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# INDIVIDUAL TREE MODELS

# Individual tree models

- Are systems of equations to simulate stand dynamics by incrementing each tree during a growth period in relation to its growing conditions.

| Regeneration | Ingrowth | Tree growth | Mortality |
|---|---|---|---|

- provide detailed information about stand development and structure, including the distribution of stand volume by size classes
- have inherent flexibility allowing modeling:
  - combinations of species mixtures and stand structures
  - management regimes
  - regeneration methods

# Individual tree models types

## No tree locations known

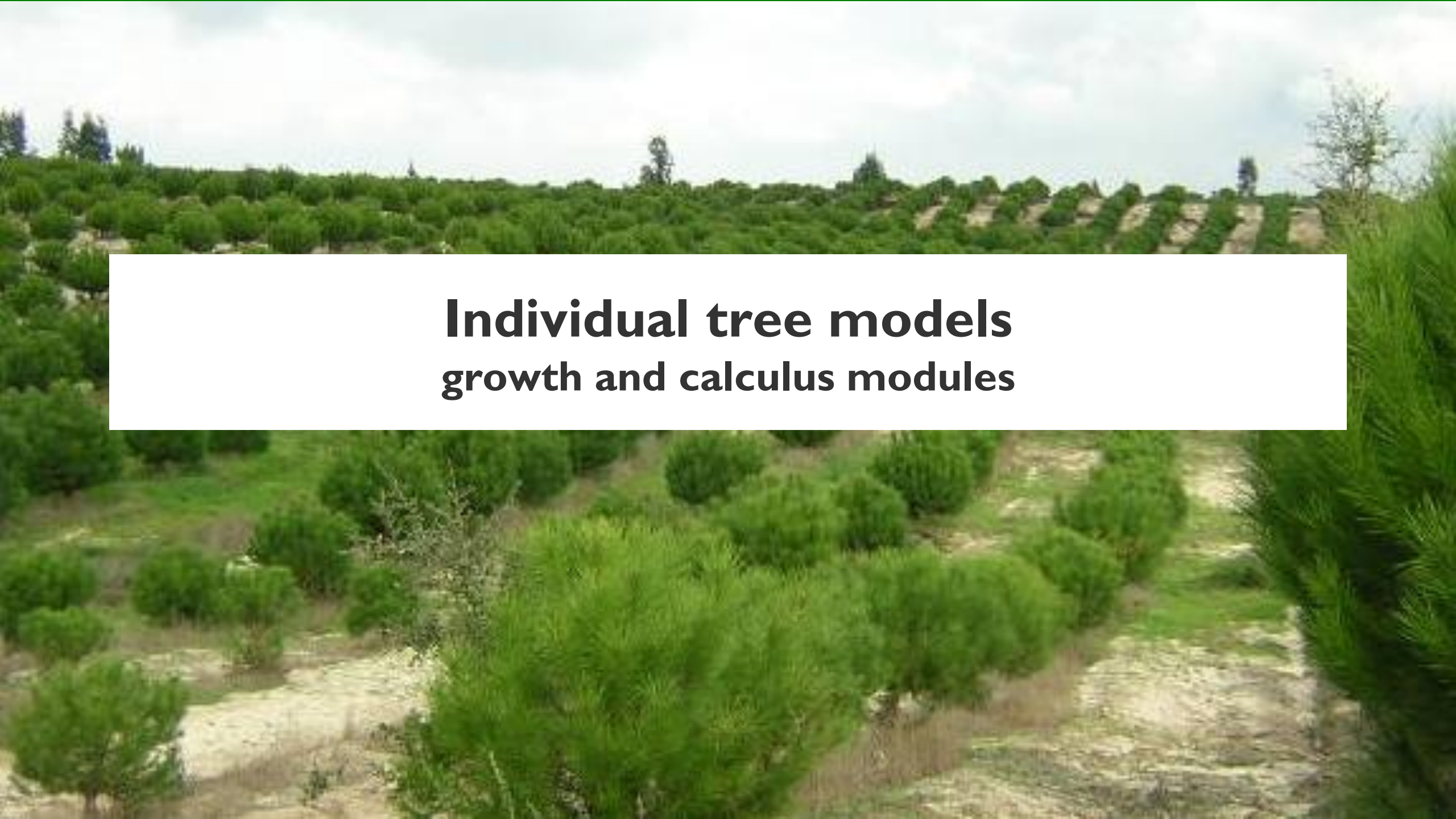
***Also called distance-independent, position-independent, location-independent, non-spatially-explicit***

- ***Usually consist of:***
  - Diameter growth equation
  - Height growth equation (or h-d relationship to estimate h from d)
  - Mortality (stochastically generated or predicted as a function of growth rate and/or tree characteristics)
  - Growth predicted as a function of tree size and stand (t and N) and site variables (S)

## Tree locations known

***Also called distance-dependent, position-dependent, location-dependent, spatially-explicit***

- ***Usually consist of:***
  - Initialization: trees inputted or generated (incliding their coordinates)
  - Growth predicted as a function of tree size, site quality (S) and a measure of competition from neighbouring trees (generally a function of size of the subject tree and (size , distance) to competitors
  - Survival controlled stochastically as a function of competition and/or tree attributes



# 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), sometimes crown width
  - **Stand**: all variables except dominant height

# Calculus of stand variables - example for stand volume

- Start with a list of all trees at time $t_1$ (at least tree diameter/or height):
  - Growth module (GM) – prediction of:
    - tree mortality
    - tree diameter growth for each tree
    - tree height growth for each tree (eventually)
  - Calculus module CM)- estimation of:
    - tree height with a height-diameter curve (if not predicted in the GM)
    - tree volume 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

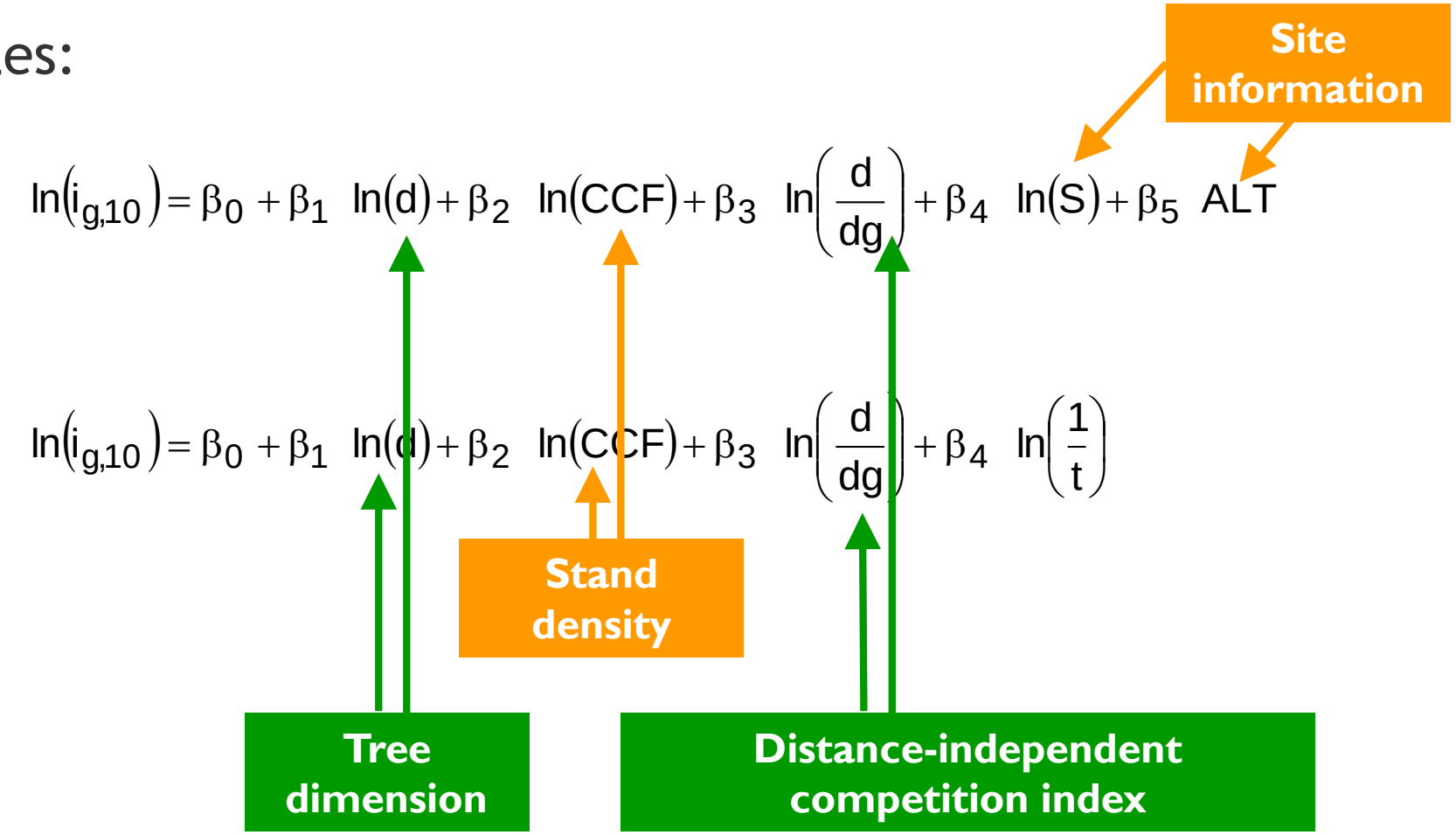
- What factors/variables influence tree dbh growth?
  - site quality
  - micro-environment conditions (mainly soil)
  - tree age
  - tree size
  - stand density
  - influence of local neighbours
  - genetics

# Modeling individual tree dbh growth

- Several methods have been used to model tree dbh growth, which may be classified as:
  - **Method I** - Linear or nonlinear regression models using $i_d$ or $i_g$ as dependent variable
  - **Method II** - Difference equations ($d_{t2}$ or $g_{t2}$ as dependent variable)
  - **Method III** - Growth potential x modifier type models
    - Dependent variable is usually $i_d$ or $i_g$
  - Let´s look at each one of the methods

# Method I - Linear regression models example

- Two examples:



# Method II - Difference equations example

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

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

**Site index**

**Tree dimension**

# Method III - Potential X modifier type models

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

$$i_d = i_d \text{ potential} \times \text{modifier}$$

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)

# Method III - 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 in "normal" conditions
  - Maximum growth of the trees in the same plot (growth of the dominant trees)

# Method III - Potential X modifier type models, example

- GLOB-tree model - potential growth

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

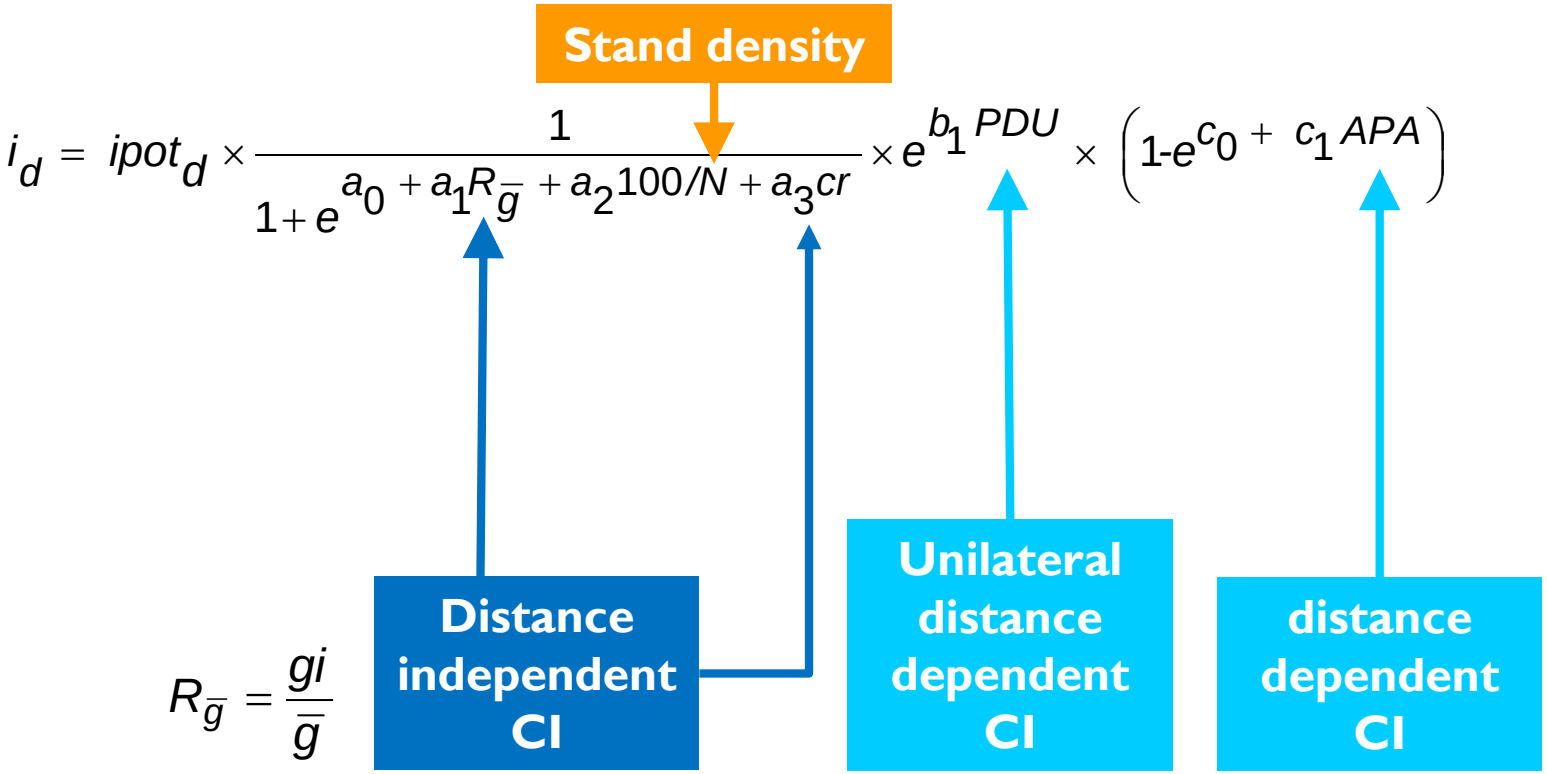
**Tree dimension**

**Site índex (in the asymptote)**

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

# Method III - Potential X modifier type models, example

- GLOB-tree model – modifier



# Height estimation - 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 - example

- GLOB-tree model – crown ratio

$$cr = \frac{1}{\left[1 + e^{\left(-5.76111 + 12.334131/t - 0.27179\, N/1000 - 0.17543\, hdom + 0.20559\, d\right)}\right]^{1/6}}$$

**Tree age**

**Stand density**

**Tree dimension**

# Predicting tree mortality - example

- GLOB-tree model

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

**Stand density**

**Distance independent CI**

**Tree dimension**

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