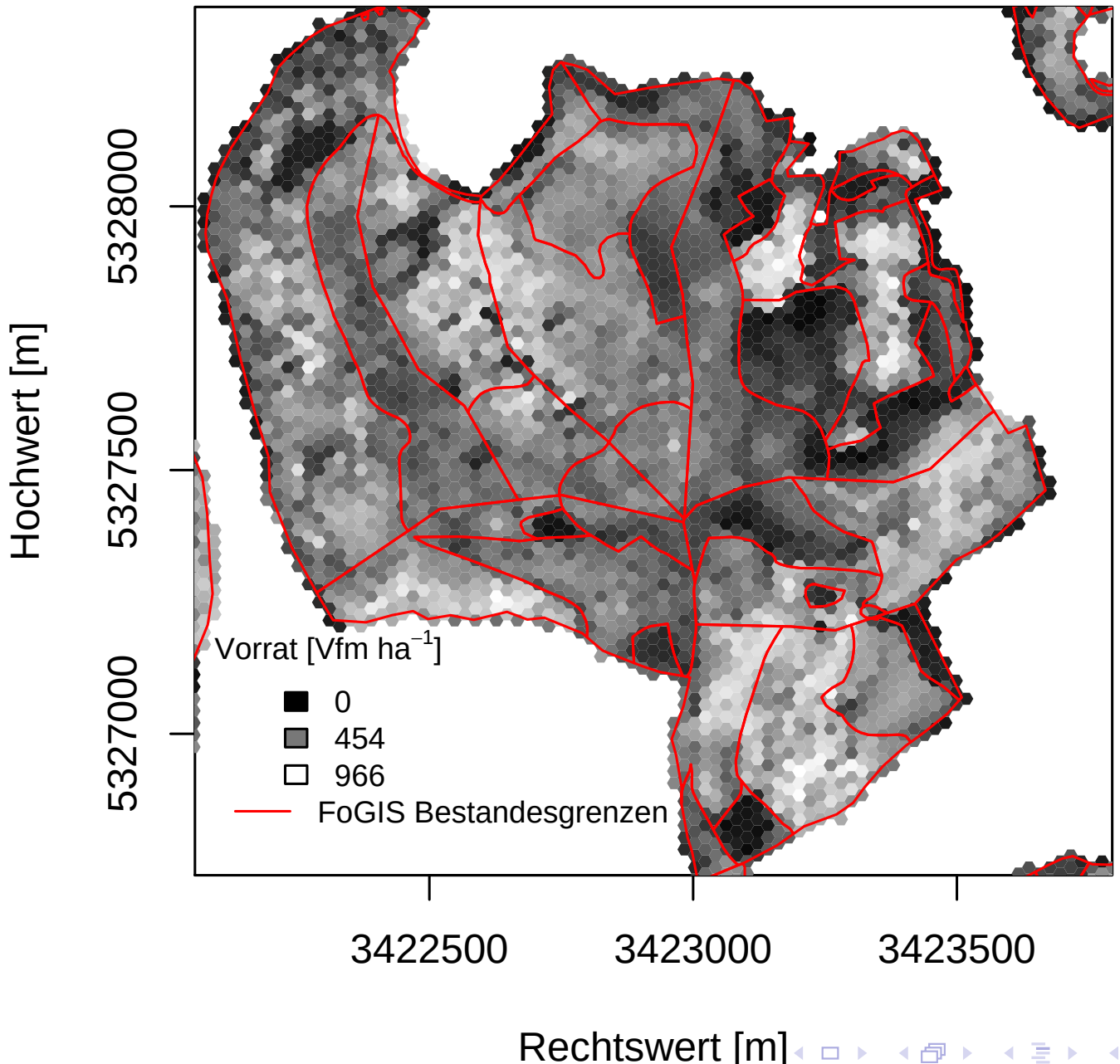

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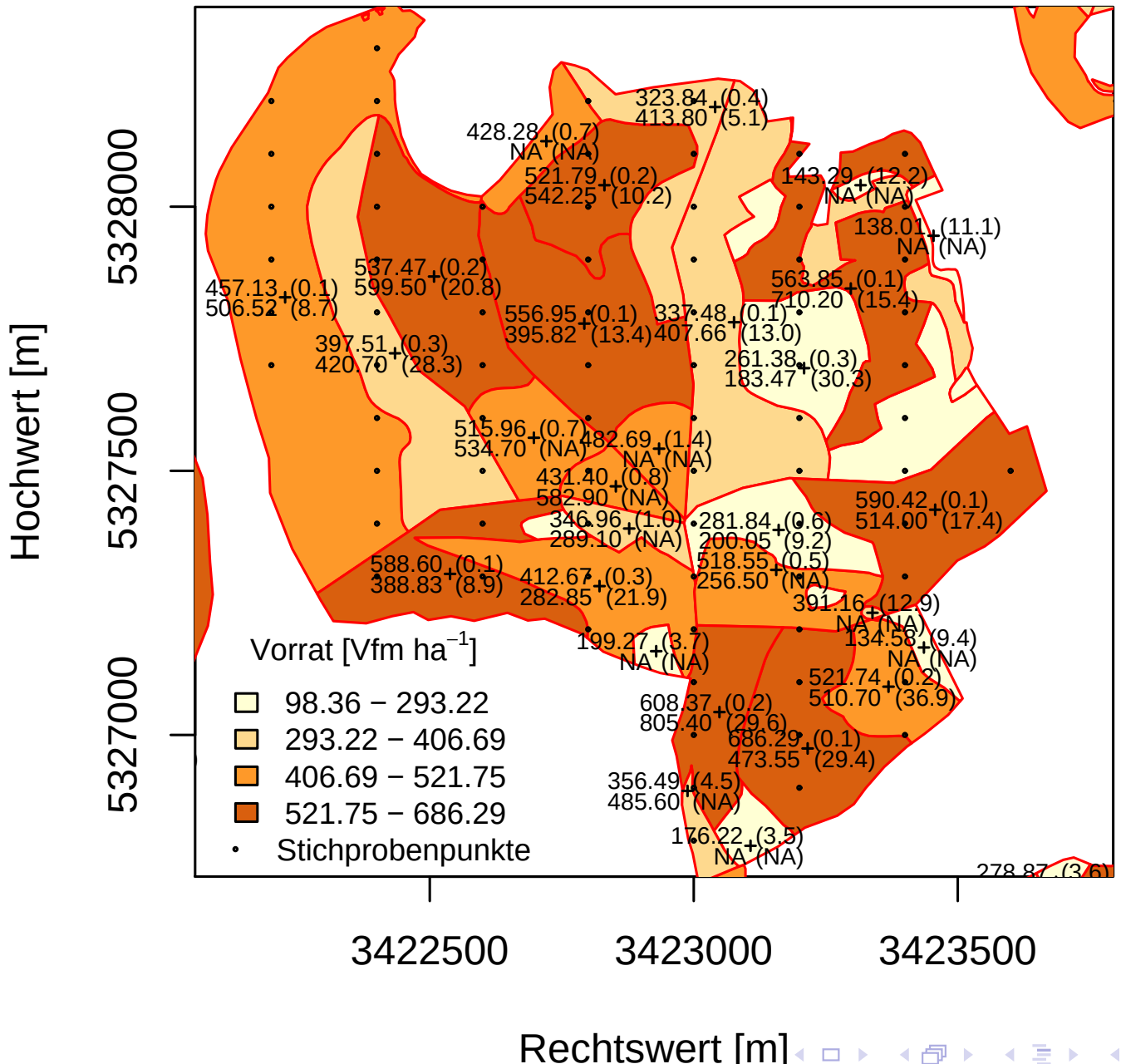
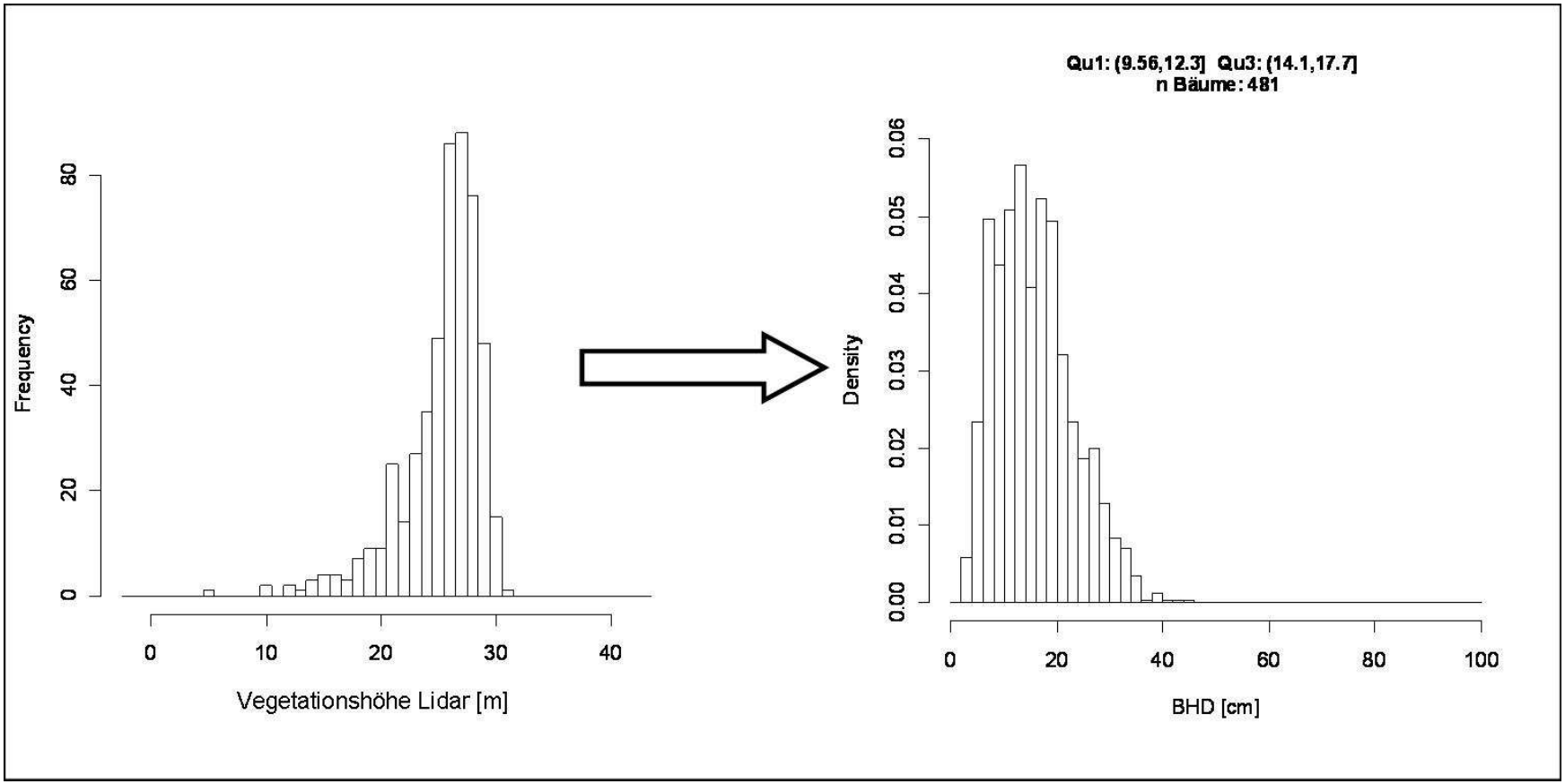


Modeling I


Frequency
0
20
40
60
80
0
10
20
30
40
Vegetationshöhe Lidar [m]
Qu1: (9.56,12.3] Qu3: (14.1,17.7]
n Bäume: 481
Density
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0
20
40
60
80
100
BHD [cm]

Modeling II

Generalized additive model for location, scale and shape - *GAMLSS*

Be

$$y \sim \text{Weibull}(a, b, c), \qquad a = 7, b, c > 0$$

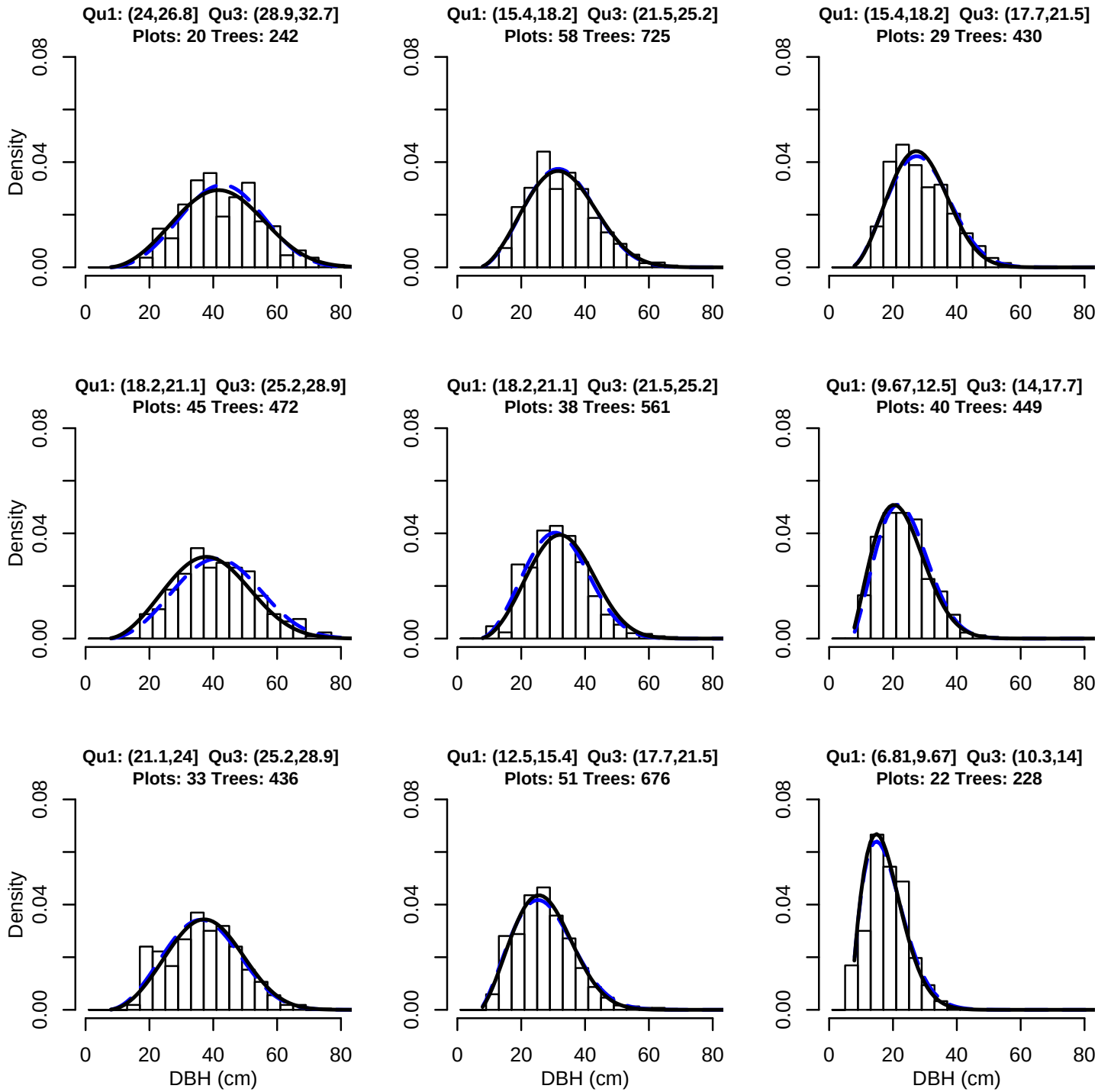
with density

$$f(y|b,c) = \frac{c}{b}\left(\frac{y}{b}\right)^{c-1} \exp\left[-\left(\frac{y}{b}\right)^{c}\right],$$

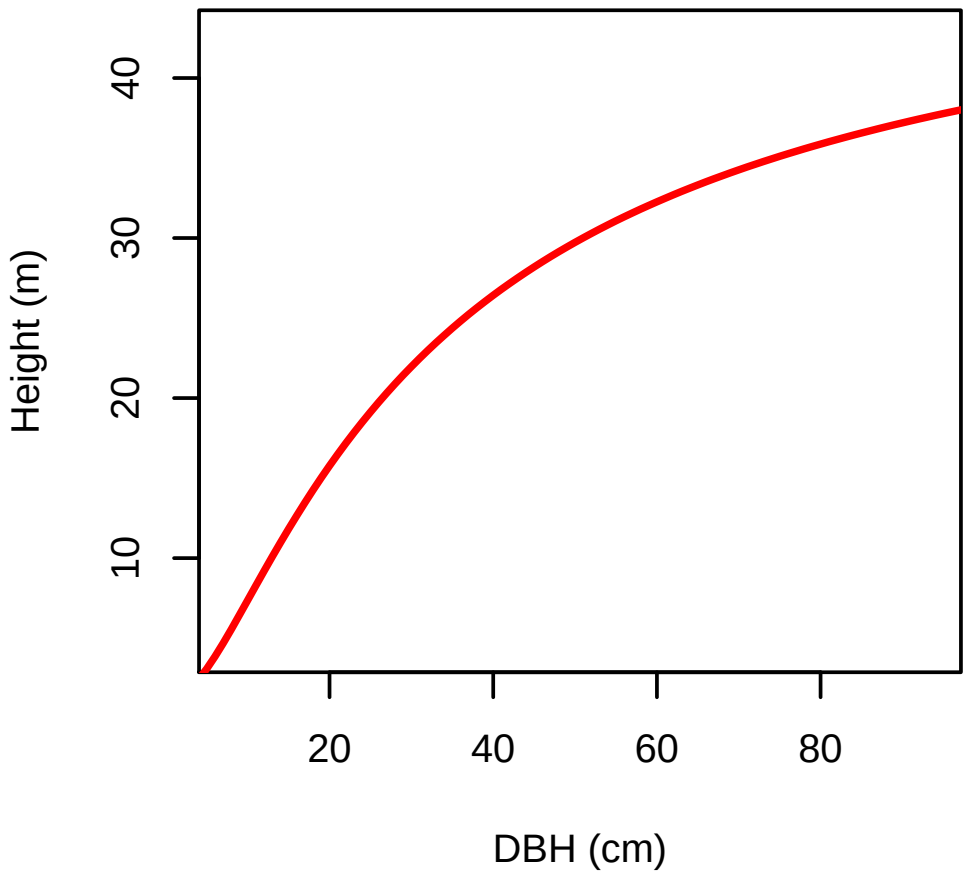
then

$$\boldsymbol{b} = h^{-1}(\boldsymbol{\eta}) \text{ und } \boldsymbol{c} = h^{-1}(\boldsymbol{\eta}).$$

Where a = Location-, b = Scale- and c = Shape parameter, $\eta_i = x_i'\beta$ as well as h = link function.


Qu1: (24,26.8] Qu3: (28.9,32.7]
Plots: 20 Trees: 242
Qu1: (15.4,18.2] Qu3: (21.5,25.2]
Plots: 58 Trees: 725
Qu1: (15.4,18.2] Qu3: (17.7,21.5]
Plots: 29 Trees: 430
Qu1: (18.2,21.1] Qu3: (25.2,28.9]
Plots: 45 Trees: 472
Qu1: (18.2,21.1] Qu3: (21.5,25.2]
Plots: 38 Trees: 561
Qu1: (9.67,12.5] Qu3: (14,17.7]
Plots: 40 Trees: 449
Qu1: (21.1,24] Qu3: (25.2,28.9]
Plots: 33 Trees: 436
Qu1: (12.5,15.4] Qu3: (17.7,21.5]
Plots: 51 Trees: 676
Qu1: (6.81,9.67] Qu3: (10.3,14]
Plots: 22 Trees: 228
Density
0.00
0.04
0.08
0
20
40
60
80
DBH (cm)

Ongoing research



- Bivariate height- and diameter distribution
- *Random forests* to estimate tree-species specific timber volume (multivariate)

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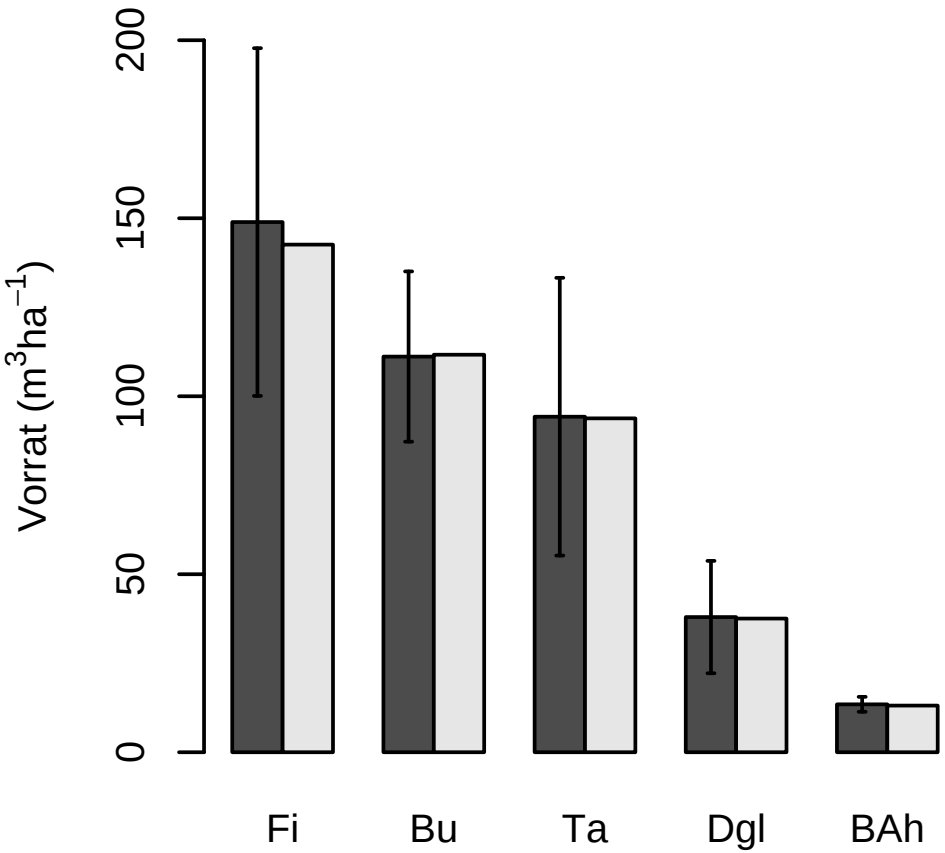

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Summary

- R is well suited for analyzing laser data due to its...
  - functionality to call other programs - *shell()*
  - flexibility (writing own functions)
  - state-of-the-art statistical methods
- Still learning R after 5 years of use...

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Thanks go to...

Christian Gläser, Drs. Edgar Kublin, Matthias Schmidt, Arne Nothdurft, Gerald Kändler

You for your attention!