Soil structure and defoliation in Norway spruce

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Background

- Some previous work on soil chemical properties and defoliation
- Higher C/N ratio may be protective
- Does better soil structure protect against poor crown condition?

Crown condition data

- Annual data collection 1983-2011 in Baden-Württemberg (Terrestrial Crown Condition Inventory)
- Different spatial resolutions in different years
- % defoliation in the upper crown estimated in 5% classes
- Mean % defoliation calculated for (up to) 24 trees on each plot

Soil data

- BZE
- Data collection 1988-1992
- 8×8 km grid, 308 locations in Baden-Württemberg

“Upscaling” of soil data

- Multiple linear regression model for each soil variable (Zirlewagen & von Wilpert, 2010)
  - topology, stand attributes, climate, bedrock, deposition
  - kriging
- Predictions for each variable at locations in crown condition survey

Problems?

- Model fit
  - e.g. $R^2 \approx 0.45\text{-}0.64$ for carbon content
- Uncertainty in estimates
  - regression dilution

Soil variables

- Sand/silt/clay content
- Carbon content
- Dry bulk density
- Coarse soil fraction
- Base saturation
- Depth of soil development
- Humus type
- Years since liming

Modelling defoliation

- Restrict to most common species (Norway spruce, *Picea abies*)
- n = 9722 (number of plots = 1433)
- Fit GAM, starting from base model (deviance explained=51.1%):

$$\text{logit}(\text{defoliation}_i)) = f_1(\text{year}_i) + f_2(\text{mean tree age}_i) + \varepsilon_i$$

$$\varepsilon_i \sim N(0,\sigma^2)$$

Different soil depths

- Most soil variables measured at several depths (2-5)
  - silt/sand/clay (2)
  - carbon (5)
  - dry bulk density (4)
  - coarse soil fraction (5)
  - base saturation (2)

Functional covariates

- How to include variables measured at different depths?
  - each depth separately
  - one depth only
  - mean of all depths
  - linear functional covariate:

$$\sum_j \text{value}_j \, f(\text{depth}_j)$$

- Depends on correlation between depths

Model fitting

- Using mgcv
- Smoothing parameters estimated by REML
- Soil variables added by forwards selection
- % deviance explained used to assess model fit (practical relevance)

Current best model

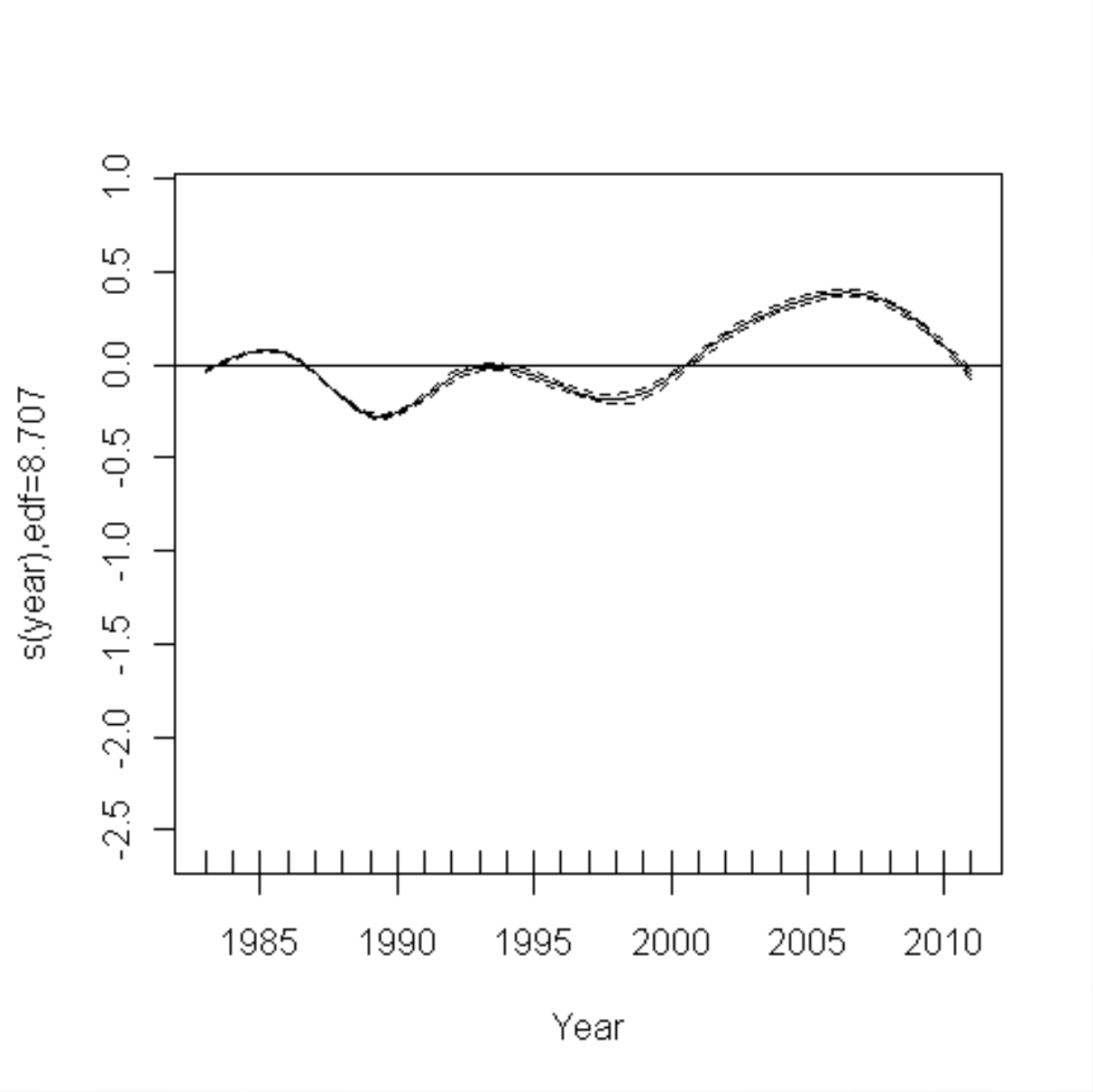
- Current best model (deviance explained=53.7%):

$$\text{logit}(\text{defoliation}_i) = f_1(\text{year}_i) + f_2(\text{mean tree age}_i) + \Sigma_j \text{carbon}_{ij}\, f_3(\text{mid.depth}_j) + f_4(\text{years.since.liming}_i) + \varepsilon_i$$

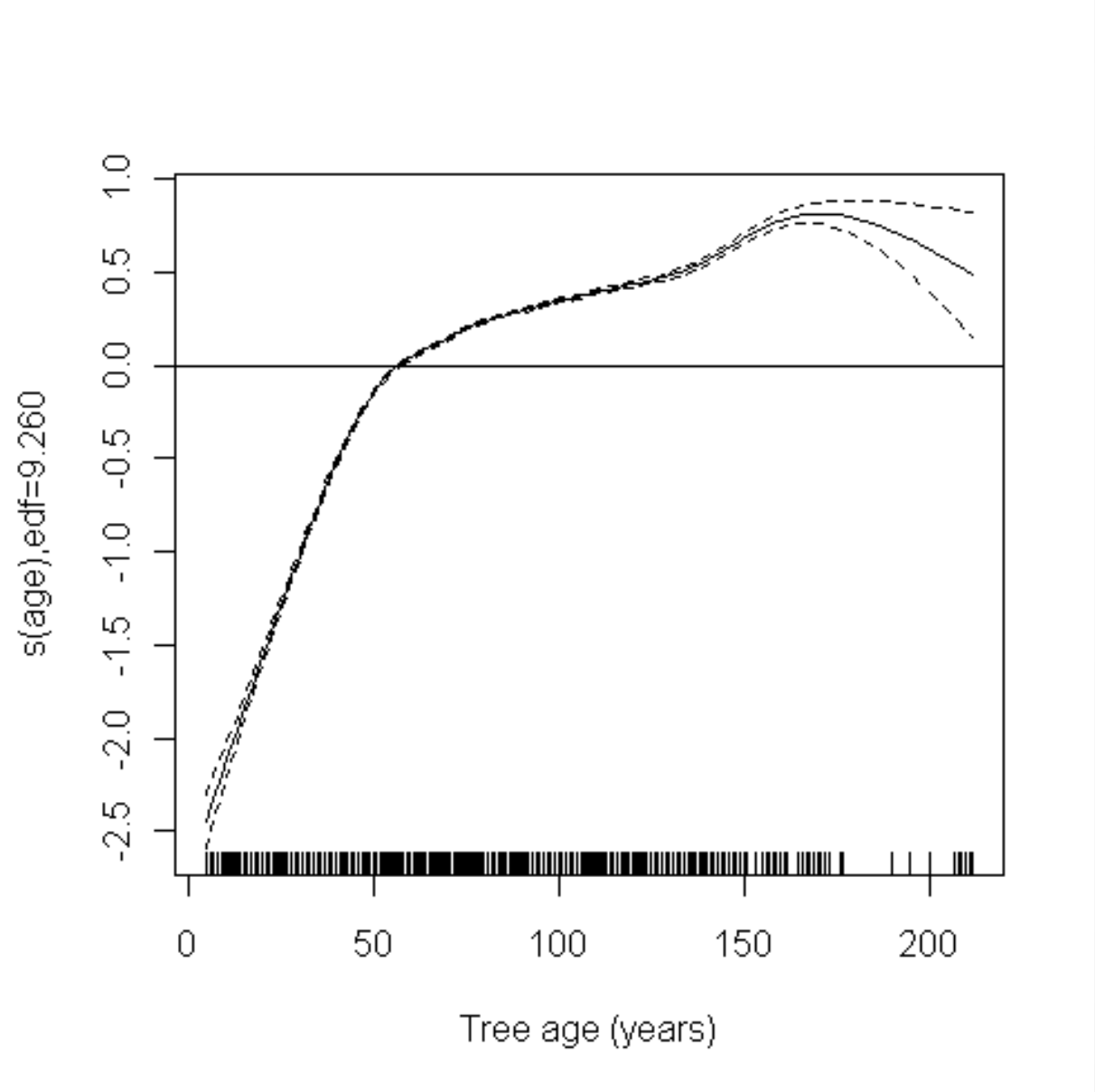
$$\varepsilon_i \sim N(0,\sigma^2)$$

	edf	Ref. df	F	p-value
s(year)	8.707	8.963	110.593	<2e-16
s(age)	9.260	10.286	355.912	<2e-16
s(P.carbon):carbon	3.976	3.999	140.334	<2e-16
s(years.since.lime)	3.248	3.663	4.523	0.00172

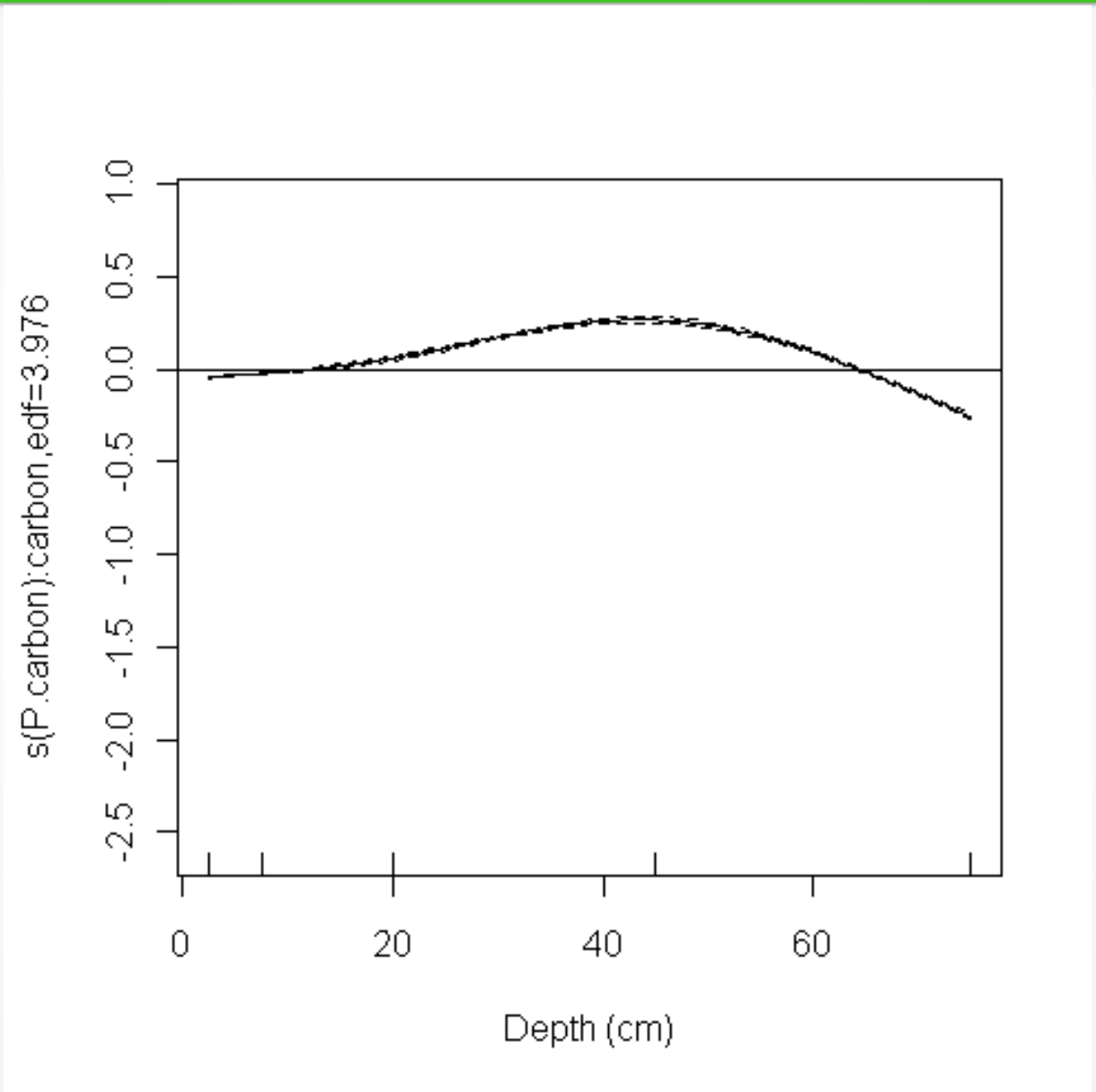
Temporal trend



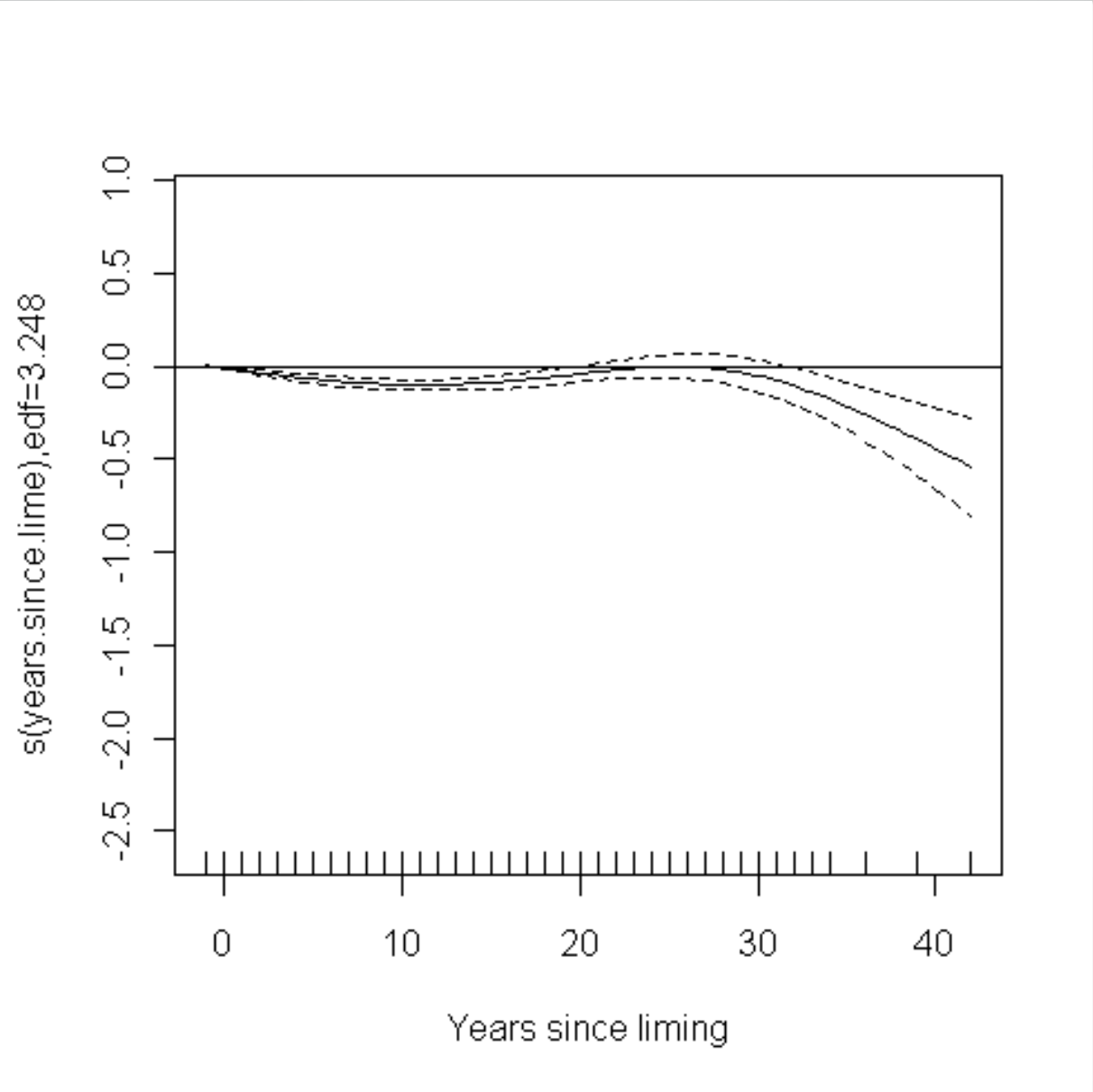
Tree age


s(age),edf=9.260
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0
50
100
150
200
Tree age (years)

Soil carbon content



Years since liming



Summary

- Higher carbon content associated with reduced defoliation, but only at lower depths (60-90cm below the surface)
- No evidence of any influence from other soil structure characteristics
  - measurement error?
  - need interaction with weather...