Site quality, site index curves (SIC) and dominant height growth

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▪Summary

- What is the **site and the site quality**?
- How can we evaluate **site index**?
- Data available for developing **site index curves** (SIC)
  - ✓ a) Temporary plots
  - ✓ b) interval and permanent plots,
  - ✓ c) stem analysis
- Types of site index curves:
  - ✓ Anamorphic
  - ✓ Polymorphic disjoint or non-disjoint
- Methods for the development of site index curves
  - ✓ i) Independent fitting of SICs
  - ✓ ii) Guide-curve method
  - ✓ iii) Parameter prediction method
  - ✓ iv) Difference equations
- Direct methods to estimate S

Site and site quality

- ✓ **What is the site?**
  - Site refers to "an area considered in terms of its **environment**, particularly as this **determines the type and quality of the vegetation** the area can carry"

(Society of American Forests 1971)

- ✓ **Site quality can be evaluted through direct and indirect methods**
  - **Direct** or geocentric methods – site is evaluated by climate and soil characteristics
  - **Indirect** or phytocentric methods – site is evaluated by the analysis of the vegetation growing in the site
    - Indicator plants (namely shrubs)
    - Site index

Site index - definition

- Site index (S) is defined as the dominant height that the stand has, had or will have at a certain age, the base age

- Therefore, the simulation of dominant height growth is intimately related with the prediction of site índex
- The site index concept assumes that the dominant height is not affected by silvicultural treatments
- The set of curves that represent dominant height growth for the range of possible site indices is know as site index curves

Building SIC - data that can be used

- Site index curves may be built with different types of data:

  → a) **temporary plots** - Independent data pairs (hdom, t)

  → b) **permanent and/or interval plots** - successive data pairs (hdom, t)

  → c) **stem analysis techniques** – reconstruct height growth data of individual trees

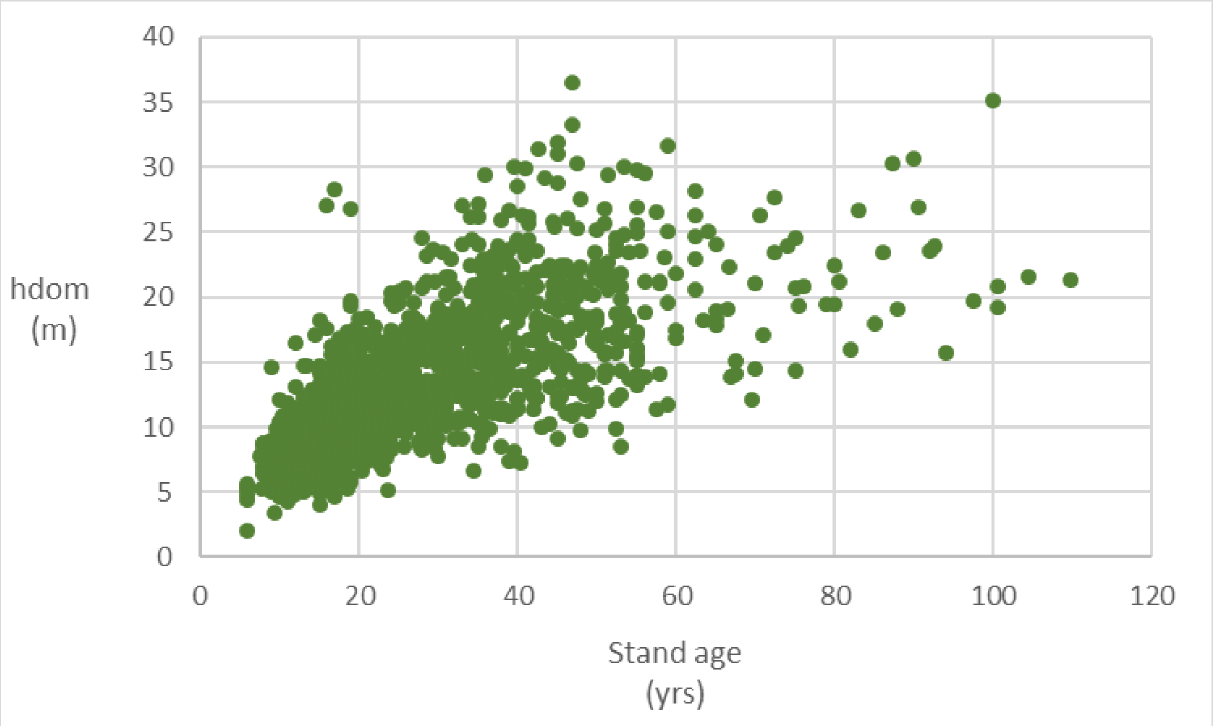
Building SIC - data that can be used

- **a) Temporary plots** - Independent data pairs (hdom,t) from

  ✓ In order to **avoid bias**ed site index curves, it is important to **guarantee that all the site index classes are equally represented** in the data set

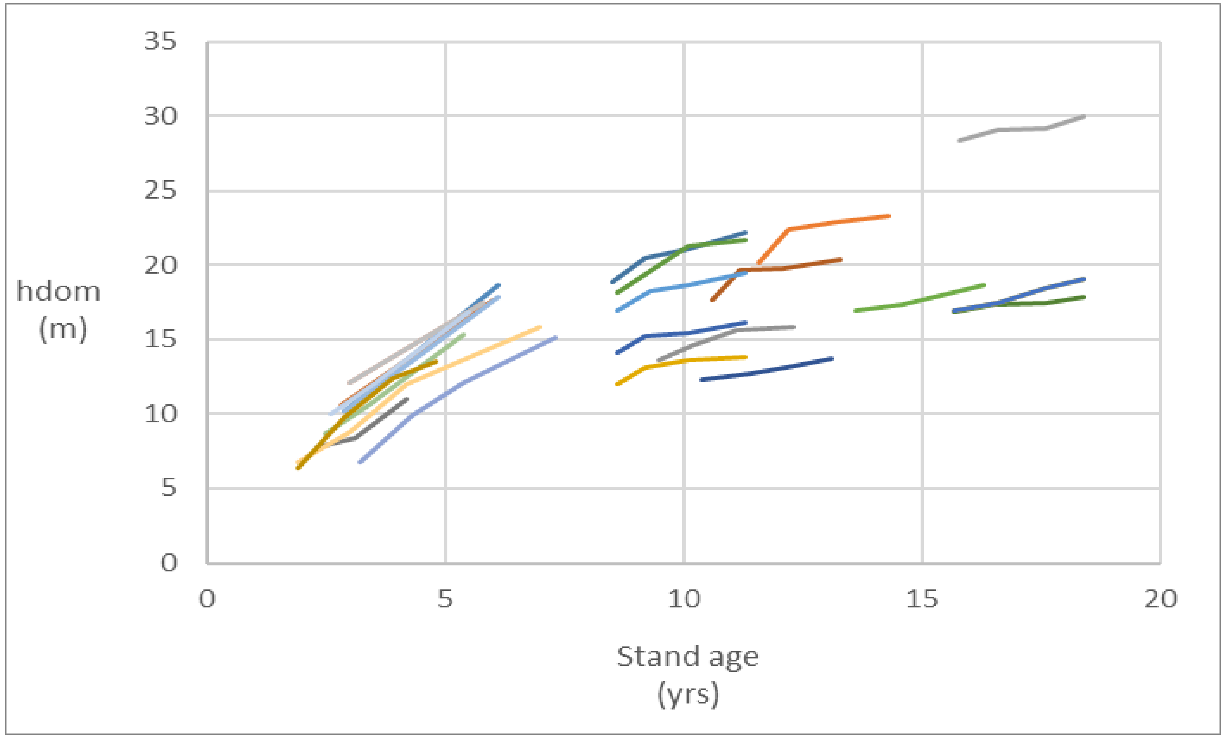
  ✓ Correlations between site index and stand age are often found

(e.g. more fertile sites were first planted) and, if this is the case, the site index curves will be influenced by this relationship



Building SIC - data that can be used

- **b) Interval and/or permanent plots** - successive data pairs (hdom,t)
  - ✓ The set of **remeasurements** from the same plot is usualy designated by "**growth series**"
  - ✓ This is the **prefered data to develop site index curves** as it allows the identification of the real growth shape
  - ✓ It is important to **have** data that give a **good representation of all the ages**, covering all the growth stages, from juvenile to senescency



Each colored line represents the measurements carried out in one plot

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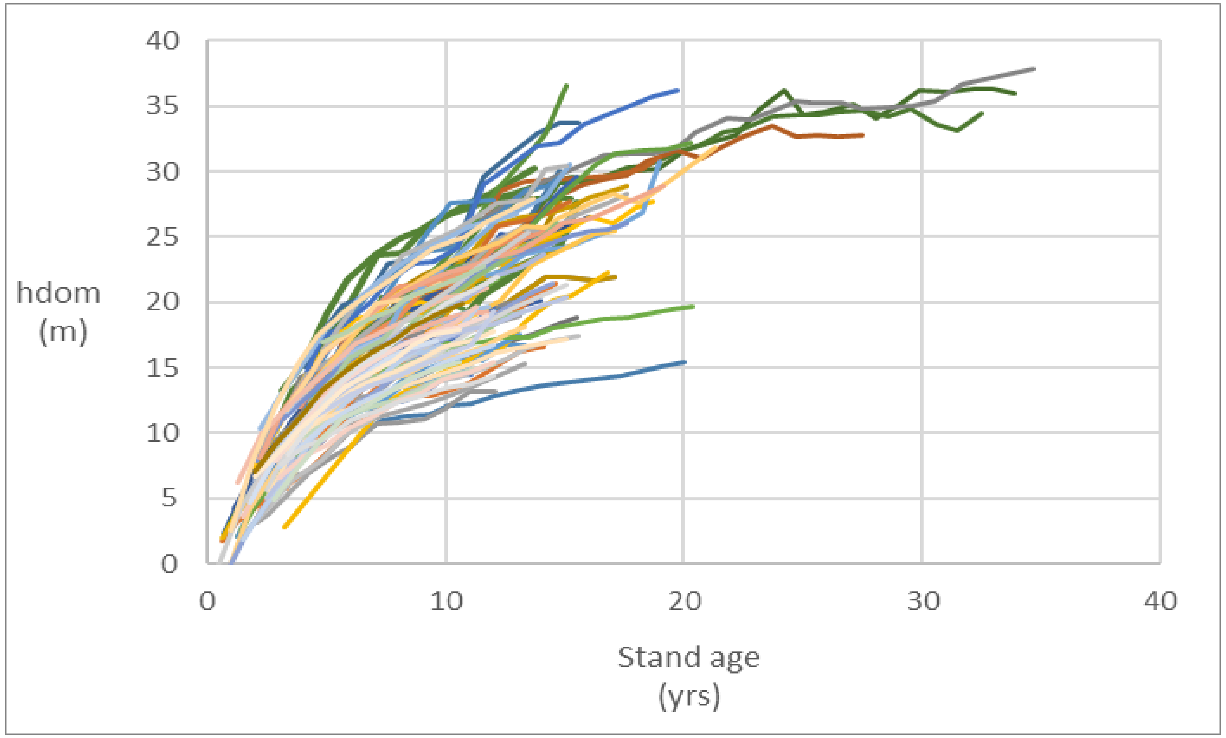

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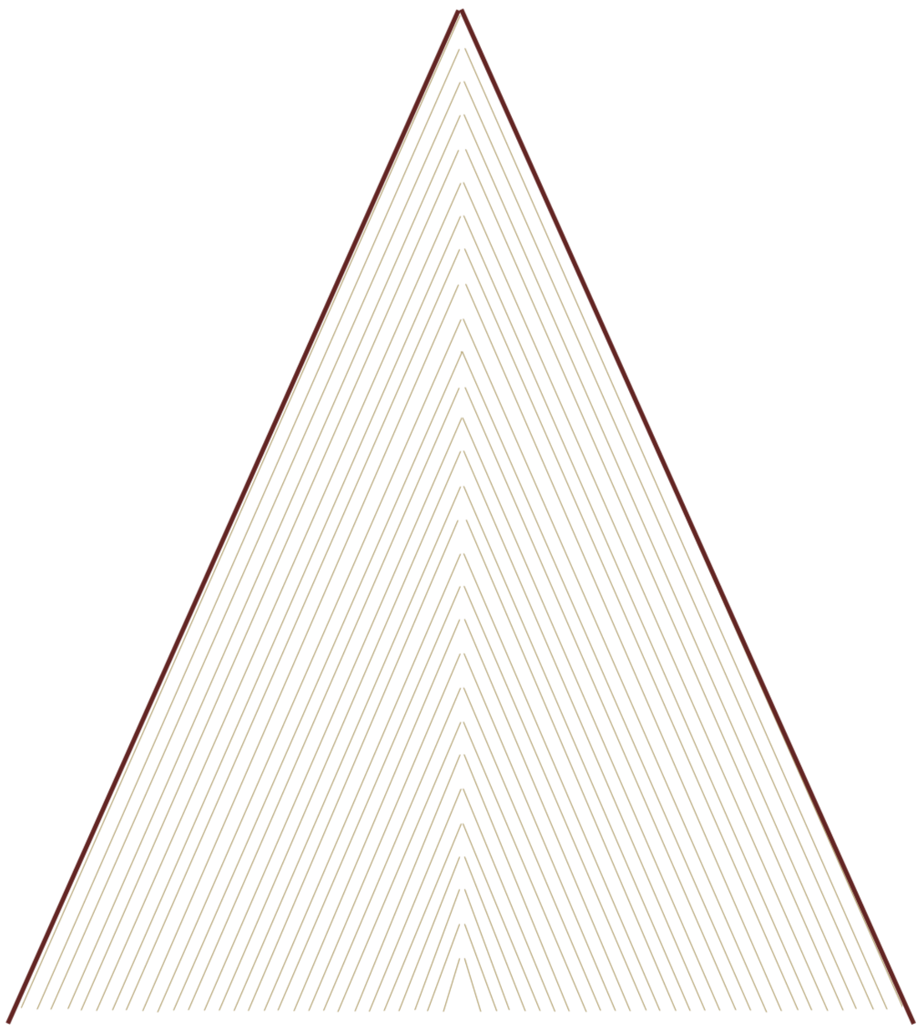
Building SIC - data that can be used

- **c) Stem analysis**

  - ✓ This method applies only in the temperate zones and with **tree species characterized by well defined growth rings**
  - ✓ One has to **assume** that the **dominant trees at the age of harvest have been the dominants during the whole life of the stand**
  - ✓ Tennent and Burkhart (1981) found out that the stem analysis **could be restricted to 2 dominant trees with d close to ddom** and the heights within the interval hdom ±5%



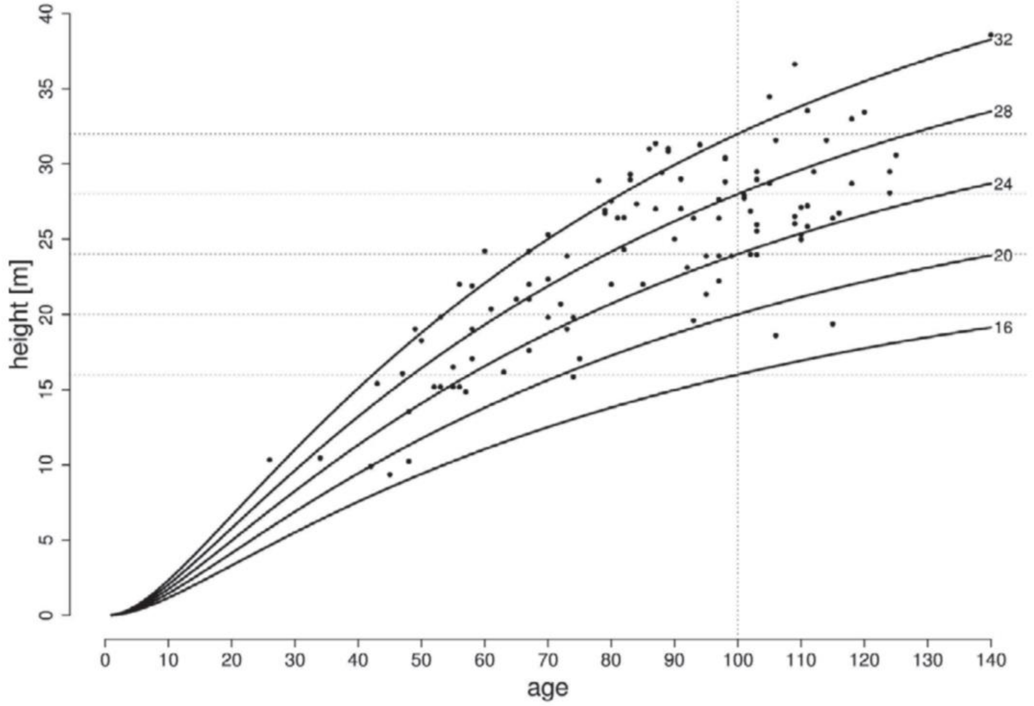
Anamorphic and polymorphic SICs

- According to the relationship between the curves that represent different site indices, the site index curves can be:

➔Anamorphic

Anamorphic curves assume that a common shape for all site classes.

For many species, height growth exhibits pronounced sigmoid shapes on higher-quality sites, and "flatter" shape on lower-quality sites



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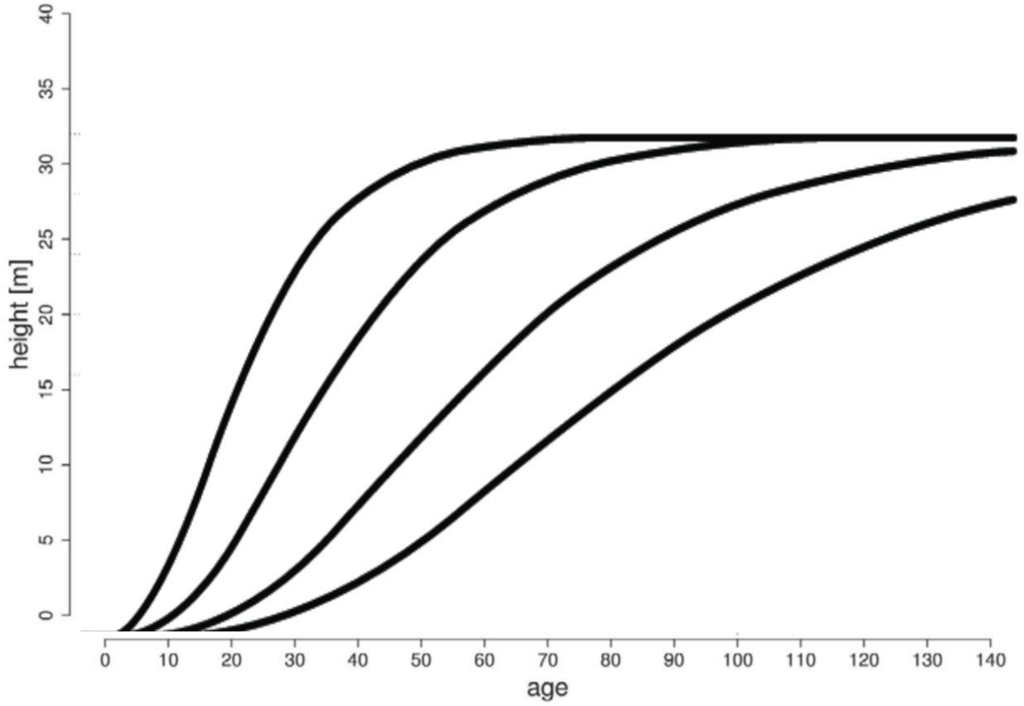


➔Polymorphic

family of site index curves display differing shapes for different site-index classes

Methods for SICs development

- The existing methods for SICs development can be grouped in the following:

  - i) Independent fitting of SICs
  - ii) Guide-curve method
  - iii) Parameter prediction method
  - iv) Difference equations
  - v) Mixed-models

Methods for SICs development

- i) Independent fitting of SICs

  - ➔Data available for each age is grouped into 3 or 5 groups, depending on the number of curves that one wants to fit
  - ➔Fit the same growth curve to the data from each one of the groups originated by this procedure
  - ➔This method may be used for temporary plots data

Methods for SICs development

- **ii) Guide-curve method**

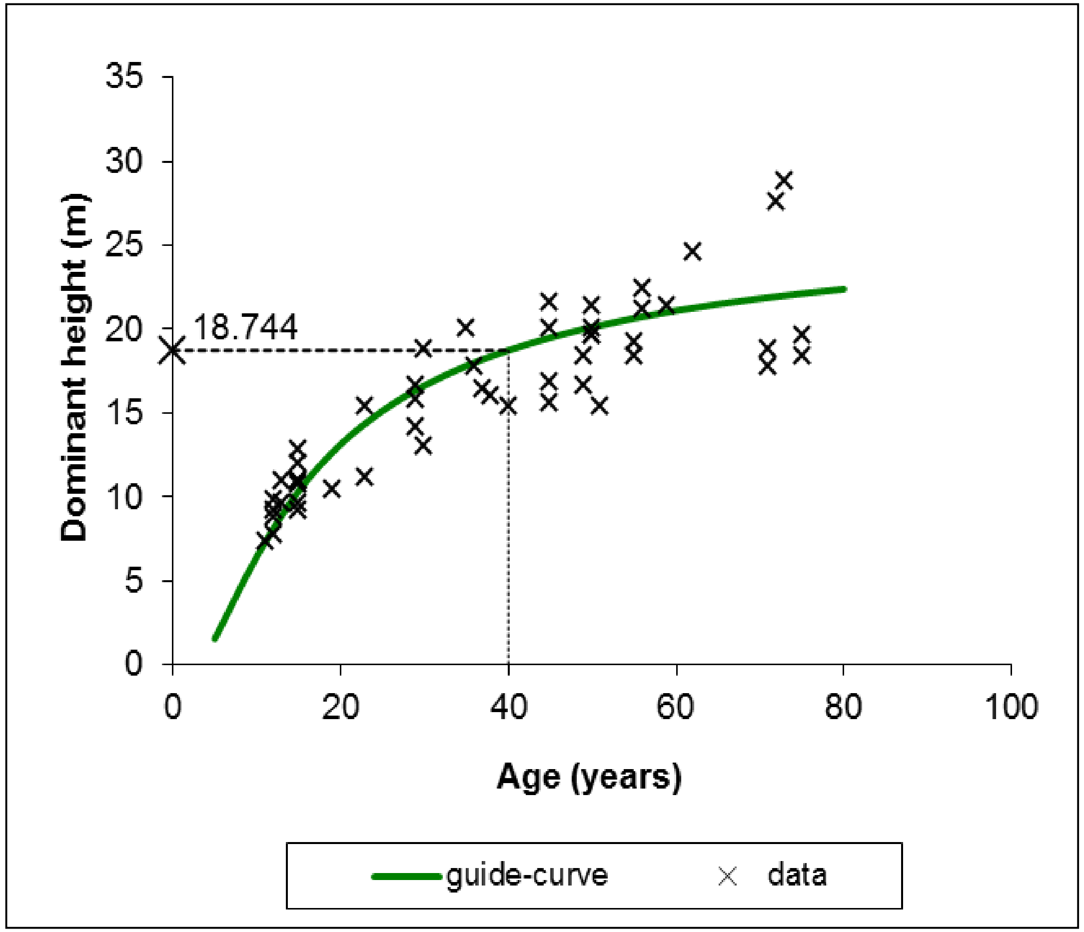
  - ➔ The guide-curve method is the adaptation of the initial graphical methods to the regression analysis techniques
  - ➔ The method is usually used with temporary plots data
  - ➔ The application of the method **implies the fitting of the selected growth curve to the whole data set** – the guide-curve
  - ➔ The curve for site index S is located at a distance from the guide-curve proportional to the distance between S and the site index of the guide-curve

Methods for SICs development

- ii) **Guide-curve method**

Oliveira (1985) fitted the following guide-curve to data from temporary plots measured in maritime pine stands in the mountain and sub-mountain region

Site index of the guide-curve is 18.744 m
(base age 40 years)



Methods for SICs development

- **ii) Guide-curve method**

→ Oliveira (1985) fitted the following guide-curve to data from temporary plots measured in maritime pine stands in the mountain and sub-mountain region:

$$\ln\left(hdom\right) = 3.2865 - 14.2234\ \frac{1}{t}$$

⬇

$$hdom = e^{3.2865}\ e^{-14.2234\ \frac{1}{t}}$$

Methods for SICs development

- **ii) Guide-curve method**

Obtaining a curve for site index S

$$\frac{hdom_{guide}(40)}{hdom_{S}(40)} = \frac{hdom_{guide}(t)}{hdom_{S}(t)} \Leftrightarrow \frac{S_{guide}}{S} = \frac{hdom_{guide}}{hdom_{S}}$$

➔ Using the guide-curve fitted by Oliveira (1985):

$$\frac{e^{3.2865}\, e^{-14.2234\frac{1}{40}}}{S} = \frac{e^{3.2865}\, e^{-14.2234\frac{1}{t}}}{hdom_{S}(t)}$$

➔ **Designating dominant height at age t by hdom:**

$$hdom = S\, e^{-14.2234\left(\frac{1}{t}-\frac{1}{40}\right)}$$

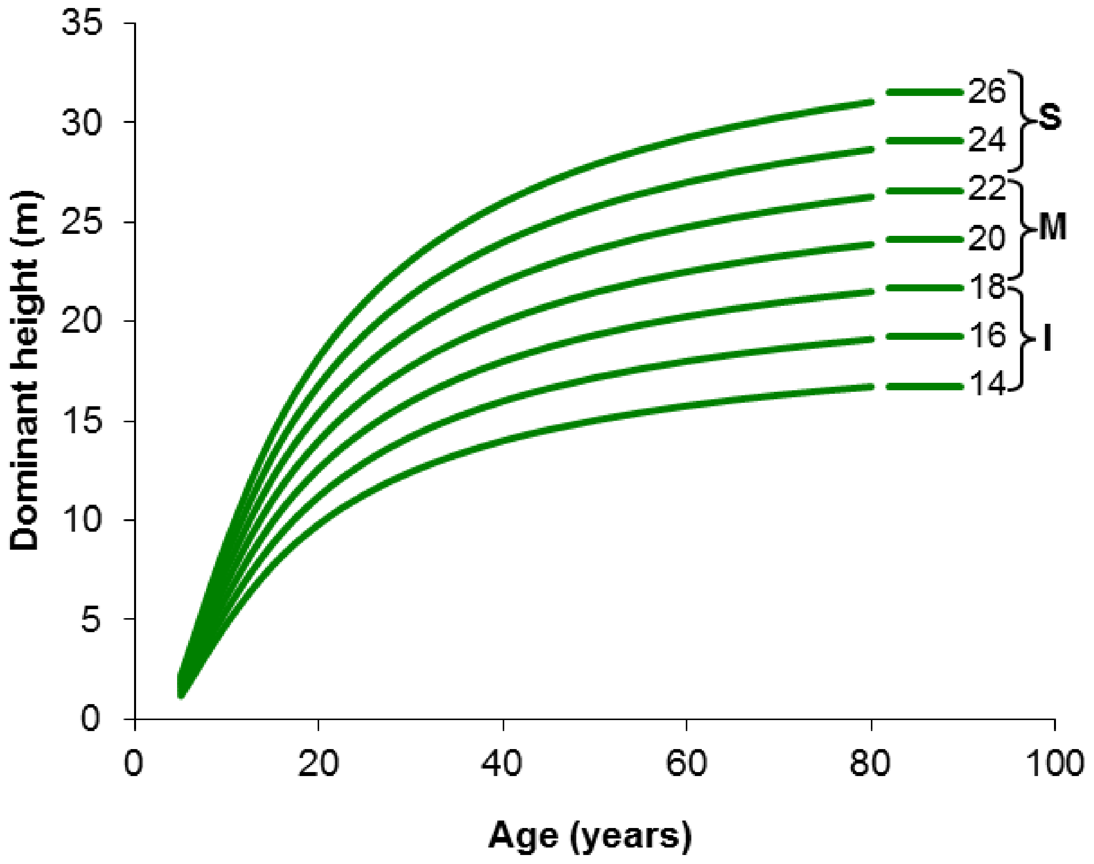
Methods for SICs development

ii) Guide-curve method

Obtaining the sheaf of curves Oliveira (1985)

$$hdom = S\ e^{-14.2234\left(\frac{1}{t}-\frac{1}{40}\right)}$$

Applying the equation to S from 14 to 26 varying t from a young age until 80 years



Methods for SICs development

- iii) **Parameter prediction method**

  - ➔This method can only be used when there is a set of long term growth series
  - ➔Therefore it has been essentially applied with stem analysis data (or to interval/permanente plots)
  - ➔It is equivalent to modelling a family of curves by expressing the parameters as a function of stand/site variables

Methods for SICs development

- **iii) Parameter prediction method**

  → It was developed on purpose to obtain polymorphic site index curves

  → It implies 4 stages:

  - Calculate S for each tree/plot (interpolation) or determine S by fitting a linear or nonlinear height/age function to the data on a tree-by-tree (stem analysis data) or plot by plot (remeasurement data) basis
  - Using each fitted curve to assign a site index value to each tree or plot (try error)
  - Establish the relationship between the parameters obtained for each tree/plot and the respective S, (i.e. study the relationship, if linear: parameter= a0 + a1 S)
  - Fit the final model with some parameter(s) expressed as a function of S

Methods for SICs development

- **iii) Parameter prediction method**

→This method has some disadvantages:

- The curves do not pass through the point corresponding to the base age (S), but it is possible to force the model to do so
- The curves are dependent from the selected base age, they will need to be refitted it a new base age is selected

Methods for SICs development

- **iv) Difference equations**

    - ➔ If the data set includes **at least two remeasurements from each plot**, it is possible to fit growth functions in the difference equation form

    - ➔ The existence of long term growth series (interval, permanent and or stem analysis) is an advantage as in this way the data has more information about the curve shape

    - ➔ There are several methods to fit difference equations (self-referencing curves) to growth data but they are out of the scope of this course

Methods for SICs development

- **iv) Difference equations**

  ➔ Lundvqvist- k

$$hdom_2 = A\left(\frac{hdom_1}{A}\right)^{\left(\frac{t_1}{t_2}\right)^n} \Leftrightarrow hdom_1 = A\left(\frac{hdom_2}{A}\right)^{\left(\frac{t_2}{t_1}\right)^n}$$

  - By making $t_2=t_p$, we have $hdom_2=S$

$$S = A\left(\frac{hdom}{A}\right)^{\left(\frac{t}{t_p}\right)^n} \Leftrightarrow hdom = A\left(\frac{S}{A}\right)^{\left(\frac{t_p}{t}\right)^n}$$

Limitations of using S to determine the quality of the site

- Exact stand age is often difficult to determine in field situations, and small errors can cause large changes in the site index estimate
- Concept of site index is not suitable for uneven-aged stands
- Site index alone may not provide a valid estimate of the growing capacity for a particular site
- Site index may change due to environmental and climatic variations or management activities
- Site index for one species can not be translated into a usable index for a difference species on the same site

Site quality when age is unknown

- It is common to use equations that express S as a function of soil and climate characteristics

➔Examples for maritime pine in Portugal (Marques, 1991):

1) S = *f* (topographic, edaphic and climate variables) (R^2=0.544)

$$S = 10.7214 + 0.780177\ \bar{T}_{\min}(autumn) + 0.0246574\ K + 0.00672025\ Porosity - 0.00441198\ Sand$$

2) S = *f* (species in the understory) (R^2=0.144)

$$S = 17.64 - 0.862\ Chamaespartium + 0.870\ Pteridium$$

Site quality when age is unknown

- It is common to use equations that express S as a function of soil and climate characteristics

➔Examples for *Pseudotsuga menziesii in* Portugal (Fontes et al., 2003):

several eqs, e.g.

***S* = *f* (region, topographic, edaphic and climate variables)**

$$S = 16.805 + 0.000008\ \ Waterdeficit\ \ Rad + 4.375\ \ North - 0.000006\ \ (alt)^2 -$$
$$3.103\ \ SAxMAxAm + 2.319\ \ MinhoLitoral$$

SAxMAxAM – ecological regions in Portugal (Pina Manique e Albuquerque, 1954)
MinhoLitoral - dummy variable for region (0,1), 1 if located Minho Litoral

Site quality when age is not known

- The SUBER model uses different equations according to the availability of data

$$S = 26.63463 + 1.82950\ sandy - 73.91054 \frac{1}{soil\ depth} - 0.00423\ insolation$$

$$S = 33.66346 + 2.14654\ sandy - 36.36852 \frac{1}{subsoil\ depth} - 0.00653\ insolation$$

$$S = 35.98420 + 2.81039\ sandy - 0.00816\ insolation$$

Soil depth - requires opening a soil profile and improves the quality of the model substancially