Individual tree models
growth and calculus modules

Individual tree models - state variables

- The most common principal variables
  - Dominant height (stand level variable)
  - Diameter at breast height
  - Tree height may also be a principal variable
- Derived variables
  - Tree: total height and height to the base of the crown, tree volume, tree biomass (total and per component)
  - Stand: all variables except dominant height

Calculus of stand variables

- Example for stand volume
  - Prediction of tree mortality and of diameter tree growth for each tree
  - Prediction of tree height with a height-diameter curve (or, eventually prediction of height growth) for each tree
  - Prediction of the volume for each tree with a volume equation
  - Calculus of plot volume by summing up the volume of every tree in the plot
  - Expansion to the ha, using the respective expansion factor (10000/plot area) - many models use 1 ha plots therefore this step is not needed

Modeling individual tree dbh growth

- Several methods have been used to model tree dbh growth, which may be classified as:
  - Linear or nonlinear regression models using i_d or i_g as dependent variable
  - Difference equations (d_{t2} or g_{t2} as dependent variable)
  - Growth potential x modifier type models
    - Dependent variable is usualy i_d or i_g

Linear regression models - examples

- Examples:

Site information

$$\ln(i_{g,10}) = \beta_0 + \beta_1 \ln(d) + \beta_2 \ln(CCF) + \beta_3 \ln\left(\frac{d}{dg}\right) + \beta_4 \ln(S) + \beta_5 ALT$$

$$\ln(i_{g,10}) = \beta_0 + \beta_1 \ln(d) + \beta_2 \ln(CCF) + \beta_3 \ln\left(\frac{d}{dg}\right) + \beta_4 \ln\left(\frac{1}{t}\right)$$

Stand density

Tree dimension

Distance-independent index

Difference equations - examples

- Dbh growth model for dominant cork oak trees (without age explicit (200 is an asymptote)

$$d_{t+a} = 200\left(1-e^{-(-0.00093+0.000275\ S)\ a}\left(1-\left(\frac{d_t}{200}\right)^{1.1207}\right)\right)^{\frac{1}{1.1207}}$$

Site index

Tree dimension

Potential X modifier type models

- These models are based on the assumption that individual tree growth may be modeled as:

  $i_d = i_d$ potential X modifier

  - The i_d potential represents the growth of a tree of the same size that grows without limitations
  - The modifier is a function that takes values between 0 and 1, defining growth restrictions (usually competition but other factors may also be taken into account)

Potential X modifier type models

- There are different concepts of potential growth that have been used:
  - Maximum growth that a tree of the same species and size/age may attain under optimum conditions in terms of water and nutrients
  - Maximum observed growth for a tree of the same species and size
  - Maximum growth of the trees in the same plot (growth of the dominant trees)

Potential X modifier type models - example

- GLOB-tree model - potential growth

$$ddom_{t2} = A\left(\frac{ddom_{t1}}{A}\right)^{(t1/t2)^{n}} = (316761 + 12067\,S)\left(\frac{ddom_{t1}}{316761 + 12067\,S}\right)^{(t1/t2)^{0.4905}}$$

$$ipot_d = ddom_{t2} - ddom_{t1}$$

Site index (in the asymptote)

Tree dimension

Potential X modifier type models - example

- GLOB-tree model - modifier

Stand density

$$i_d = ipot_d \times \frac{1}{1+e^{a_0 + a_1 R_{\bar{g}} + a_2 100/N + a_3 cr}} \times e^{b_1 PDU} \times \left(1\text{-}e^{c_0 + c_1 APA}\right)$$

Distance independent CI

$$R_{\bar{g}} = \frac{gi}{\bar{g}}$$

Unilateral distance dependent CI

distance dependent CI

Height prediction - example

GLOB-tree model

- Young stands (t<4 years)

$$h = 130 + hdom\left(1 + \left(-0.43487 - 0.0108\ t + 0.09772\ hdom - 0.06021\ dg\right)e^{-0.04864\ hdom}\right)\left(1 - e^{-158926\ \frac{d}{hdom}}\right)$$

- Adult stands (t>4 years)

$$h = hdom\left(1 + \left(0.10694 + 0.02916\ \frac{N}{1000} - 0.00176\ d\max\right)e^{0.03540\ hdom}\right)\left(1 - e^{-181117\ \frac{d}{hdom}}\right)$$

Crown variables - examples

- GLOB-tree model - crown ratio

$$cr = \frac{1}{\left[1 + e^{-\left(-5.76111 + 12.33413\,1/t - 0.27179\,N/1000 - 0.17543\,hdom + 0.20559\,d\right)}\right]^{1/6}}$$

Stand density

Tree age

Tree dimension

Predicting tree mortality - examples

- GLOB-tree model

$$P(\text{tree dies}) = \frac{e^{2.2735 - 0.0469\,G + 15340\,R_{\bar{g}} + 0.2841\,d}}{1 + e^{2.2735 - 0.0469\,G + 15340\,R_{\bar{g}} + 0.2841\,d}}$$

Stand density

Distance independent CI

Tree dimension

$$R_{\bar{g}} = \frac{gi}{\bar{g}}$$