

A decorative graphic consisting of numerous thin, white, wavy lines that flow across the top half of the image, creating a sense of movement and depth against the dark green background.

Austrian Research Centre for Forests



Serving Forest & People

Research - Monitoring - Training



The long term effects of repeated application of the upper diameter model for Norway Spruce

Ambros Berger

BFW – Wien (Federal Research Centre for Forest, Natural Hazards and Landscape, Vienna, Austria)

Kroměříž

05-25-2016

Measurements for Stem Volume

1. DBH - diameter at breast height
2. H - height of the tree
3. D03H - upper diameter at $3/10$ of H
4. HK - height to the beginning of the living crown

Current Volume Models

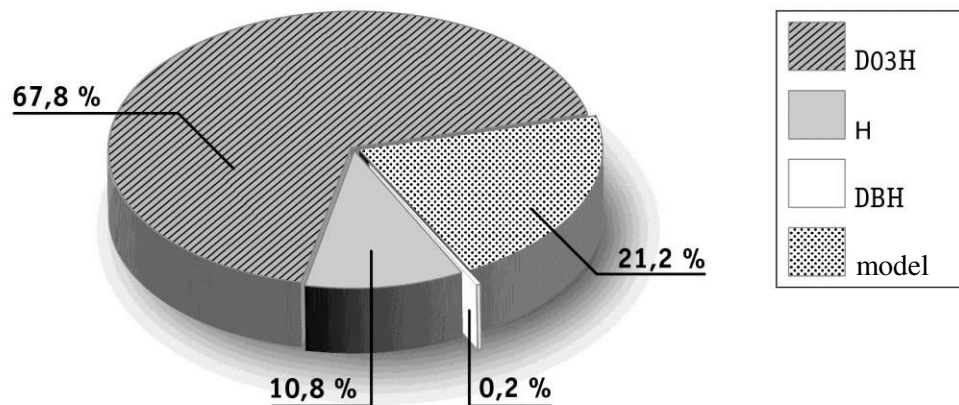
$$V_{Stem} = \frac{\pi}{4} \cdot DBH^2 \cdot H \cdot f(DBH, H, D03H, HK)$$

- volume = cylinder * form factor function
- coefficients in the form factor function are determined by linear regression
- different functions for different species

- Norway Spruce: $f = c_0 + c_1 \cdot \frac{D03H}{DBH} + c_2 \cdot \frac{H}{DBH} + c_3 \cdot \frac{1}{DBH}$

Sources of Uncertainty

conifers



variable	average SD	contribution
<i>d03h</i>	6.1 %	67.8%
<i>h</i>	3.3 %	10.8%
<i>dbh</i>	1.1 %	0.2%

Upper Diameter Dilemma

- Contains a lot of information about the stem shape, improves the models
- Difficult to measure (relascope)
 - Takes a long time
 - Expensive
 - Imprecise

Measuring and modelling D03H

- Measure D03H when tree grows into angle count sample ($DBH \geq 10.5$ cm)
- Measure D03H only on subsample of trees that are already in the sample
- Measure DBH on every tree
- Create D03H model which uses initial D03H and DBH at both inventory periods

Model for D03H

- Two step approach
- Linear regression model:

$$D03H_1 = b_0 + b_1 \cdot DBH_1 + b_2 \cdot DBH_1^2 + b_3 \cdot \frac{D03H_0}{DBH_0}$$

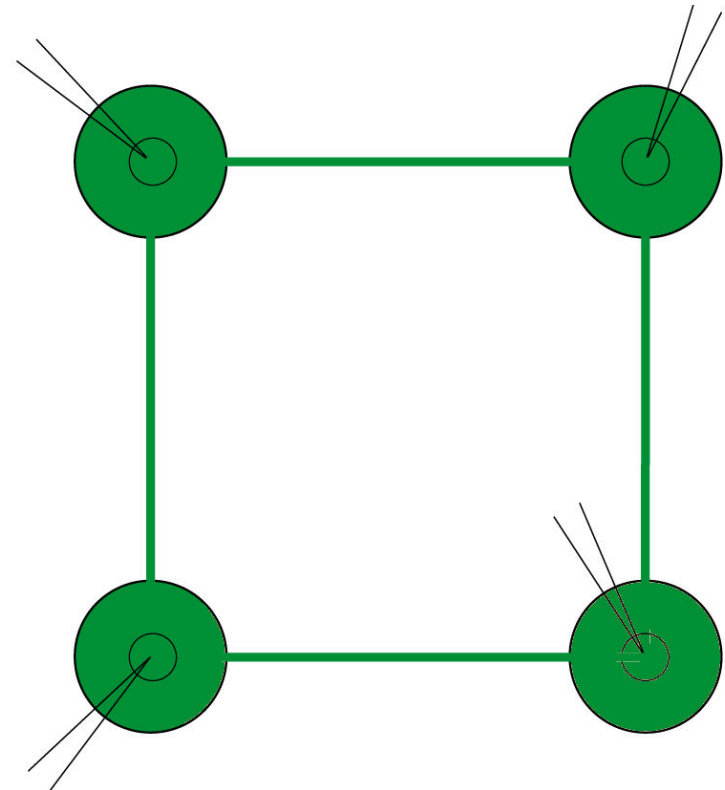
- Corrected model for avoiding multi-collinearities:

$$D03H_1 = b_0 + b_1 \cdot (DBH_1 - max)^2 + b_2 \cdot \frac{D03H_0}{DBH_0}$$

- *max* from first derivative (DBH) of first model

Available Data

- Regular square shaped grid of clusters ("tracts") with 3.89 km distance
- Permanent since NFI 3 (1981-1985)
- Four plots per cluster; called 00, 08, 16, 24
- Underlying cluster of 32 plots

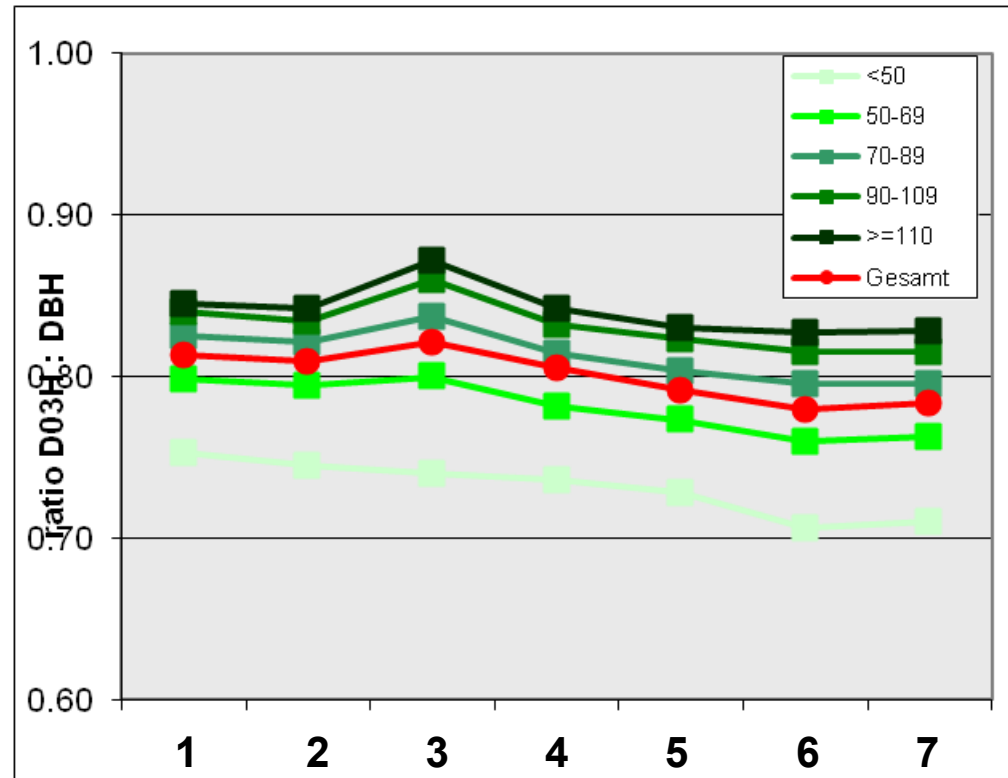


Data Difficulties

- NFI 3: Start of permanent grid, all D03H measured
- NFI 3: D03H measured with tele-relascope
- NFI 4: Measured D03H almost exclusively on Plot 04
- Pairs for investigation:
 - NFI 3 – NFI 7: Different (biased) instrument
 - NFI 4 – NFI 7: Almost no pairs
 - NFI 5 – NFI 7: Only one NFI in-between

Data Difficulties

ratio D03H : DBH over time by H/D classes

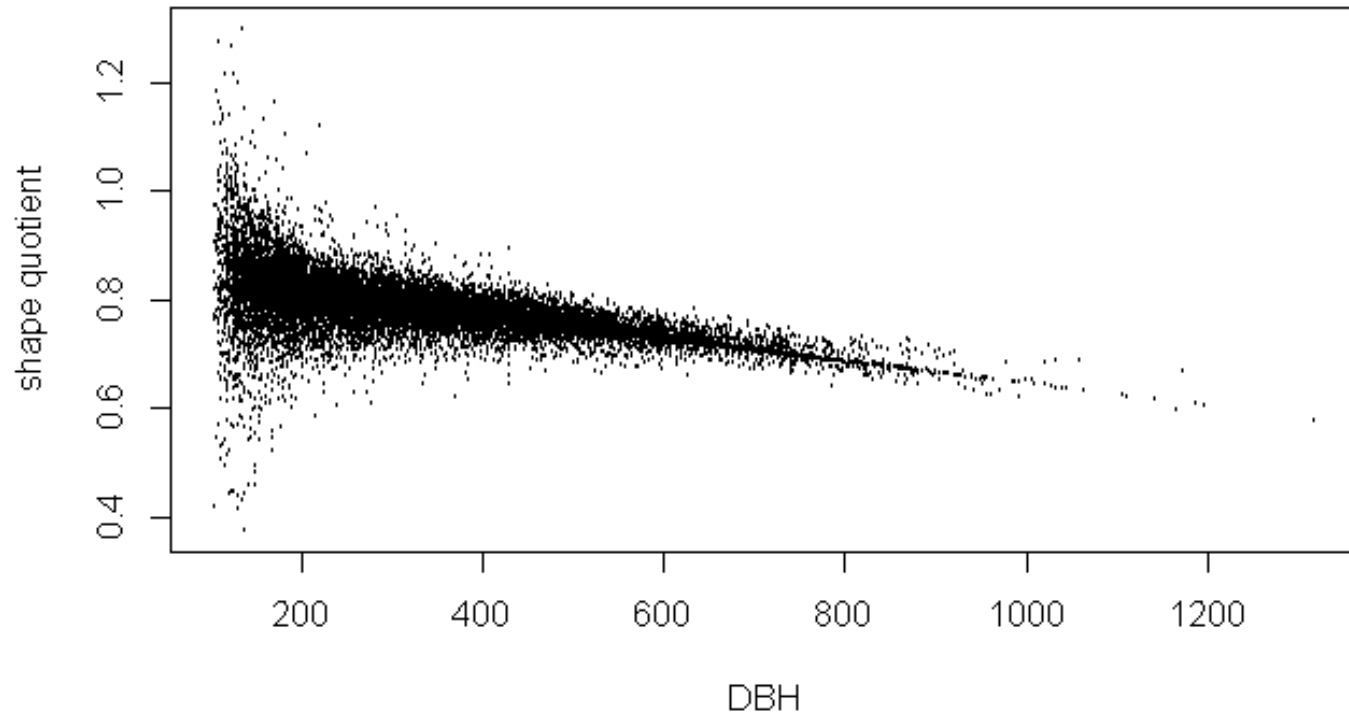


Inventory period

Effects of Modelling 1

- Data from NFI 7
- Smoothing effect

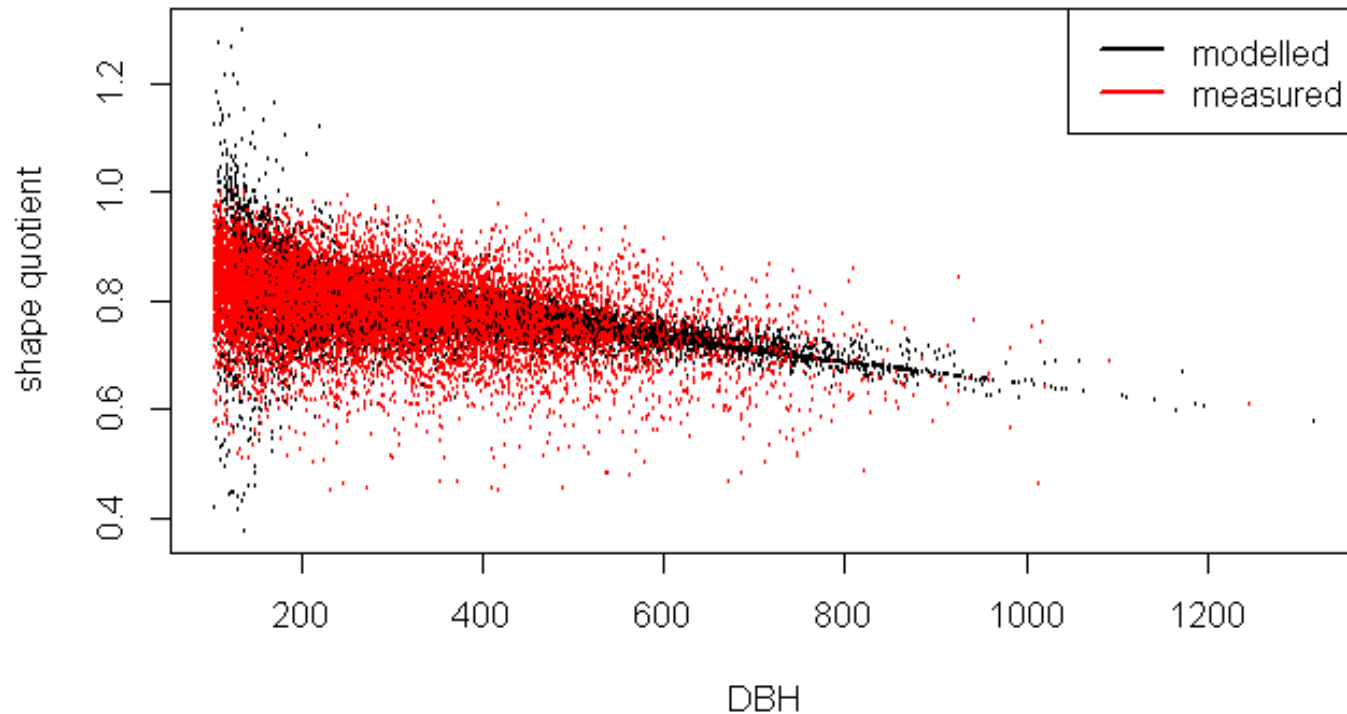
Shape Quotient over DBH



Effects of Modelling 1

- Data from NFI 7
- Smoothing effect

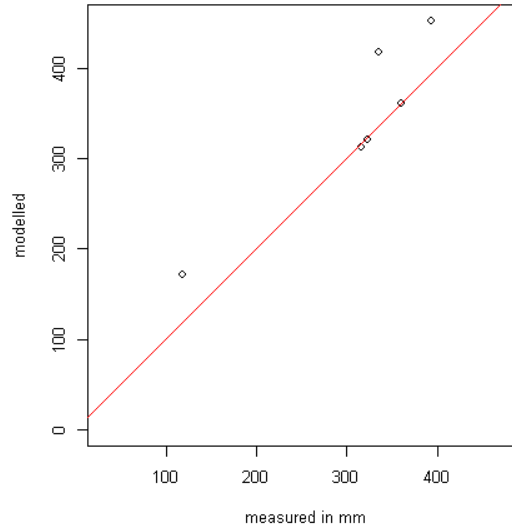
Shape Quotient over DBH



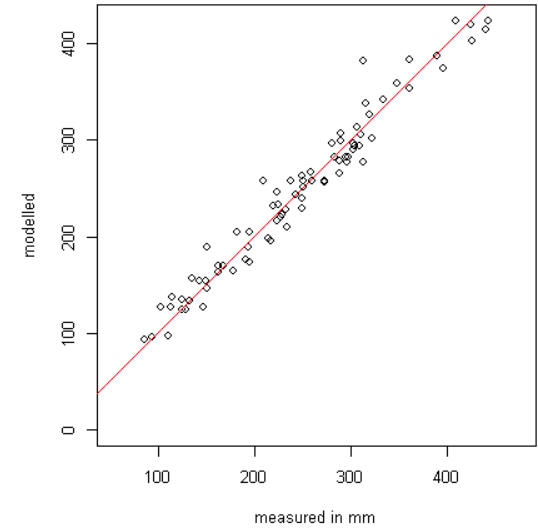
Effects of Modelling 2

- Systematic Deviations?

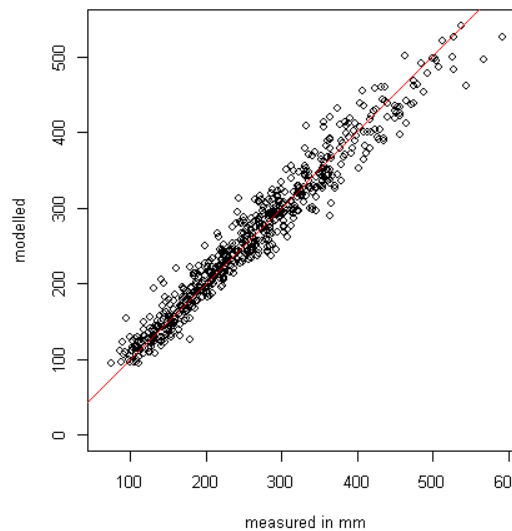
D03H modelled vs measured, NFI 4



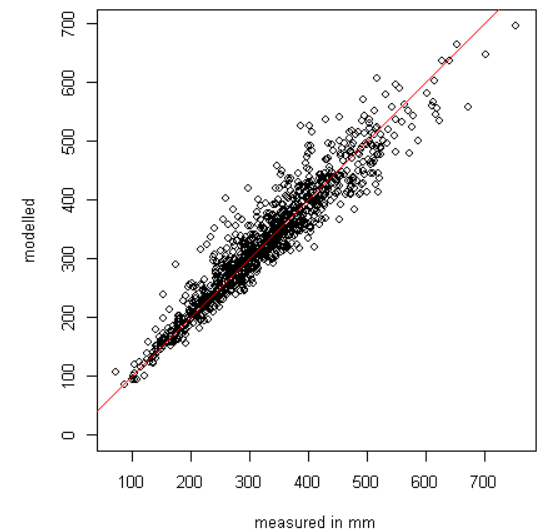
D03H modelled (from NFI 3) vs measured, NFI 5



D03H modelled (from NFI 3) vs measured, NFI 6

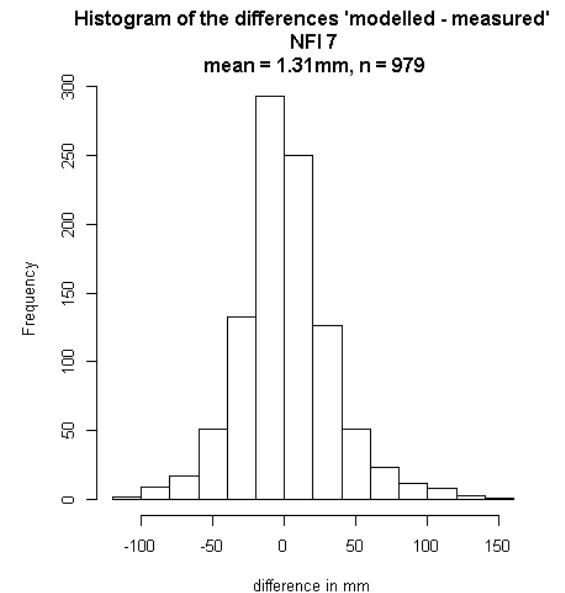
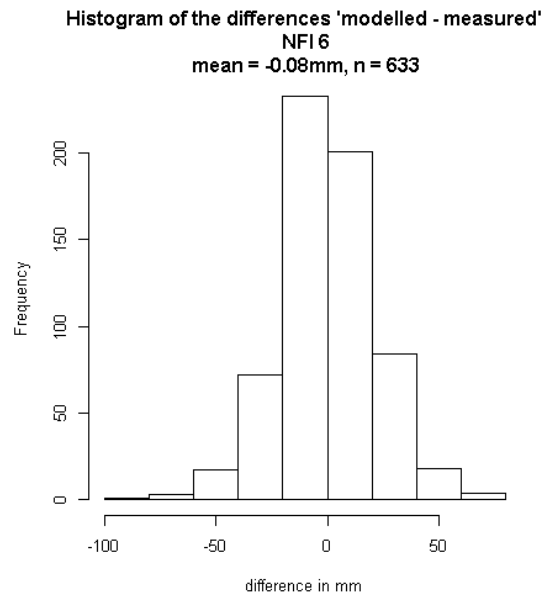
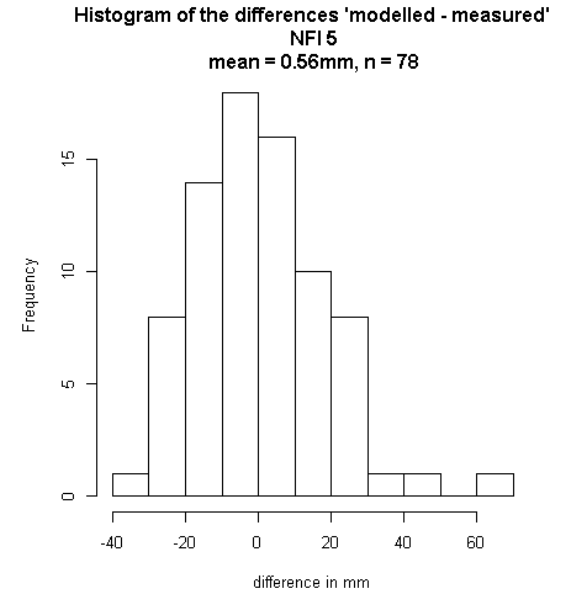
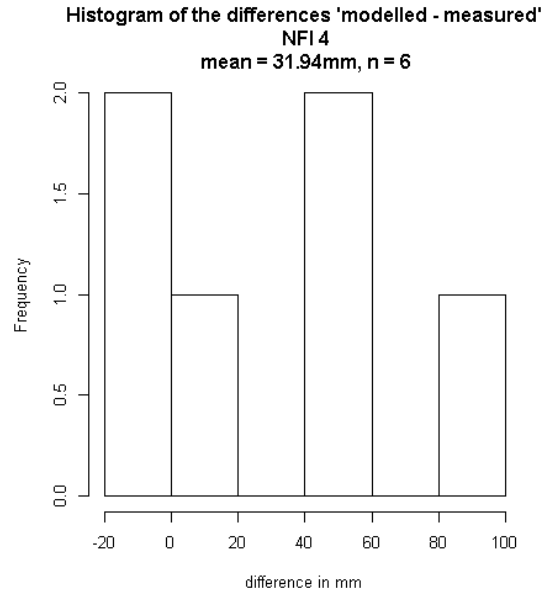


D03H modelled (from NFI 3) vs measured, NFI 7



Effects of Modelling 2

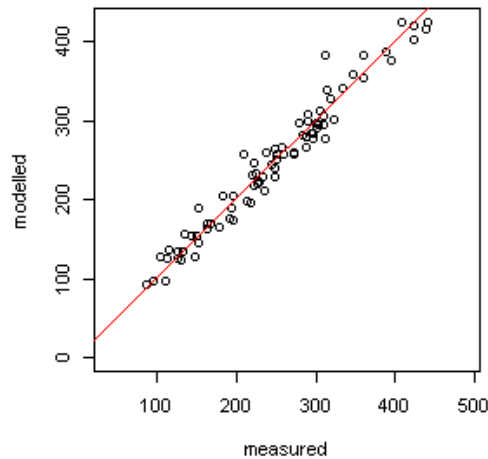
- Systematic Deviations?



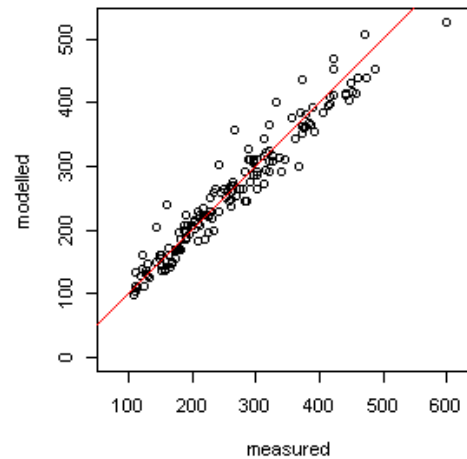
Effects of Modelling 2

- Starting at NFI 4

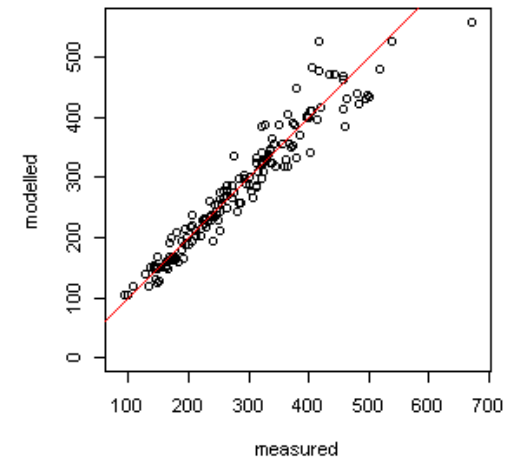
D03H modelled (from NFI 4) vs measured, NFI 5



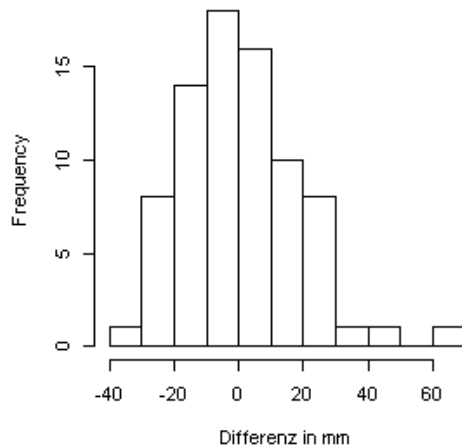
D03H modelled (from NFI 4) vs measured, NFI 6



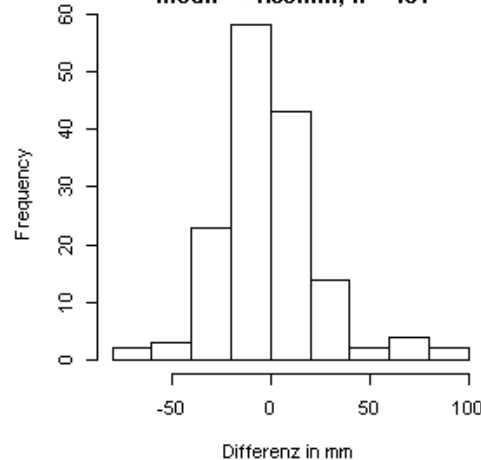
D03H modelled (from NFI 4) vs measured, NFI 7



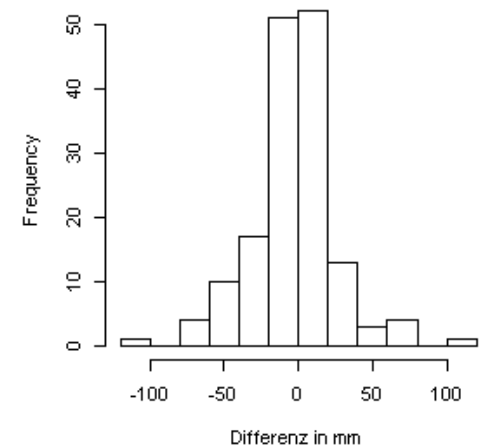
Histogram of the differences 'modelled-measured', NFI 5
mean = 0.56mm, n = 78



Histogram of the differences 'modelled-measured', NFI 6
mean = -1.08mm, n = 151



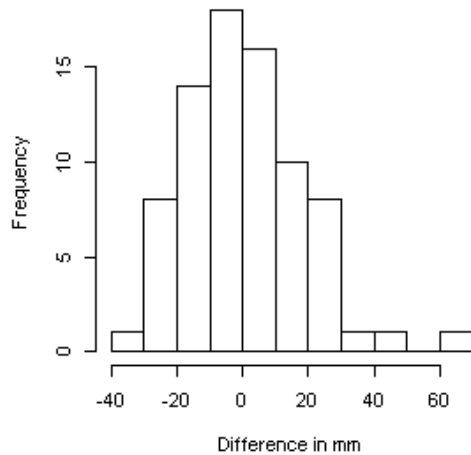
Histogram of the differences 'modelled-measured', NFI 7
mean = -2.36mm, n = 156



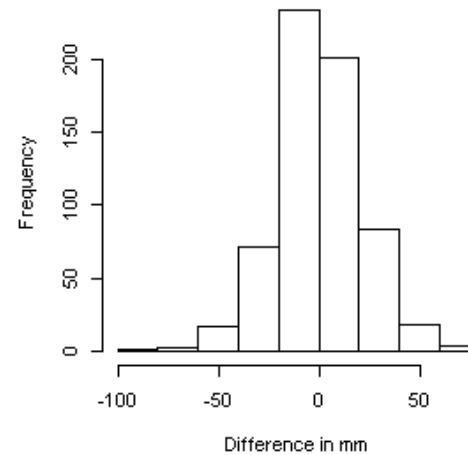
Effects of Modelling 2

- Starting at NFI 4, relative differences

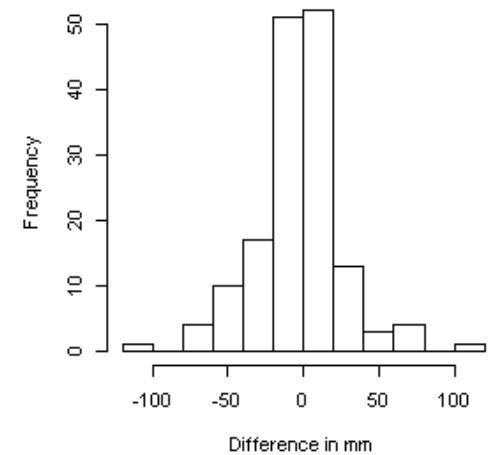
Histogram of the differences
'modelled-measured', NFI 5
mean = 0.56mm, n = 78



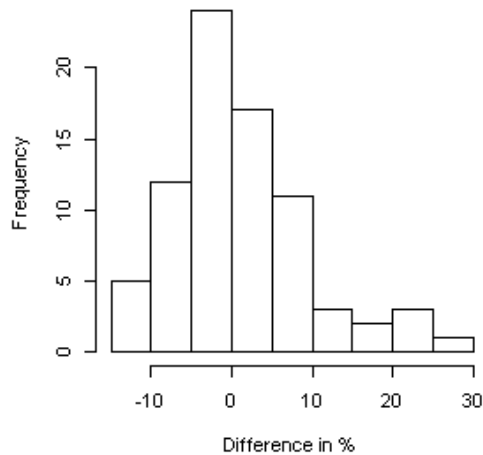
Histogram of the differences
'modelled-measured', NFI 6
mean = -0.08mm, n = 633



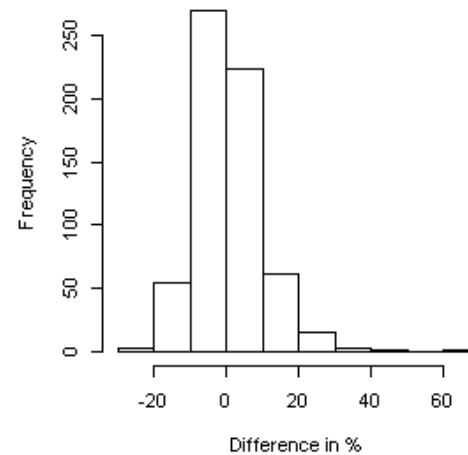
Histogram of the differences
'modelled-measured', NFI 7
mean = -2.36mm, n = 156



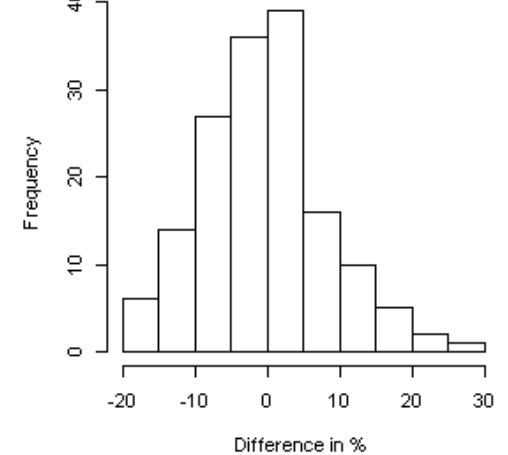
Histogram of the relative differences
'modelled-measured', NFI 5
mean = 1.03%, n = 78



Histogram of the relative differences
'modelled-measured', NFI 6
mean = 0.89%, n = 633



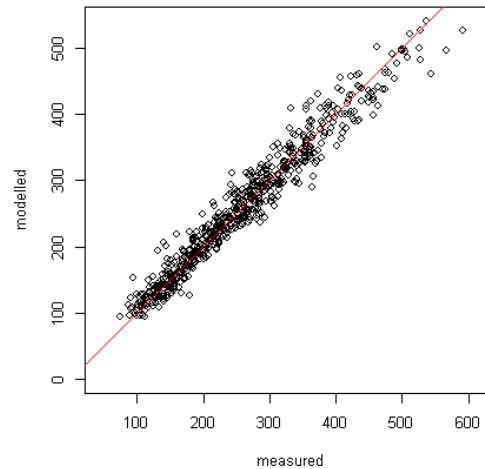
Histogram of the relative differences
'modelled-measured', NFI 7
mean = -0.38%, n = 156



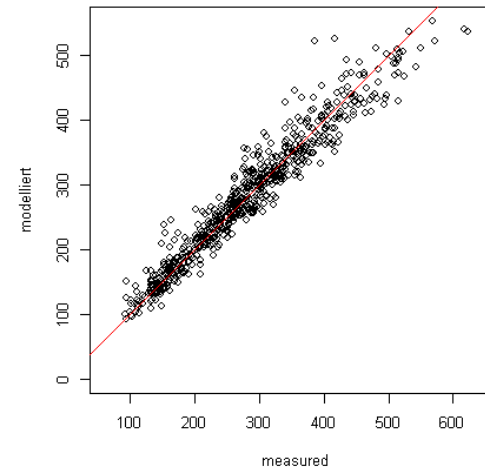
Effects of Modelling 2

- Starting at NFI 5

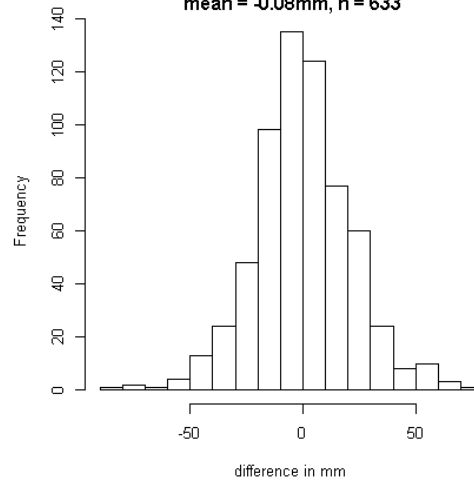
D03H modelled (from NFI 5) vs measured, NFI 6



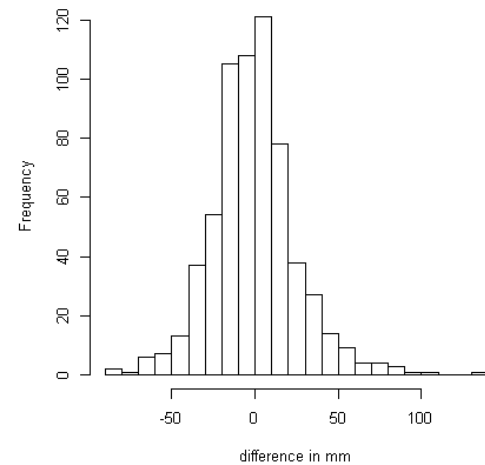
D03H modelled (from NFI 5) vs measured, NFI 7



Histogram of the differences
'modelled-measured', NFI 6
mean = -0.08mm, n = 633

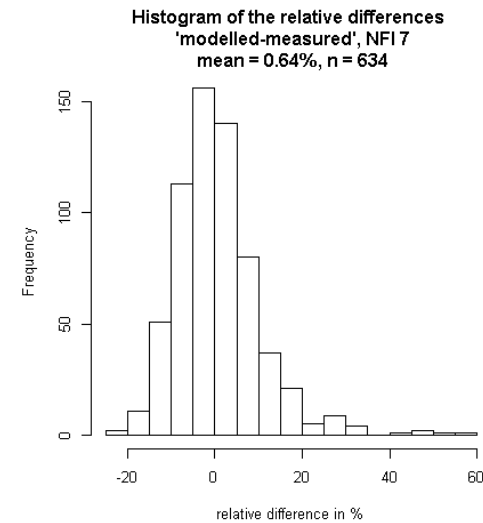
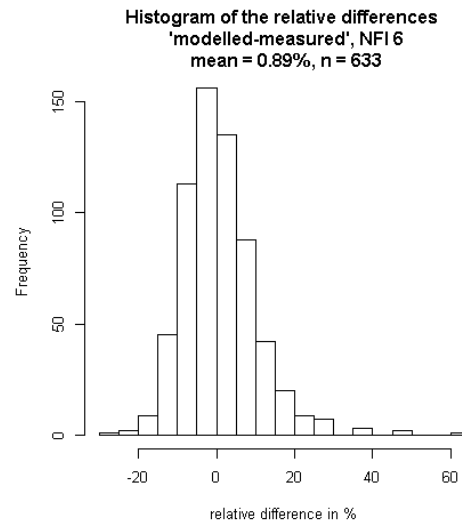
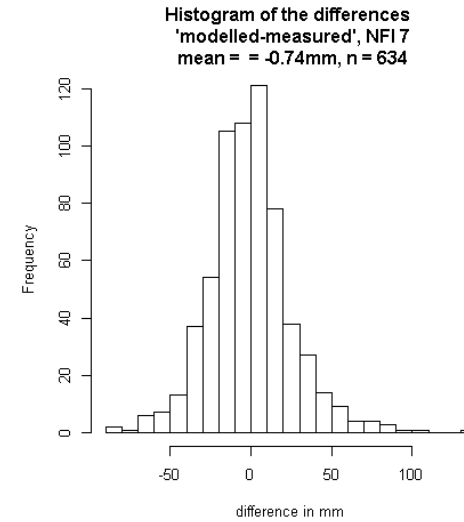
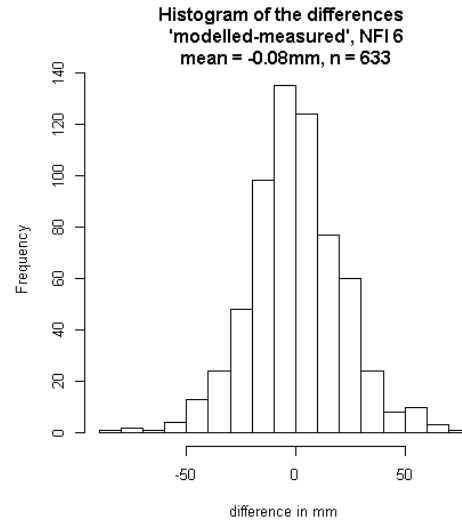


Histogram of the differences
'modelled-measured', NFI 7
mean = -0.74mm, n = 634



Effects of Modelling 2

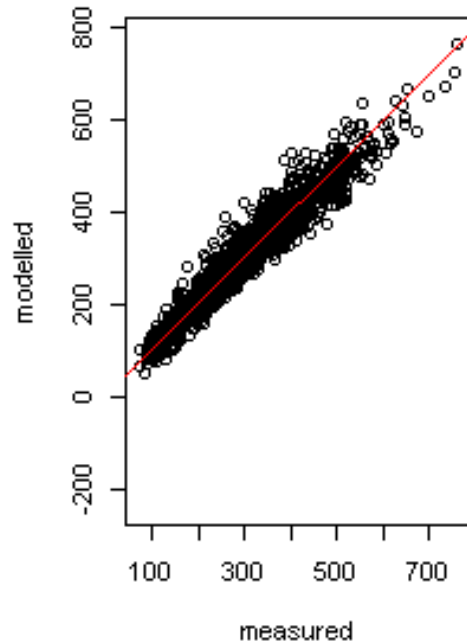
- Starting at NFI 5



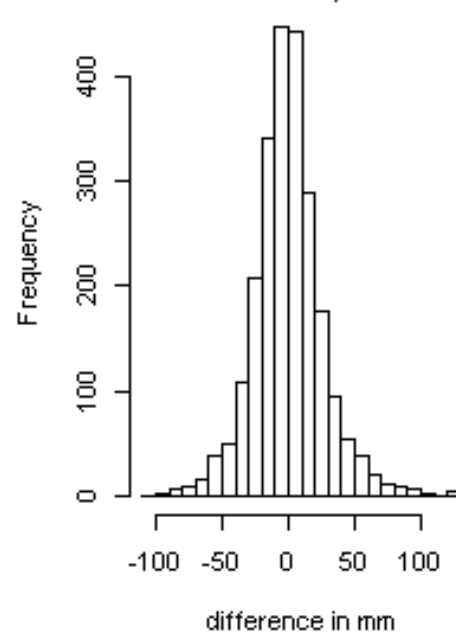
Effects of Modelling 2

- Starting at NFI 6, fits a lot better
 - Model and application on same stems
 - Model applied only once
 - Time difference only 7 years

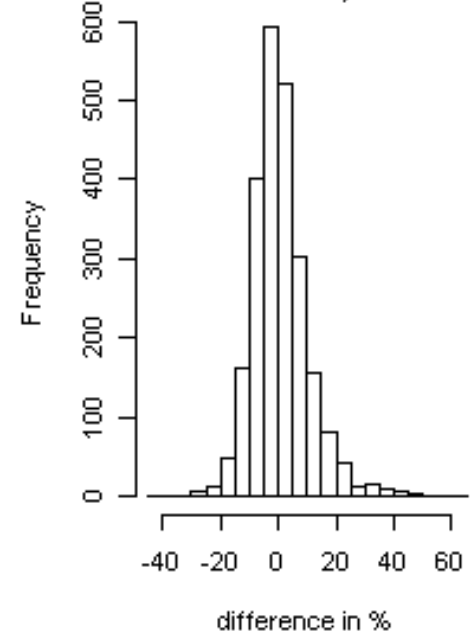
D03H modelled vs measured,
NFI 7



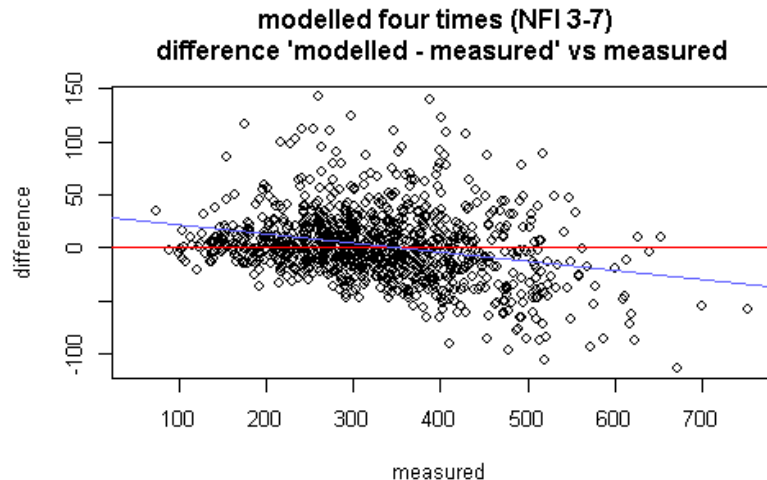
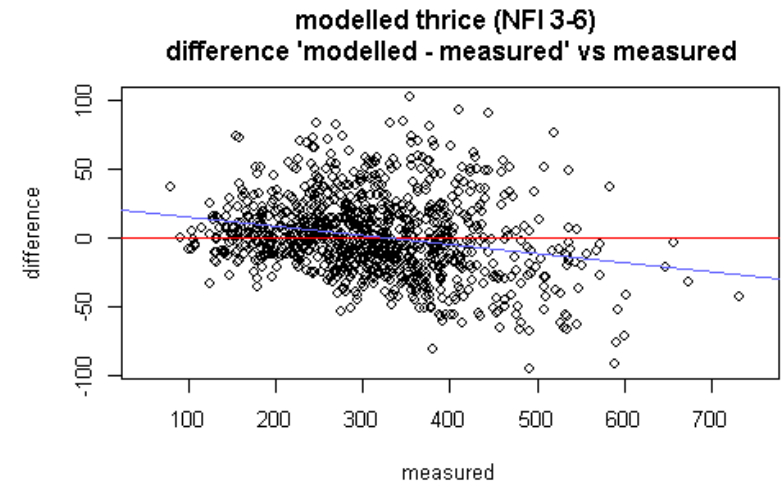
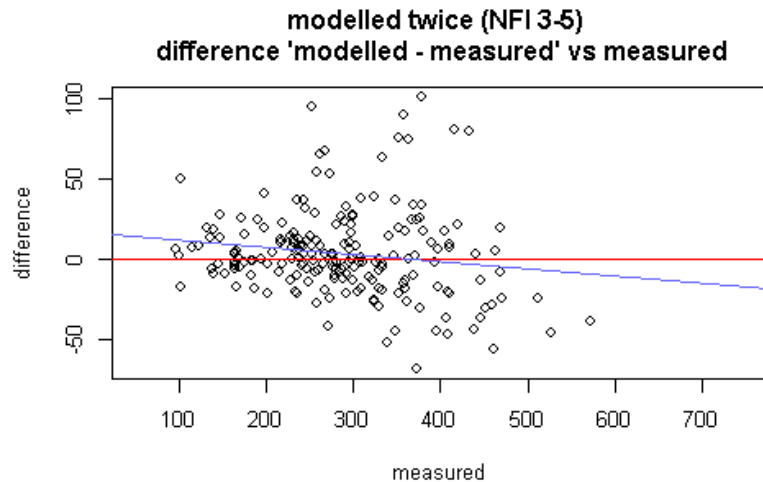
Histogram of the differences
'modelled-measured', NFI 7
mean = 0mm, n = 2369



Histogram of the rel. differences
'modelled-measured', NFI 7
mean = 0.72%, n = 2369



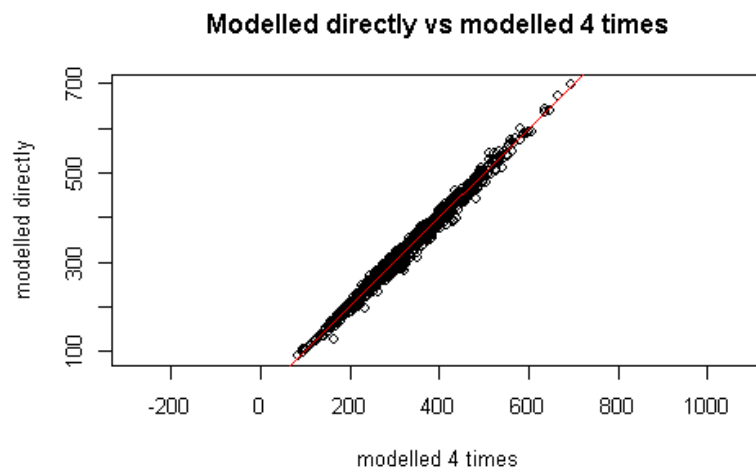
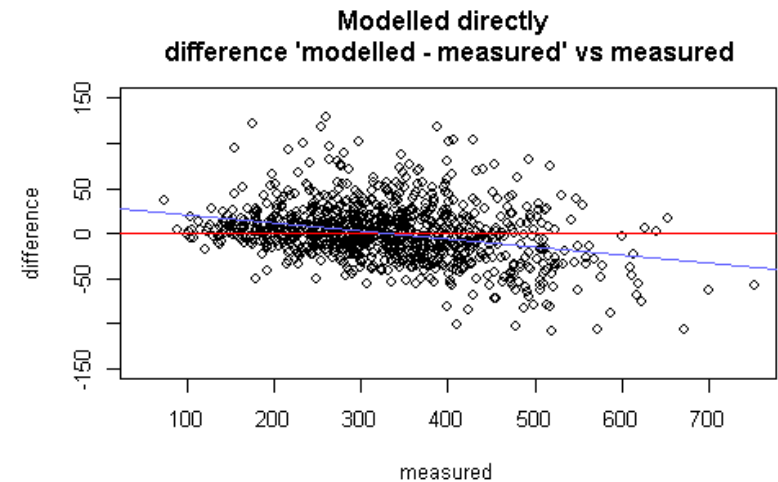
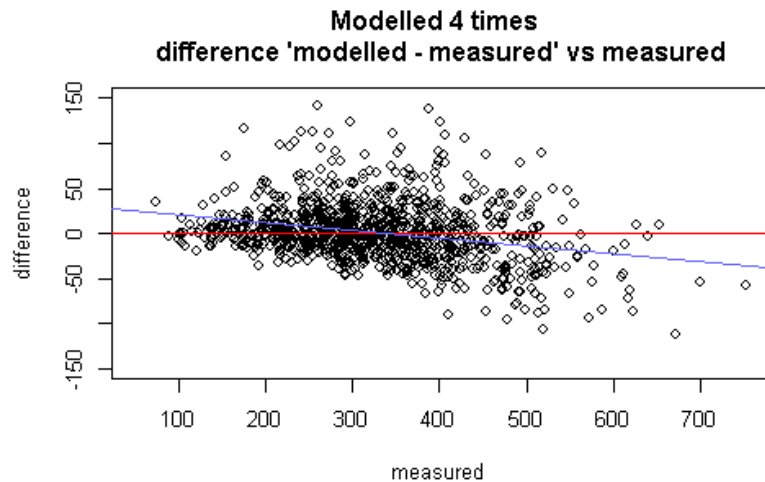
Estimation over multiple Periods



	NFI 3-5	NFI 3-6	NFI 3-7
Intercept	16.509	21.445	29.601
slope	-0.044	-0.065	-0.086

Stepwise Application vs direct

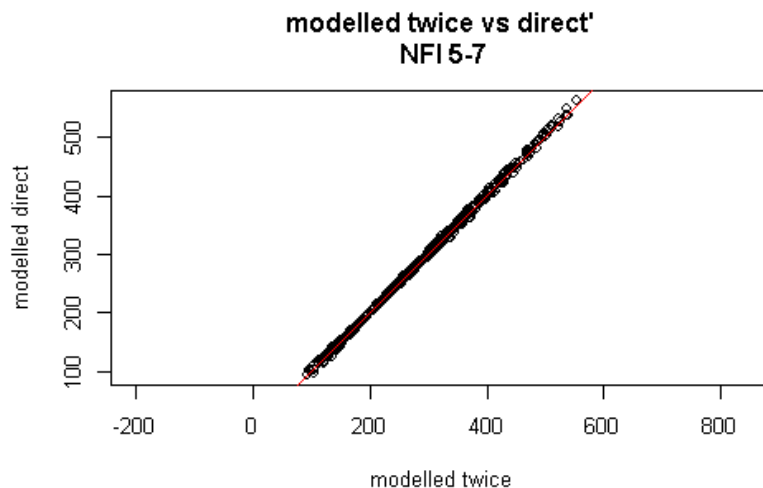
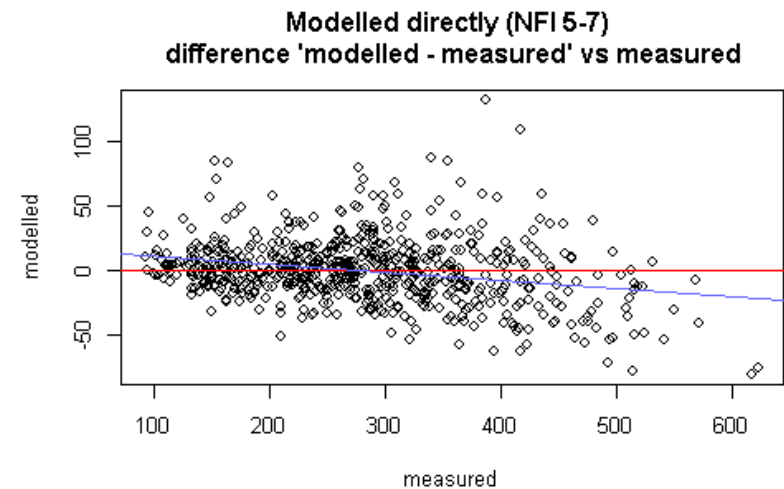
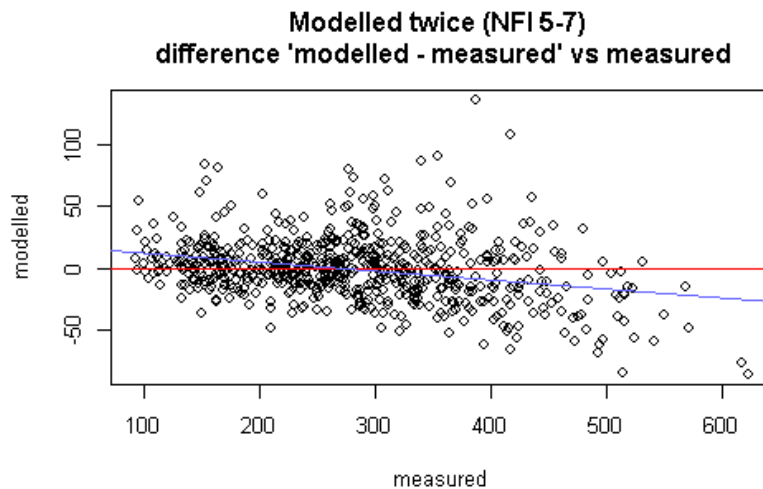
- NFI 3-7, almost identical results



	NFI 3-7 direct	NFI 3-7
Intercept	29.601	28.843
slope	-0.086	-0.087

Stepwise Application vs direct

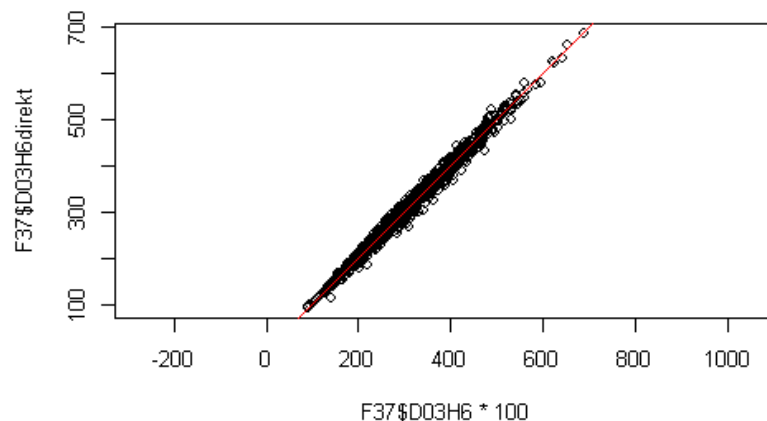
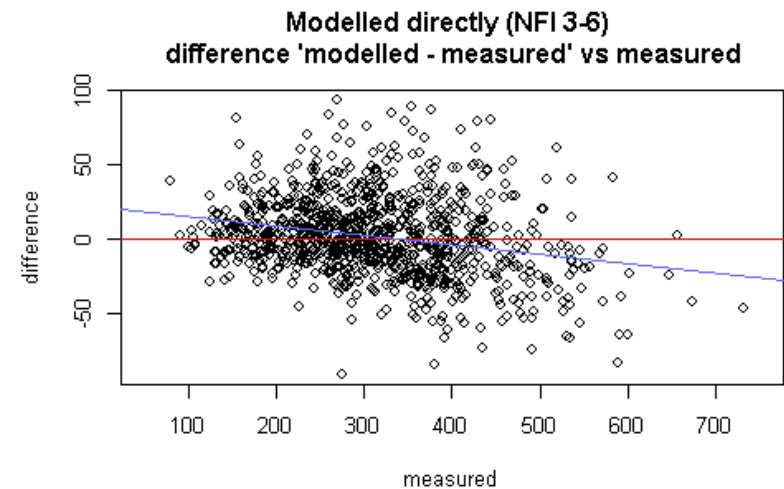
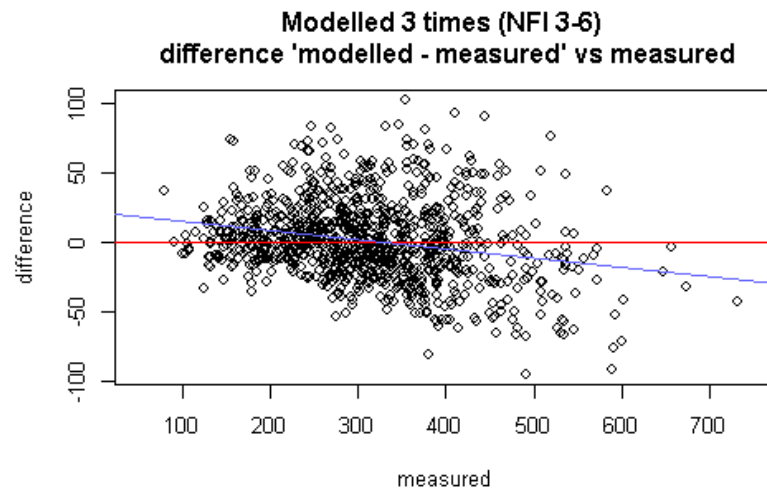
- NFI 5-7:



	NFI 5-7 direct	
Intercept	19.786	17.416
slope	-0.073	-0.062

Stepwise Application vs direct

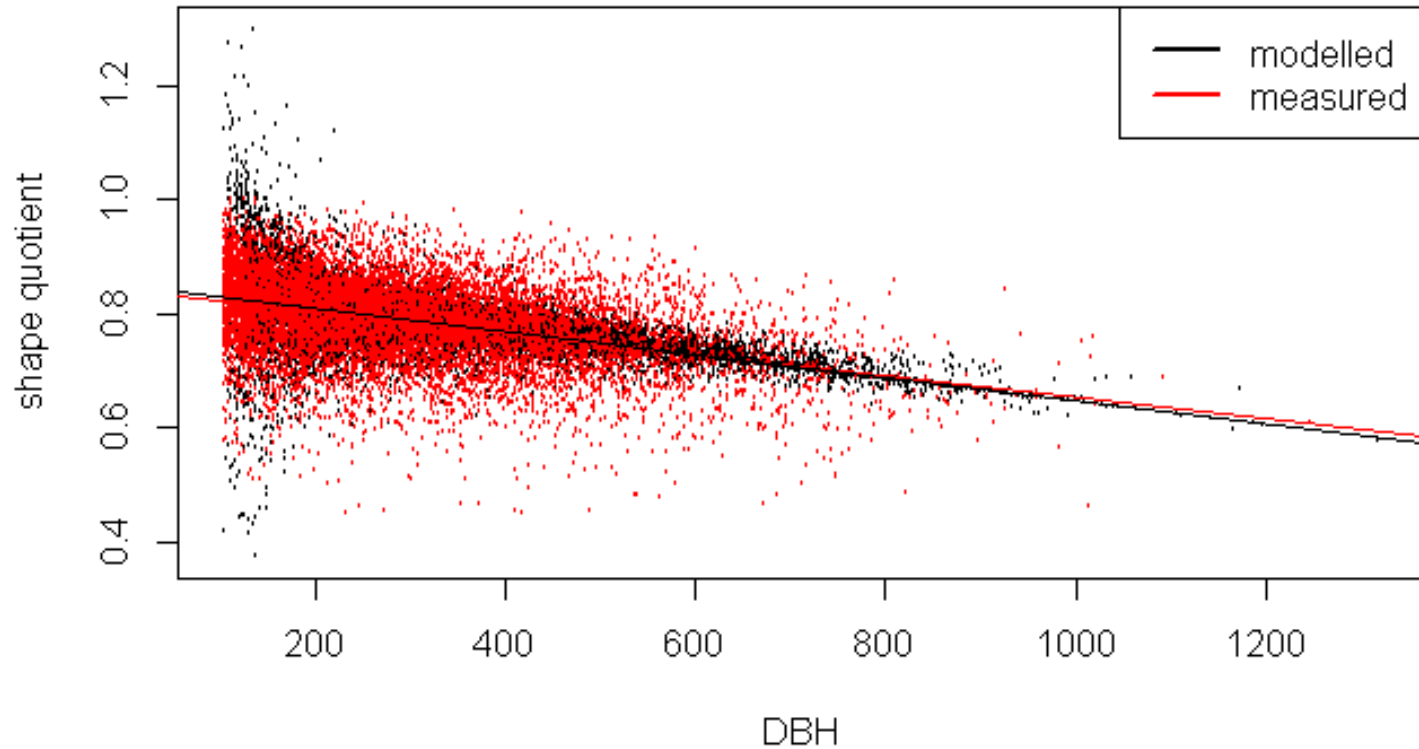
- NFI 3-6:



	NFI 3-6	direct
Intercept	21.445	21.292
slope	-0.065	-0.063

Effects of Modelling

Shape Quotient over DBH



	measured	modelled
Intercept	0.840773	0.850966
slope	-0.000186	-0.000204

Increase of Uncertainty

- First measurement has uncertainty
- Modelling process adds uncertainty
- Compare it to measured value in NFI 7 – this value contains uncertainty as well, ~5.5%
- Look at difference between modelled and measured – variances add

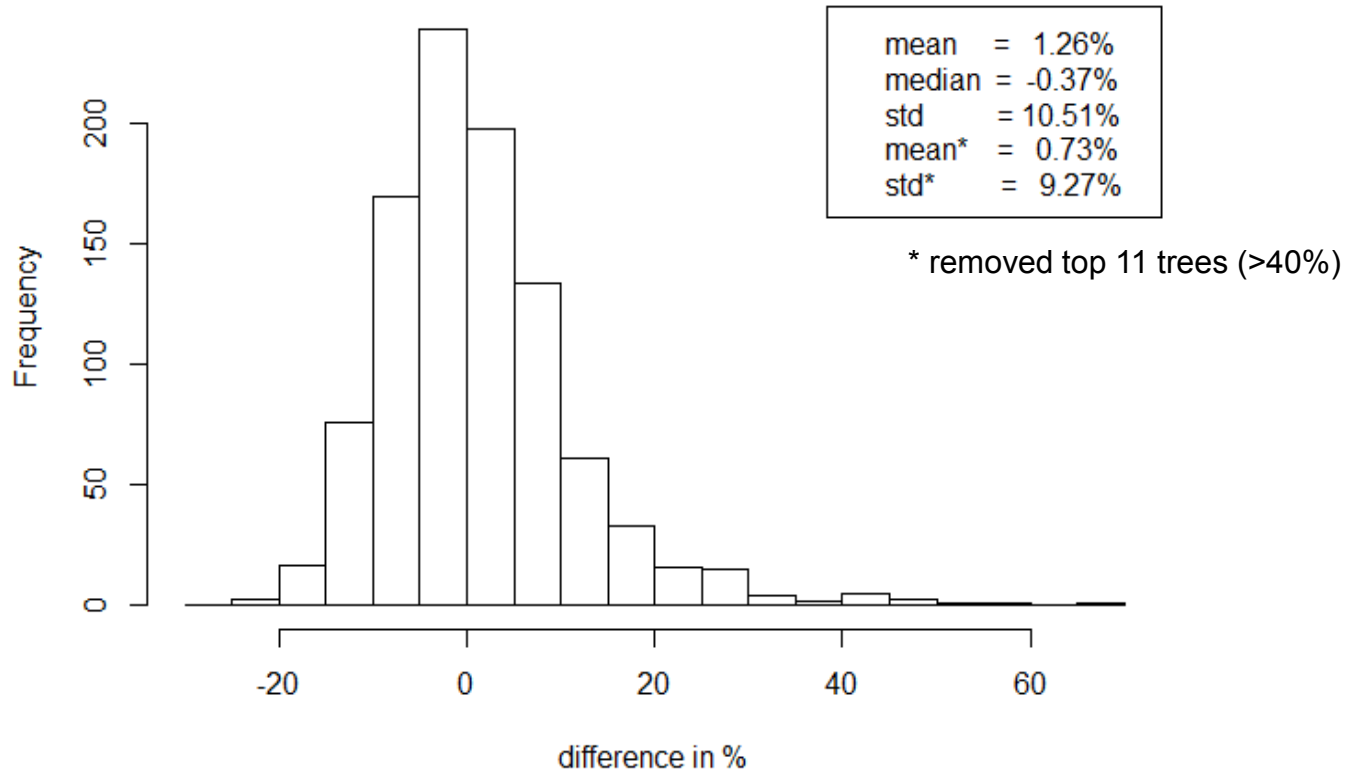
$$Var_{diff} = Var_{mod} + Var_{meas}$$

$$Var_{mod} = Var_{diff} - Var_{meas}$$

Increase of Uncertainty

NFI 3-7

Histogram of relative differences
modelled - measured, NFI 3-7

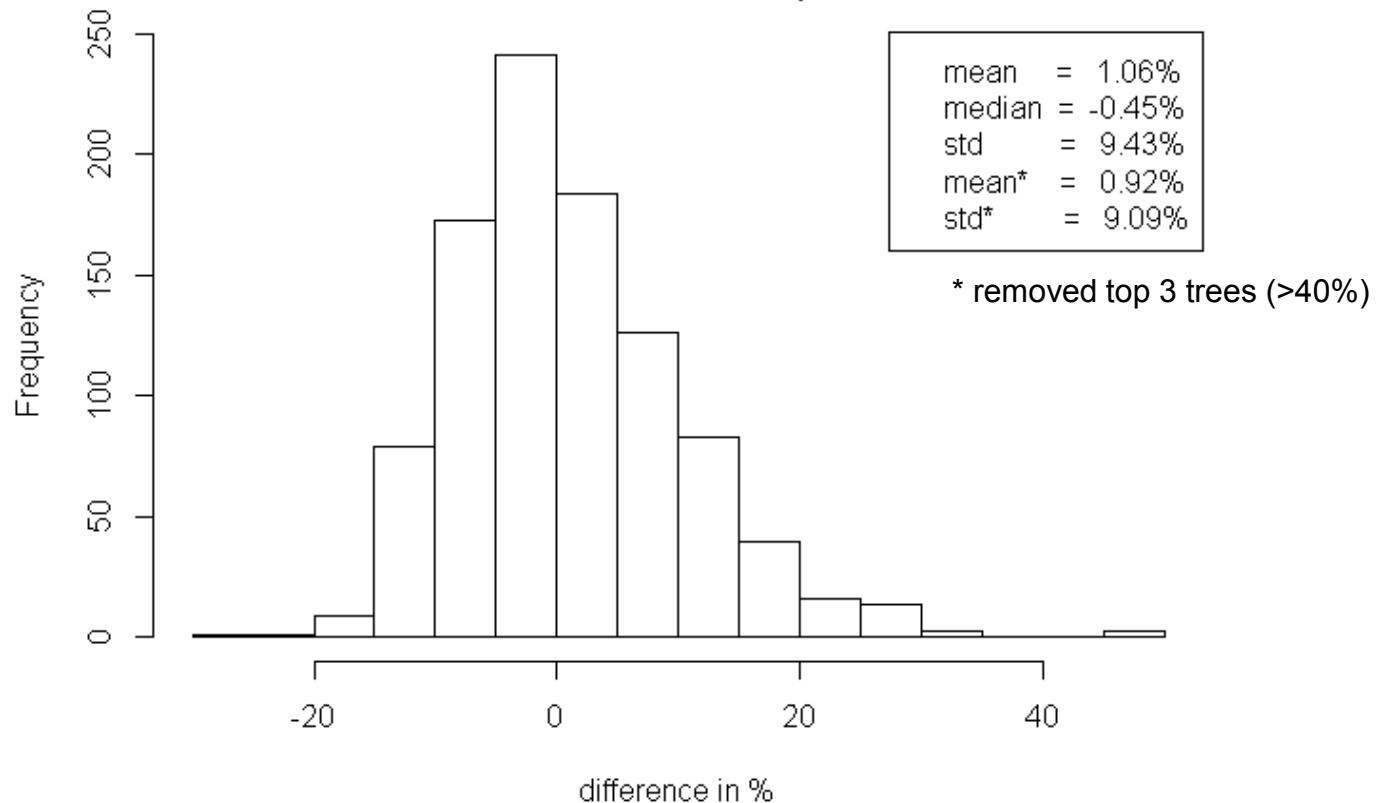


std of D03H measured	5.50%
std of D03H modelled	8.96%
std* of D03H modelled	7.47%

Increase of Uncertainty

NFI 3-6

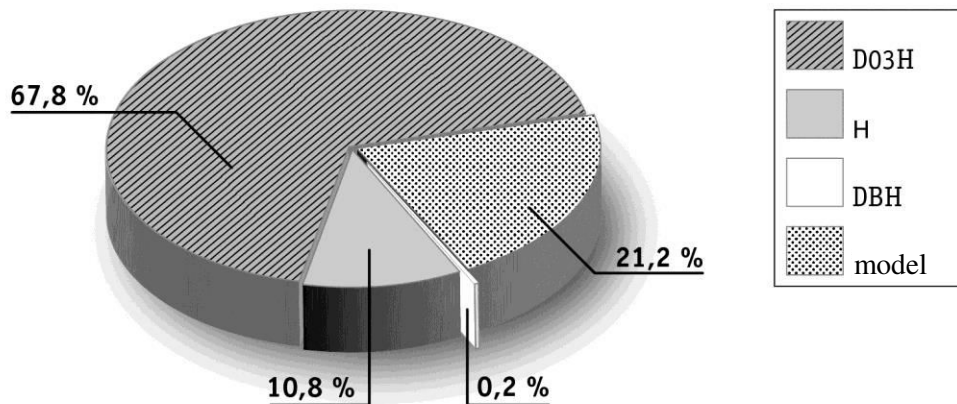
Histogram of relative differences
modelled - measured, NFI 3-6



std of D03H measured	5.50%
std of D03H modelled	7.66%
std* of D03H modelled	7.23%

Sources of Uncertainty

conifers

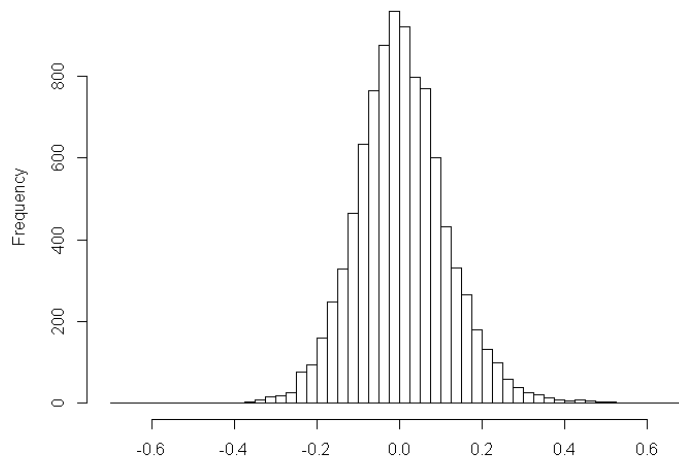


variable	average SD	contribution
<i>d03h</i>	6.1 %	67.8%
<i>h</i>	3.3 %	10.8%
<i>dbh</i>	1.1 %	0.2%

Stem Volume

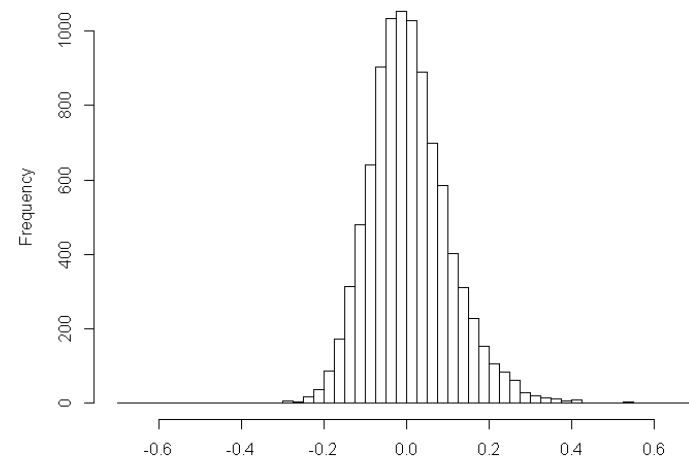
- Uncertainty of stem volume is about equal for model with and without upper diameter ($\sim 10\%$ std)
- Increased uncertainty of D03H: Lower uncertainty for model without upper diameter
- Residuals of model with upper diameter more symmetrical

Histogramm der relativen Residuen, mit D03H
Mittelwert = 0.00573 Median = 0.00086



with D03H

Histogramm der relativen Residuen, Modell ohne D03H
Mittelwert = 0.00733 Median = -0.00125



without D03H

Conclusion

- Keep measuring D03H
 - For stem volume model
 - For trends
- Can't measure all D03H (too expensive)
- Revise the model / the modelling procedure?
- Model error or change in growth (climate, management,...)?



Thank you for your attention!