# INDIVIDUAL TREE CROWN PROJECTION AREA MODELS BASED ON THE DATA OF NATIONAL FOREST INVENTORY OF THE CZECH REPUBLIC

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# Introduction

- Individual tree crown projection area is an important part of many forest models, e.g. estimation of tree biomass, species composition, canopy or natural regeneration (estimation of seed production).
- Models made in this project will be used especially for estimation of species composition in CZNFI on the levels of the whole state and selected administrative regions.

# Data

- Data were collected on 7 772  inventory plots of CZNFI2 network (second period of inventory 2011 – 2015)
- Totally 32 650 trees
  - 22 873 with DBH above 7 cm
  - 9 777 with DBH below 7 cm
- 8 main species – Norway spruce, beech, Scots pine, European larch, pedunculate oak, sessile oak, black alder, silver birch

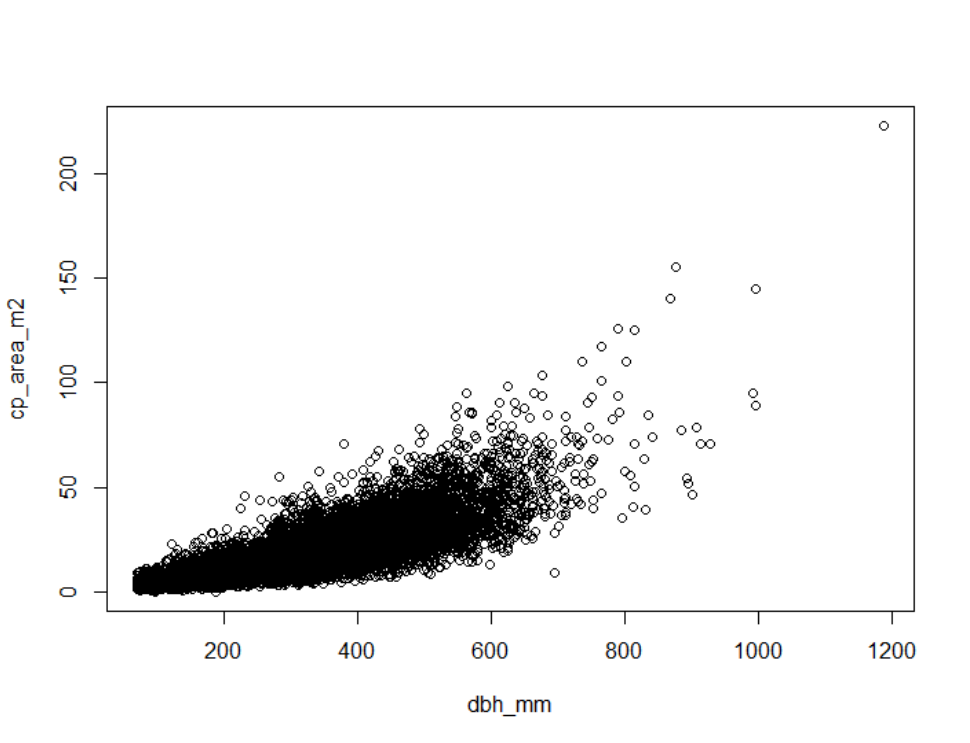
# Results – DBH > 7 cm over bark

- Data structure

| pname | segment_id | stem_id | dbh_mm | height_m | age | cp_area_m2 | species | iufro_height | stem_break | twin_stem | vegetative_origin |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011_1_16_36_21 | 2011_1_16_36_21_12472 | 1 | 321 | 29.04 | 64 | 36.671617 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_36_21 | 2011_1_16_36_21_12472 | 7 | 385 | 29.25 | 64 | 31.500193 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_36_21 | 2011_1_16_36_21_12472 | 8 | 360 | 29.54 | 64 | 20.226435 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_36_21 | 2011_1_16_36_21_12472 | 11 | 335 | 30.04 | 64 | 21.974423 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_36_21 | 2011_1_16_36_21_12472 | 12 | 298 | 29.05 | 64 | 17.866600 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_57_18 | 2011_1_16_57_18_16330 | 4 | 228 | 26.75 | 50 | 5.420961 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_57_18 | 2011_1_16_57_18_16330 | 5 | 226 | 27.47 | 50 | 3.711379 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_57_18 | 2011_1_16_57_18_16330 | 13 | 134 | 20.54 | 50 | 2.323745 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_57_18 | 2011_1_16_57_18_16330 | 14 | 138 | 17.93 | 50 | 2.686605 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_57_18 | 2011_1_16_57_18_16330 | 15 | 339 | 28.09 | 50 | 10.046871 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_57_18 | 2011_1_16_57_18_16330 | 26 | 274 | 26.94 | 50 | 6.472146 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_57_18 | 2011_1_16_57_18_16330 | 28 | 99 | 16.89 | 50 | 1.998953 | smrk ztepily | stredni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_71_29 | 2011_1_16_71_29_12367 | 5 | 288 | 14.11 | 35 | 11.645127 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_79_17 | 2011_1_16_79_17_15934 | 1 | 427 | 29.42 | 113 | 16.565964 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_79_17 | 2011_1_16_79_17_15934 | 14 | 490 | 33.19 | 113 | 14.540185 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_16_83_24 | 2011_1_16_83_24_12152 | 11 | 284 | 18.87 | 30 | 24.653141 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_2_100_17 | 2011_1_2_100_17_11786 | 6 | 509 | 32.94 | 118 | 24.822583 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_2_100_17 | 2011_1_2_100_17_11786 | 19 | 598 | 34.16 | 118 | 41.143093 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_2_100_17 | 2011_1_2_100_17_11786 | 20 | 544 | 33.39 | 118 | 31.612825 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |
| 2011_1_2_100_19 | 2011_1_2_100_19_11798 | 1 | 375 | 28.95 | 65 | 23.653966 | smrk ztepily | horni vrstva | bez poskozeni | strom neni rozdvojen do 1,3m | generativni puvod |

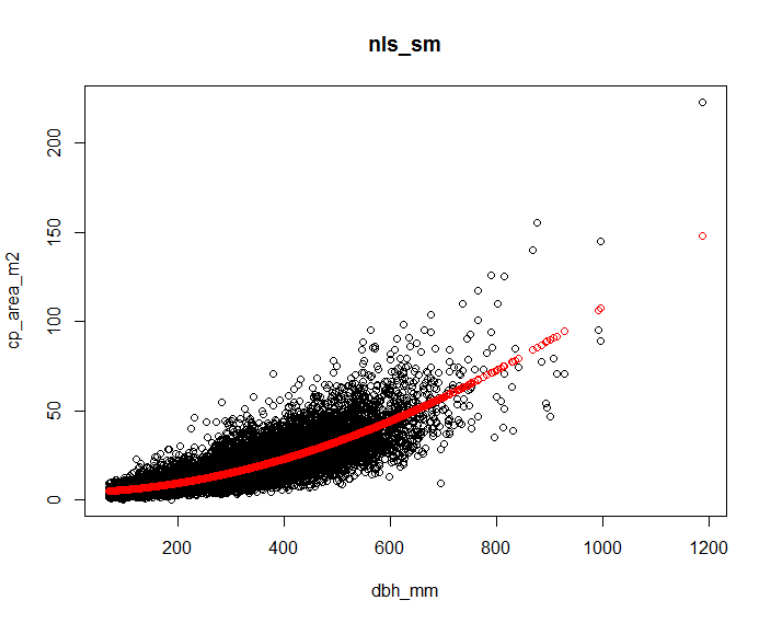
# Results – DBH > 7 cm over bark

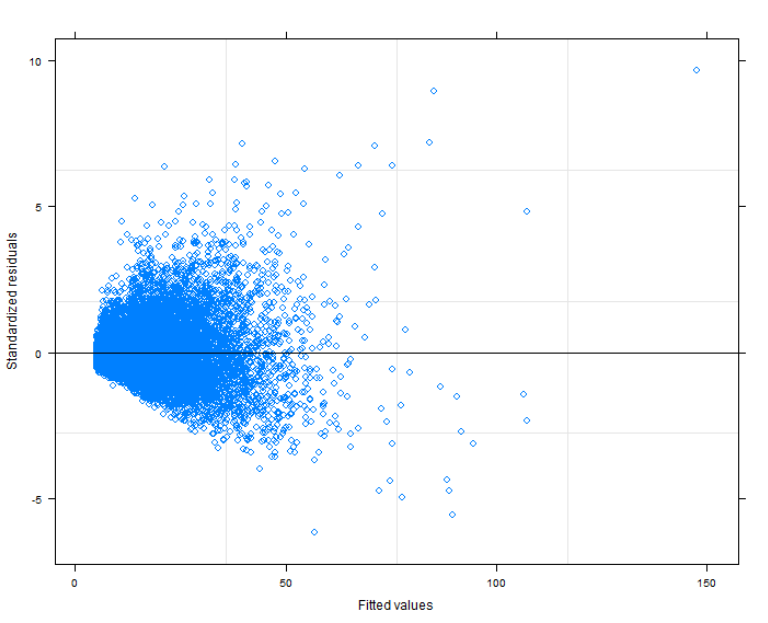
- Example of Norway spruce



# Results – DBH > 7 cm over bark

- Example of Norway spruce - nonlinear model - $Y=a+b*X^c$ - only fixed effect DBH
- AIC = 89 846.8



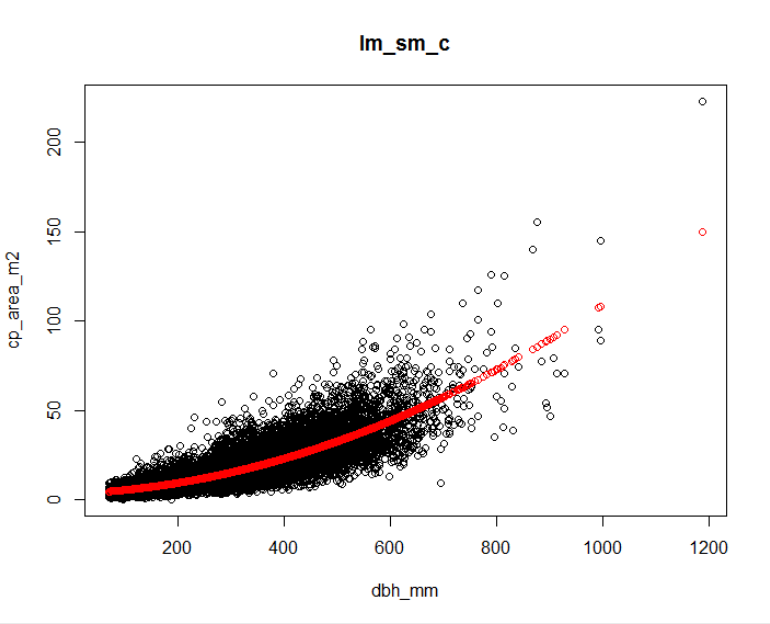
# Results – DBH > 7 cm over bark

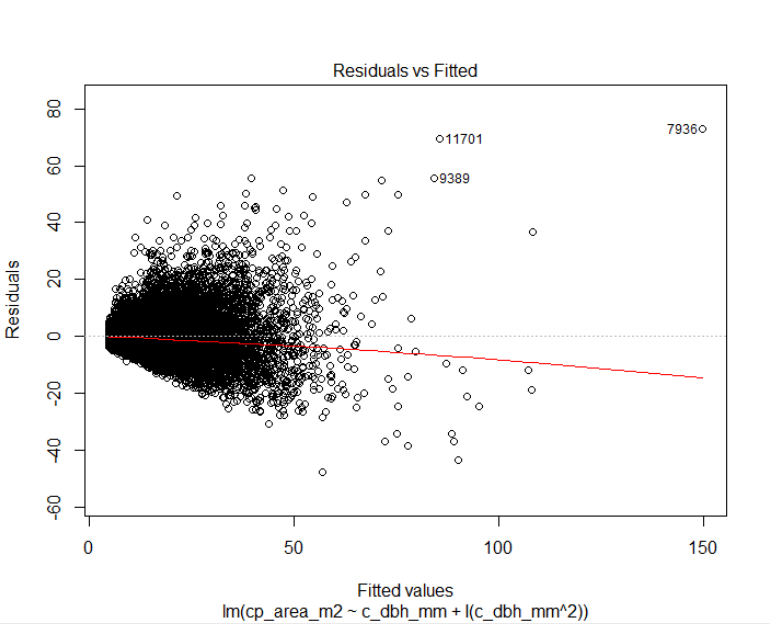
- Example of Norway spruce - nonlinear model $Y=a+b*X^c$ - mixed effects model
- Fixed effects - DBH, IUFRO height categories
- Random effects - segment of inventory plot - parameters a, c

- AIC = 81 023.3
- Problem with fixed effects parameters - high correlation (-0.999)

# Results – DBH > 7 cm over bark

- Example of Norway spruce - 2nd order polynomial model - only fixed effect DBH
- AIC = 89 835.2

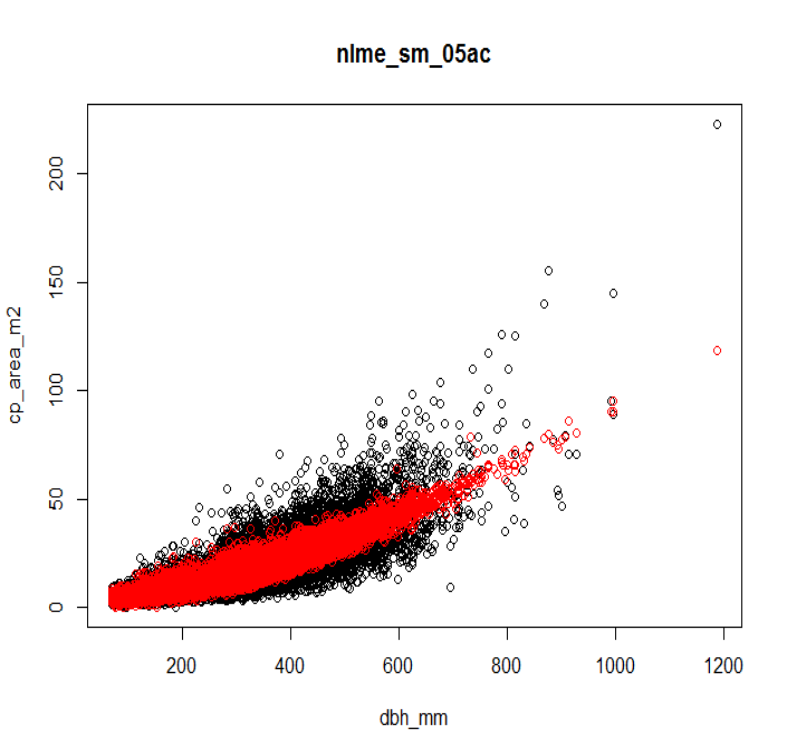


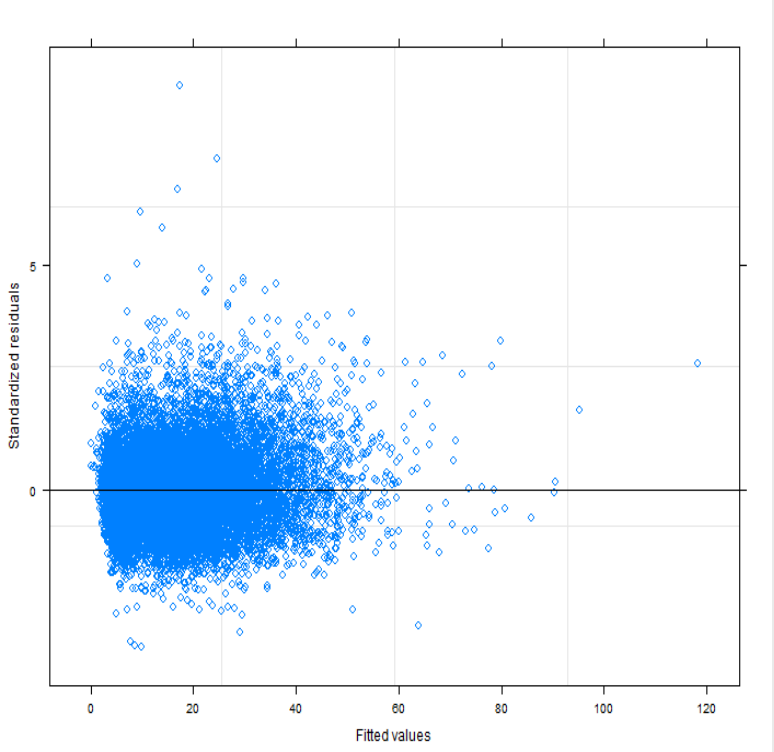



# Results – DBH > 7 cm over bark

- Example of Norway spruce - 2nd order polynomial mixed effects model
- Fixed effects - centred DBH, IUFRO height categories
- Random effects - segment of invetory plot - intercept only
- AIC = 80 986.9

# Results – DBH > 7 cm over bark



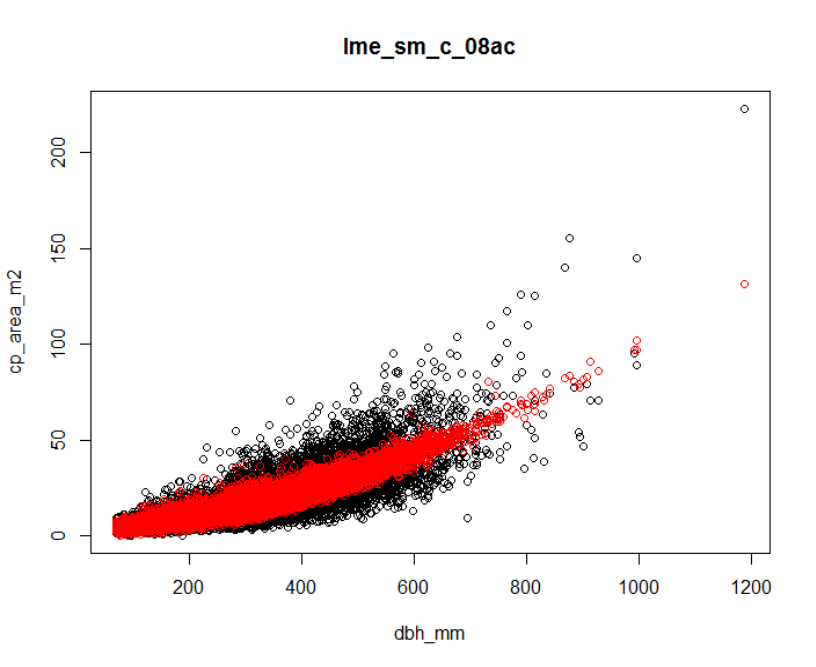



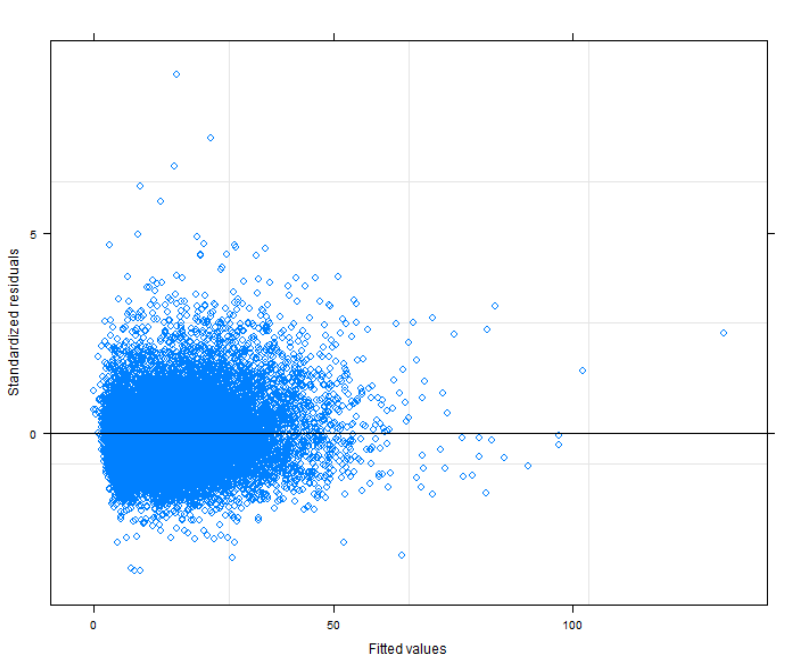
# Results – DBH > 7 cm over bark

All species

- **2nd order polynomial mixed effects model**
- Fixed effects
  - centred DBH
  - IUFRO height categories (only spruce, beech and pedunculate oak)
- Random effects
  - level - segment of inventory plot - different parameters
- Problem of heteroscedasticity - weight function - power function of IUFRO height categories

# Results – DBH > 7 cm over bark



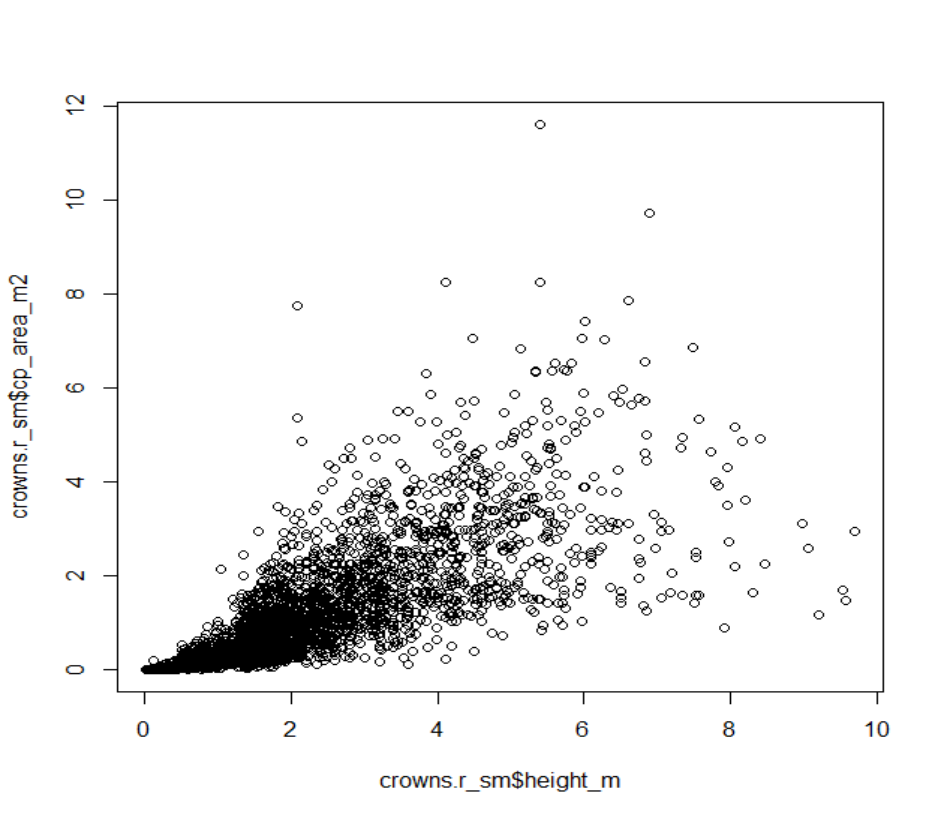
# Results – DBH < 7 cm over bark

Data structure (DBH < 7 cm over bark)

| plot_id | tree_id | height_m | age | cp_area_m2 | species | damage | point_type | regeneration_origin | vegetative_origin |
|---|---|---|---|---|---|---|---|---|---|
| 1009 | C-13 | 0.17 | 4 | 2.120575e-02 | smrk ztepily | bez poskozeni | nehroubi vychod | prirozena obnova | generativni puvod |
| 1125 | A-3 | 2.75 | 53 | 3.123921e+00 | smrk ztepily | poskozeny | nehroubi zapad | prirozena obnova | generativni puvod |
| 1125 | A-4 | 4.75 | 53 | 1.566869e+00 | smrk ztepily | poskozeny | nehroubi zapad | prirozena obnova | generativni puvod |
| 1243 | A-1 | 1.75 | 12 | 1.580614e+00 | smrk ztepily | bez poskozeni | nehroubi zapad | prirozena obnova | generativni puvod |
| 1789 | A-13 | 1.61 | 8 | 7.461283e-01 | smrk ztepily | bez poskozeni | nehroubi zapad | prirozena obnova | generativni puvod |
| 1789 | B-2 | 1.08 | 8 | 3.369358e-01 | smrk ztepily | bez poskozeni | nehroubi zapad | prirozena obnova | generativni puvod |

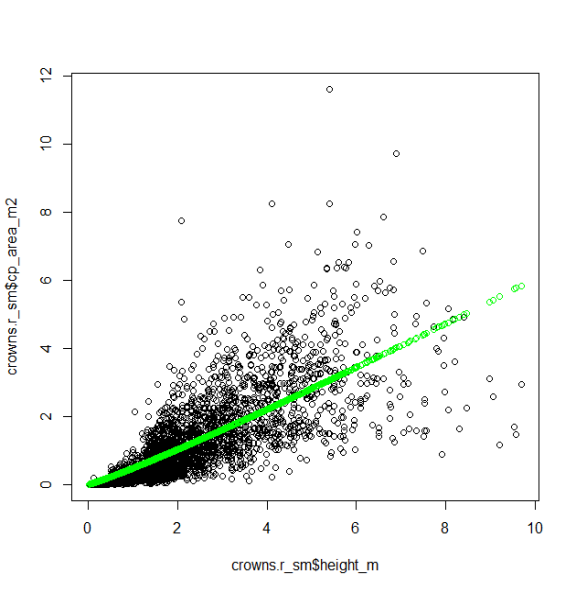
# Results – DBH < 7 cm over bark

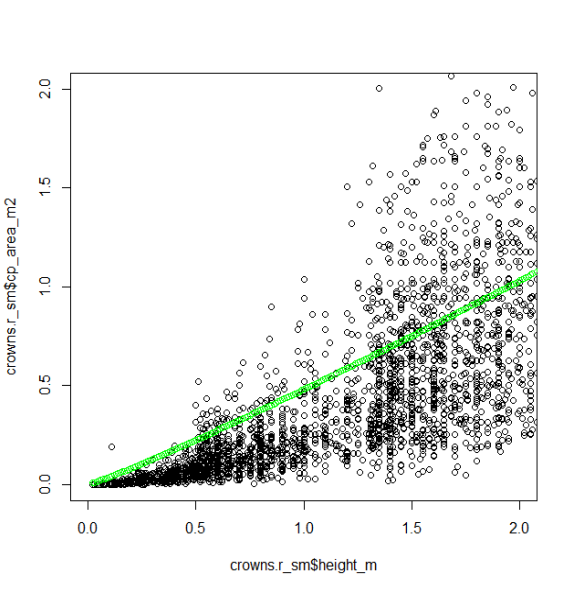
- Example of Norway spruce

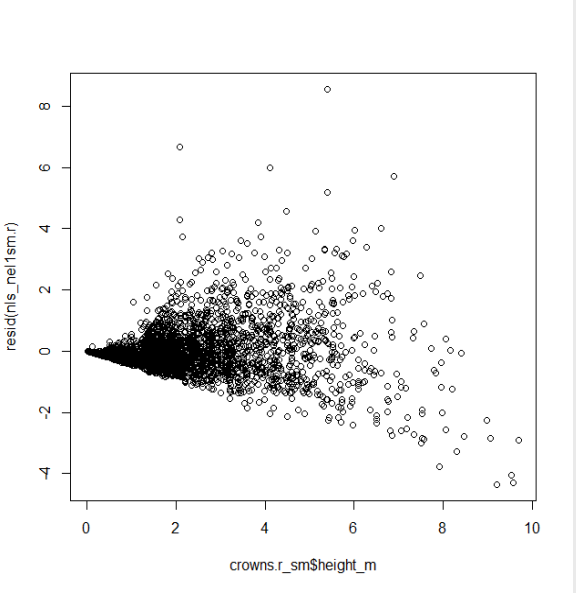


# Results – DBH < 7 cm over bark

- Example of Norway spruce - simple non-linear function $a*X^b$

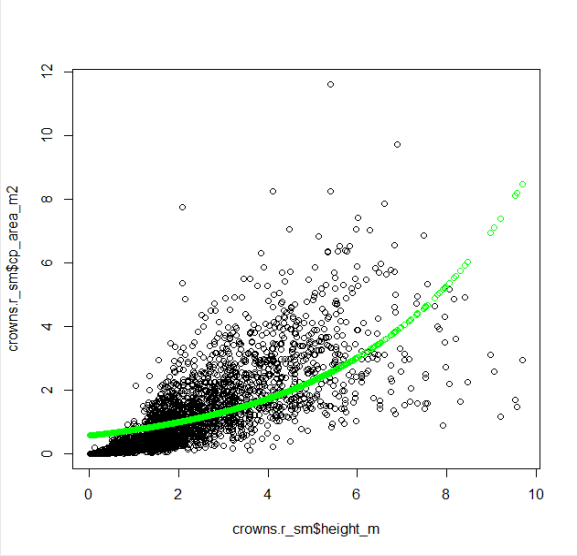


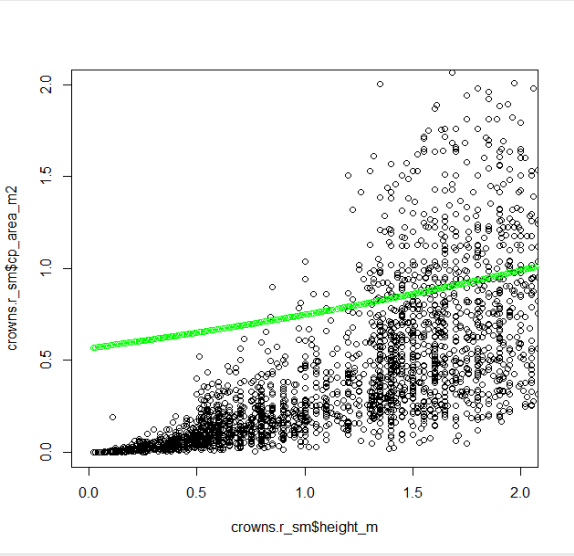



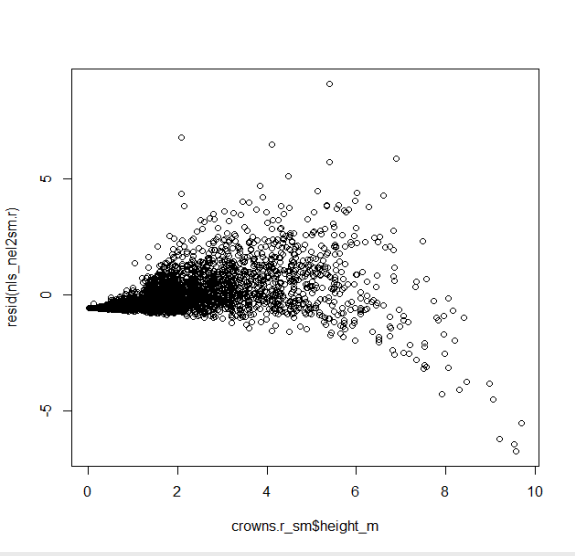



# Results – DBH < 7 cm over bark

- Example of Norway spruce - simple non-linear function $a*e^{X*b}$

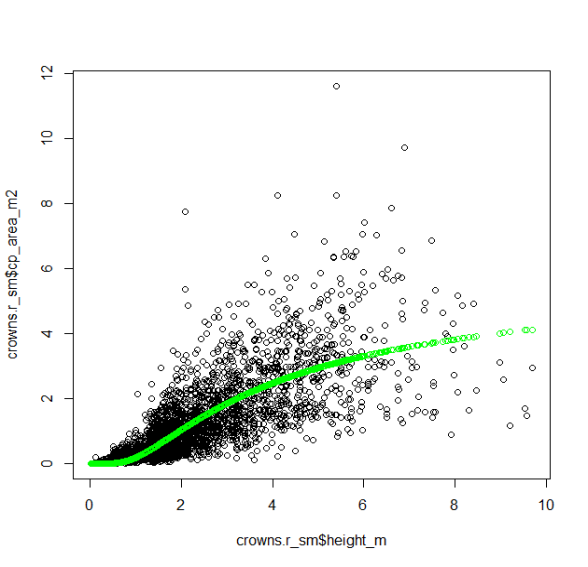


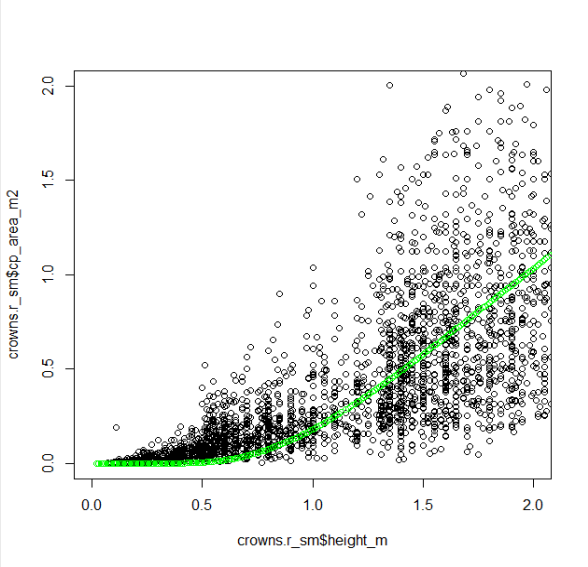



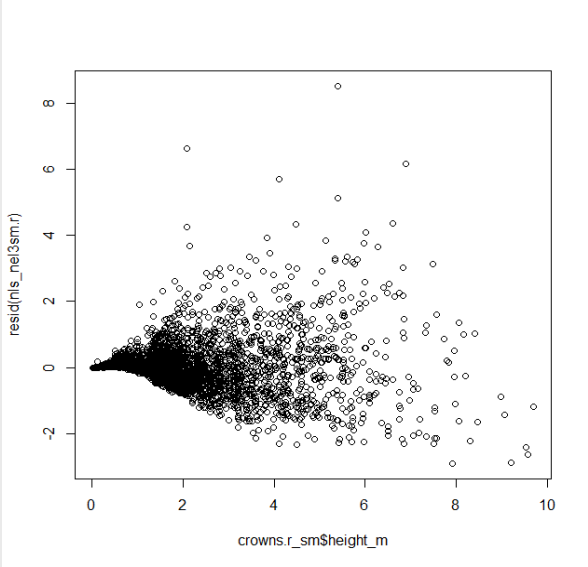



# Results – DBH < 7 cm over bark

- Example of Norway spruce - Michailoff function - $a*e^{b/X}$



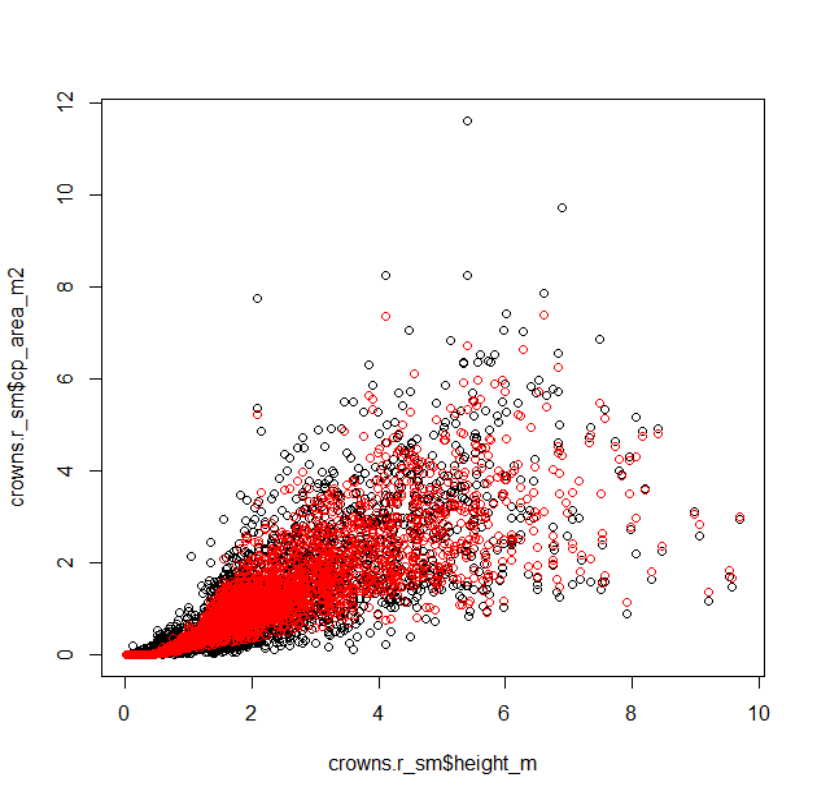



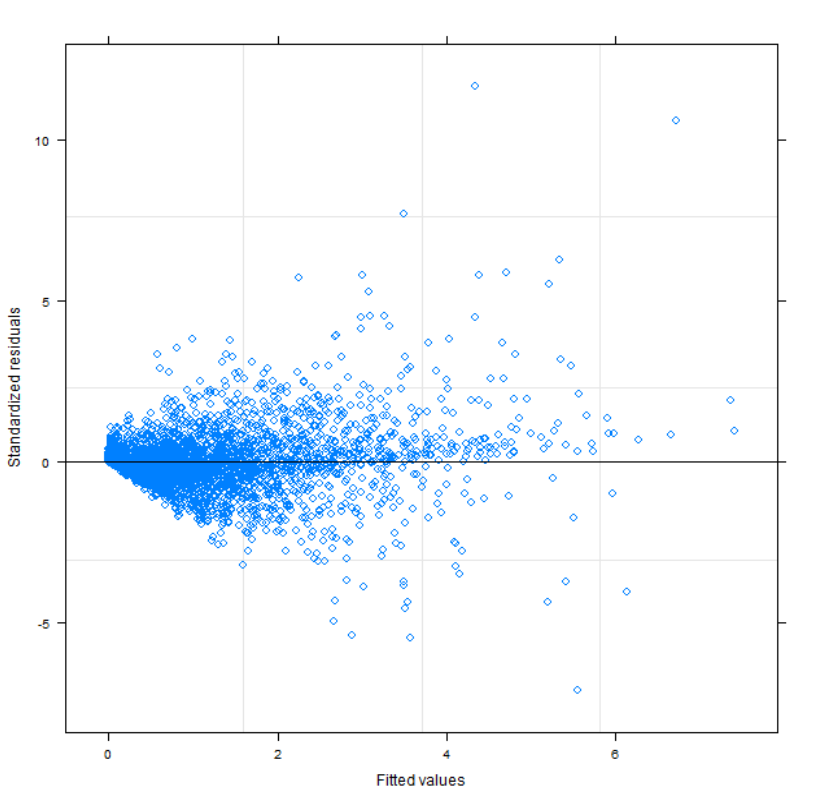



# Results – DBH < 7 cm over bark

- Example of Norway spruce – Michailoff function – mixed model
- Fixed effect – height of a tree
- Random effect – inventory plot, both parameters
- AIC = 6 862

# Results – DBH < 7 cm over bark

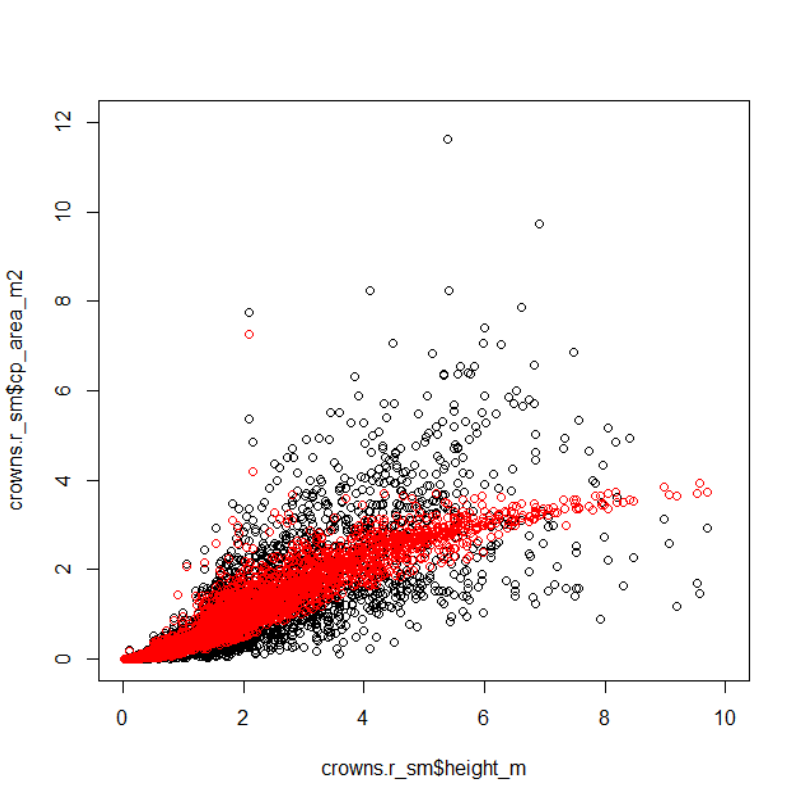


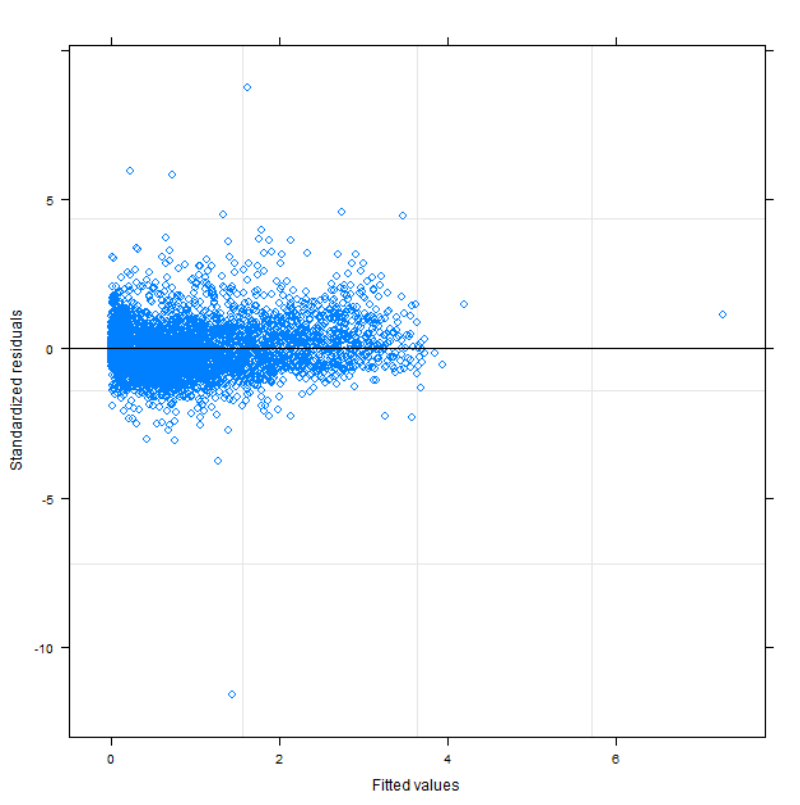



# Results – DBH < 7 cm over bark

- Example of Norway spruce – Michailoff function with offset $a*e^{b/X+s}$ – mixed model
- Fixed effect – height of a tree, damage of a tree (parameter a), offset
- Random effect – inventory plot, parameter b
- Weight function - power function of tree height
- AIC = 1 747

# Results – DBH < 7 cm over bark



# Results – DBH < 7 cm over bark

All species

- **Nonlinear Michailoff function with offset**
- Fixed effects
  - tree height
  - damage of the tree (significant only for spruce, beech, birch, pine and pedunculate oak models)
  - the type of regeneration (natural or artificial - significant only for larch model)
- Random effect
  - inventory plot
- Power weight function - coping with heteroscedasticity

# Models in progress

- Model of DBH from stump diameter
  - volume estimation of harvest trees
- Model of height-diameter relationship
  - progress between CZNFI 1 and CZNFI 2
- Diameter increment model
  - problem with increment of harvest trees

# Thank you for your attention!