SUBER model

The new version of the SUBER model - predicting multi products from the cork oak ecosystem

SUBER model – modules

- ➔ Estimation of site productivity
- ➔ Model initialization

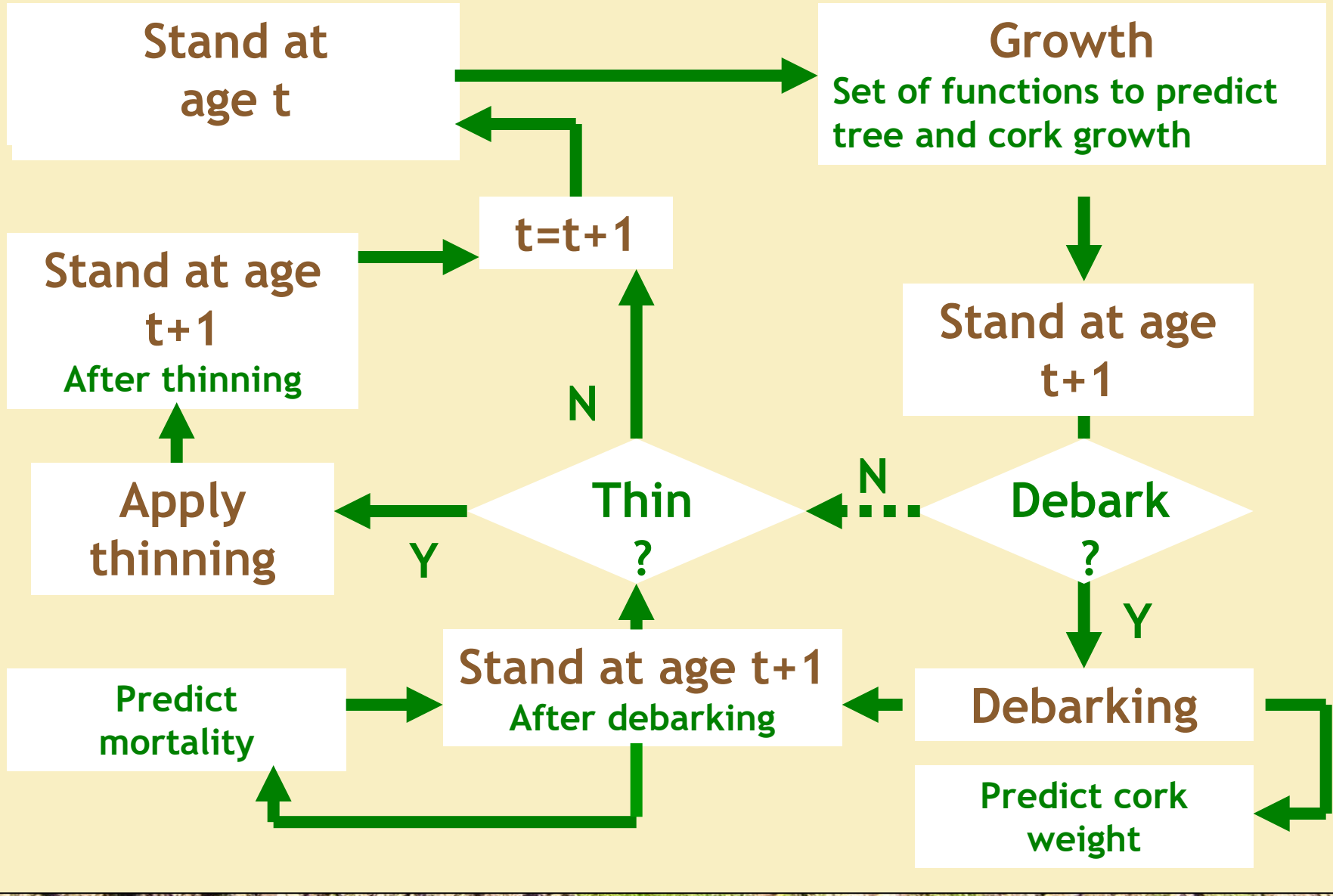
  in which the model simulates the variables that are not available from forest inventory
- ➔ Simulation of the growth of each tree (individual tree model)
- ➔ Simulation of cork parameters

  cork growth, evolution of cork thickness, cork weight prediction, cork quality
- ➔ Simulation of silvicultural practices

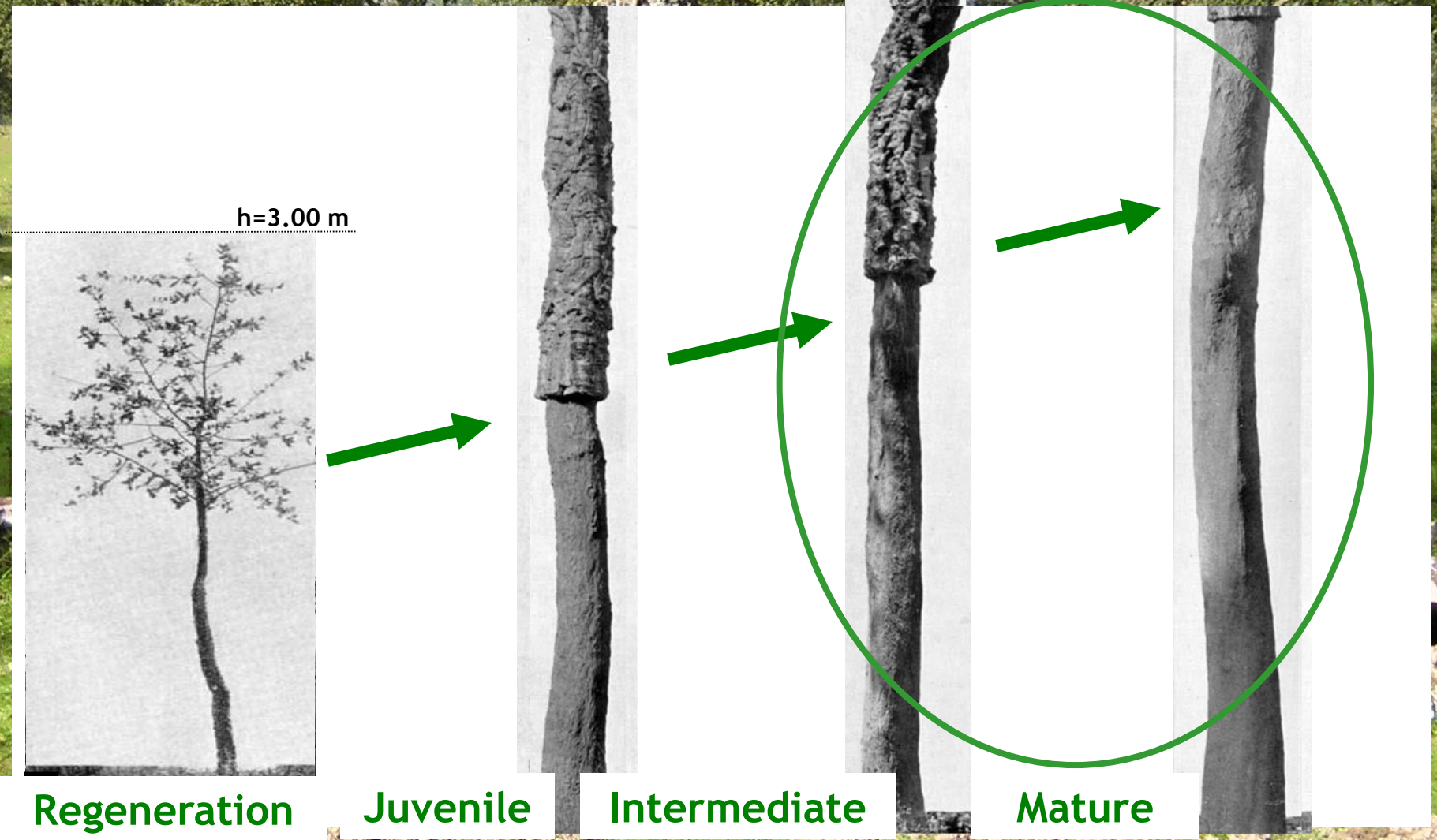
  Thinning (uniform system, selection system)

  Regeneration
- ➔ Non-cork products and services

Structure of the model



Stages of tree development



SUBER model – modules

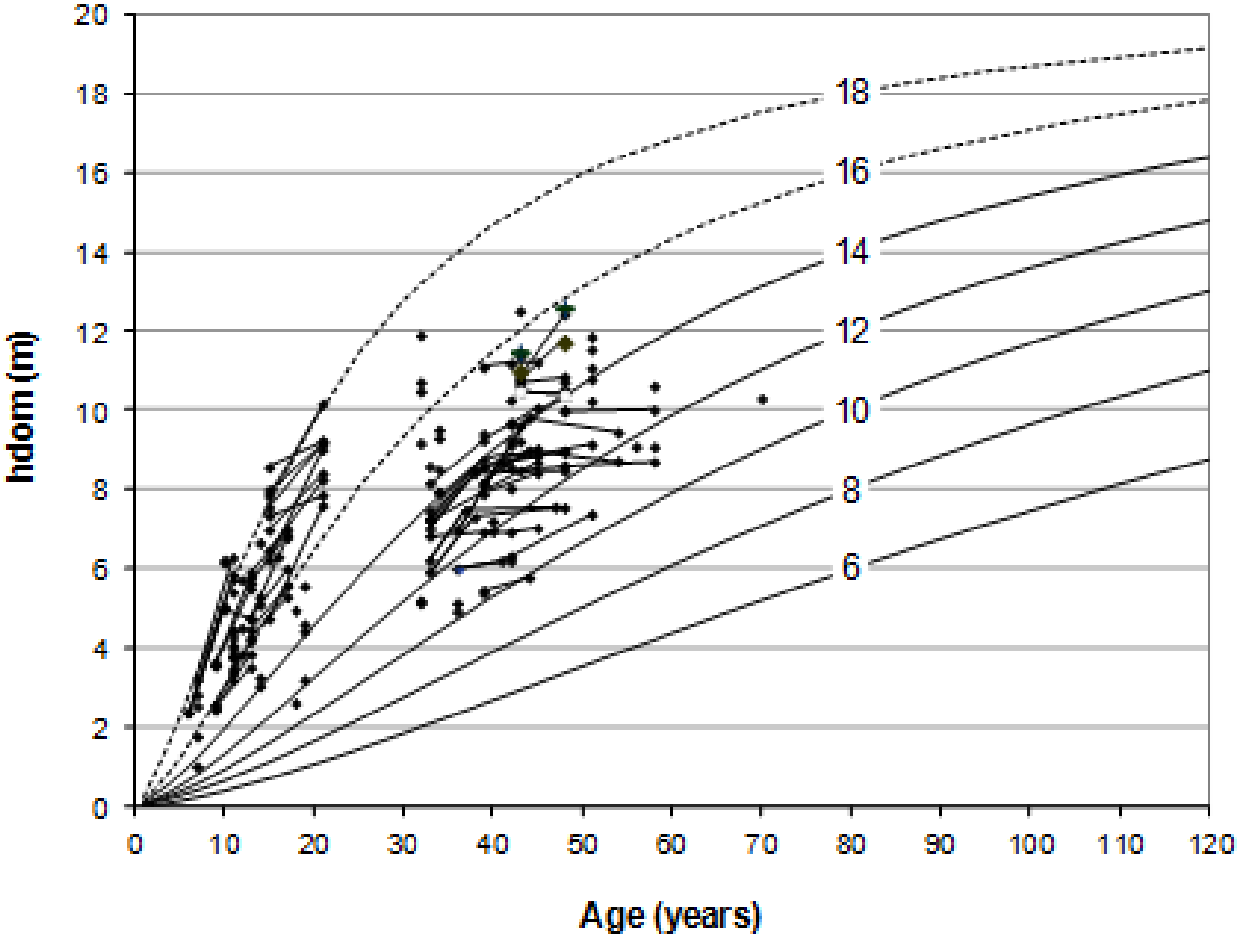
➔ **Modules:**

- ✓ **Prediction of site productivity**

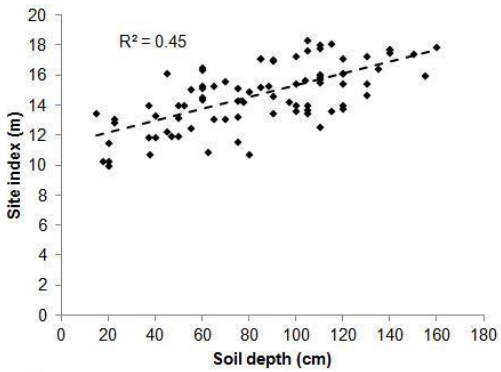
Prediction of site productivity

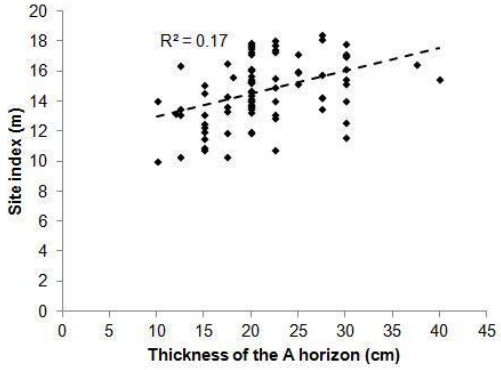
- The development of this module was based on several plots established in juvenile stands (age known) representative of the cork oak stands in Portugal (contrasting climate and soil)
- Each site was object of a detailed characterization of the soil, including the study of the whole profile
- Climate was characterized by the nearest weather station (IM) and by available soil digital information
- The site index curves for cork oak developed for Spain - Mariola Gonzaléz - were used to estimate site index (S) for each plot
- The relationship between S and climate and soil characteristics was then modeled (reduced model and full model)

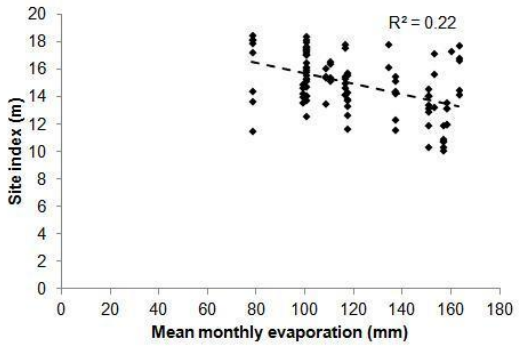
Prediction of site productivity

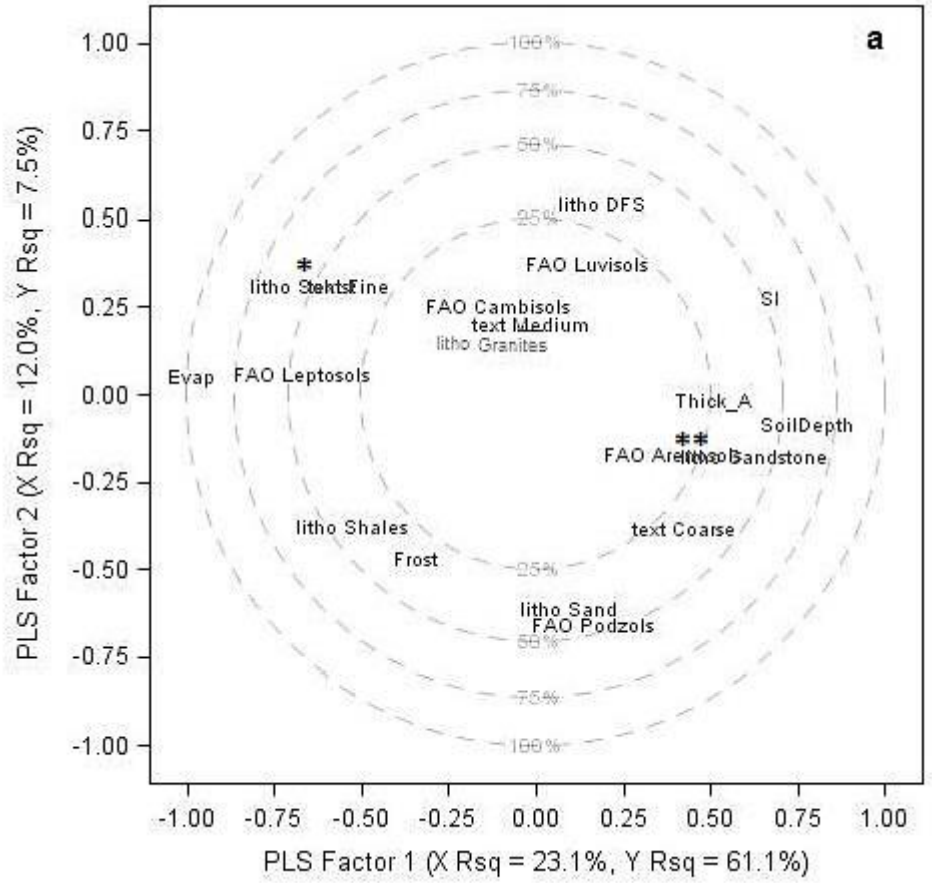


Prediction of site productivity

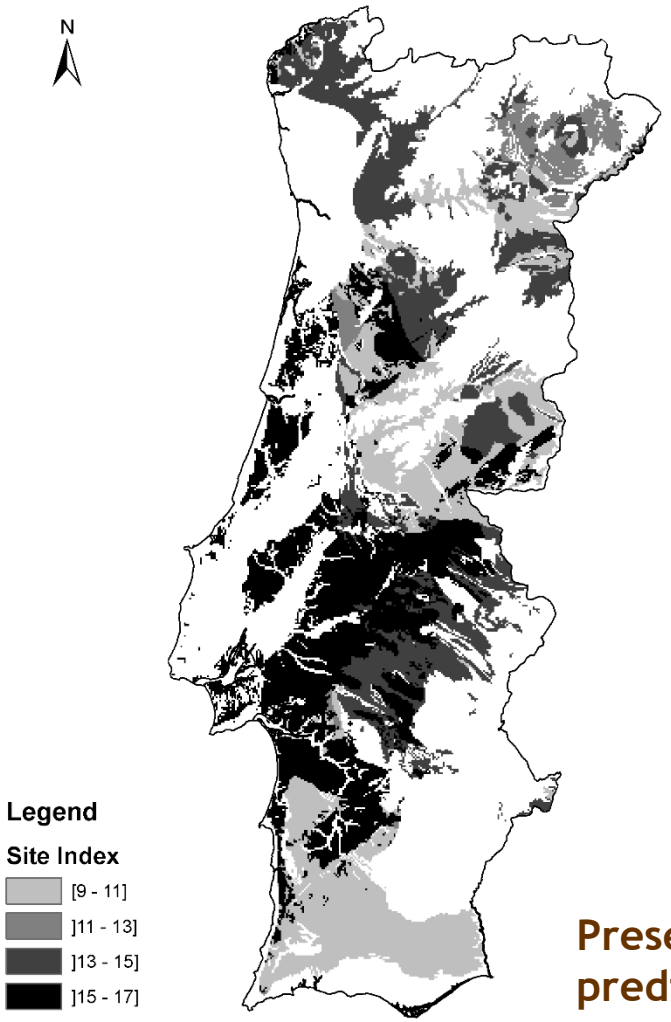








Prediction of site productivity



Presently working on the prediction and mapping of cork growth index distribution

SUBER model – modules

➔ **Modules:**

- ✓ Methodology to estimate site productivity
- ✓ Growth model for trees in the regeneration stage

Growth of trees in the regeneration stage

- The growth model for trees in the regeneration stage was based on data from provenance and regeneration trails (M. H. Almeida)
  - Dominant height growth is modeled with the Spanish site index curves
  - Mean and minimum tree heights are predicted from dominant height
  - Height distribution is modeled from those variables
  - Each tree is given a height according to the height distribution

SUBER model – modules

➔ **Modules:**

- ✓ Methodology to estimate site productivity
- ✓ Growth model for trees in the juvenile stage
- ✓ Transition between the regeneration and juvenile stages
- ✓ Growth model for the juvenile stage

Transition regeneration → juvenile

➔ The transition of a tree from the regeneration to the juvenile stage was modelled with data from a large set of plots established in juvenile stands

- When a tree attains a height = 3 m, it comes to the juvenile stage and its diameter is predicted (with some random effect added):

$$d = -8.16726 + 4.52004\ h + 0.02467\ N - 0.00653\ h\ N + 0.33615\ h_{mean}$$

- From then on tree dbh growth is modeled with an equation specifically developed for this stage:

$$id = \frac{1}{3}\left(0.7356 + 0.0178\ d - 0.0475\ G + 0.0763\ Si\right)$$

- Tree height and crown diameter are predicted with the same functions used for the adult stage, using du estimated from

$$du = -1.5276 + 0.8321\ d$$

SUBER model – modules

➔ **Modules:**

- ✓ Methodology to estimate site productivity
- ✓ Module to simulate growth of trees in the juvenile stage
- ✓ Transition between the regeneration and juvenile stages
- ✓ Growth model for trees in the juvenile stage
- ✓ Transition between the juvenile and adult stages

Transition juvenile → adult

➔ The transition of a tree from the juvenile to the adult stage includes three sub-models:

- ✔ Decision about debarking (for even-aged stands, when p% of the trees have a d>22.28 cm)
- ✔ Prediction of diameter under cork

$$du = -1.5276 + 0.8321\ d$$

- ✔ Simulation of height of branching
- ✔ Simulation of the number of branches that will be debarked

Monte-Carlo simulation using observed distributions by NUTII or a user defined distribution

SUBER model – modules

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- ✓ Methodology to estimate site productivity
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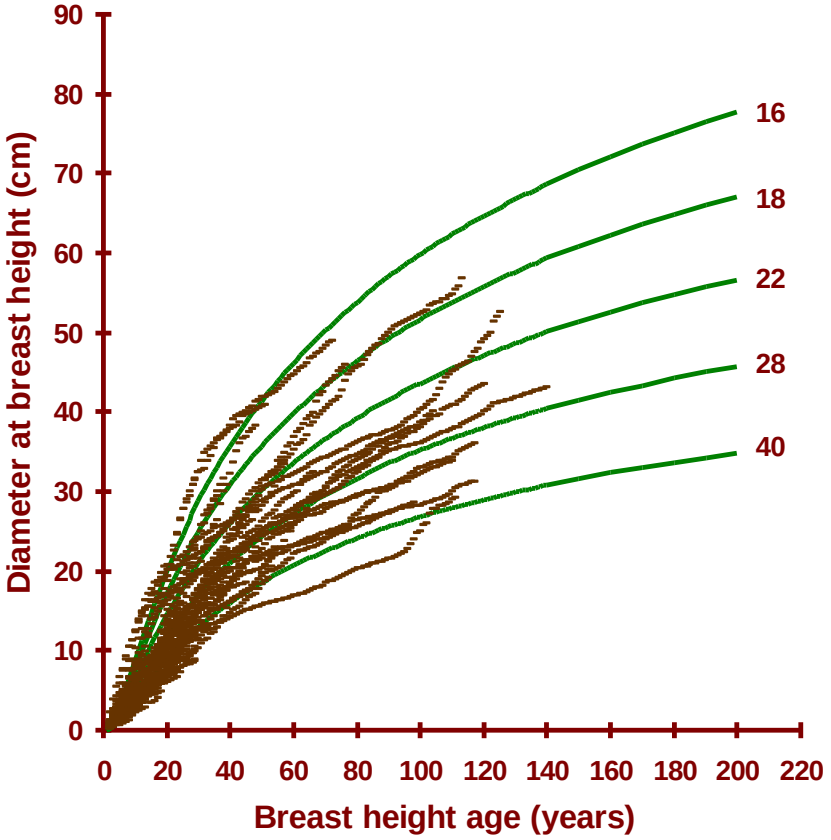
- ✓ Growth model for trees in the adult stage

SUBER - tree growth at dbh

data from stem analysis



Growth of trees in the adult stage

➔ Diameter under cork growth model for dominant trees was developed using the Richards function formulated as an age-independent difference equation

k parameter

$$d_{t+a} = 200 \left(1 - e^{-\left(-0.00173 + 0.000383\ Si\right) a} \left(1 - \left(\frac{d_t}{200}\right)^{1.0819}\right)\right)^{\frac{1}{1.0819}}$$

- ✔ If stand age is known, S can be directly estimated, if not it can be predicted from soil and climate characteristics
- ✔ Genetic variability is simulated through the k parameter
- ✔ Tree height and crown diameter are also predicted with prediction functions common to juvenile and mature stages

SUBER model – modules

➔ **Modules:**

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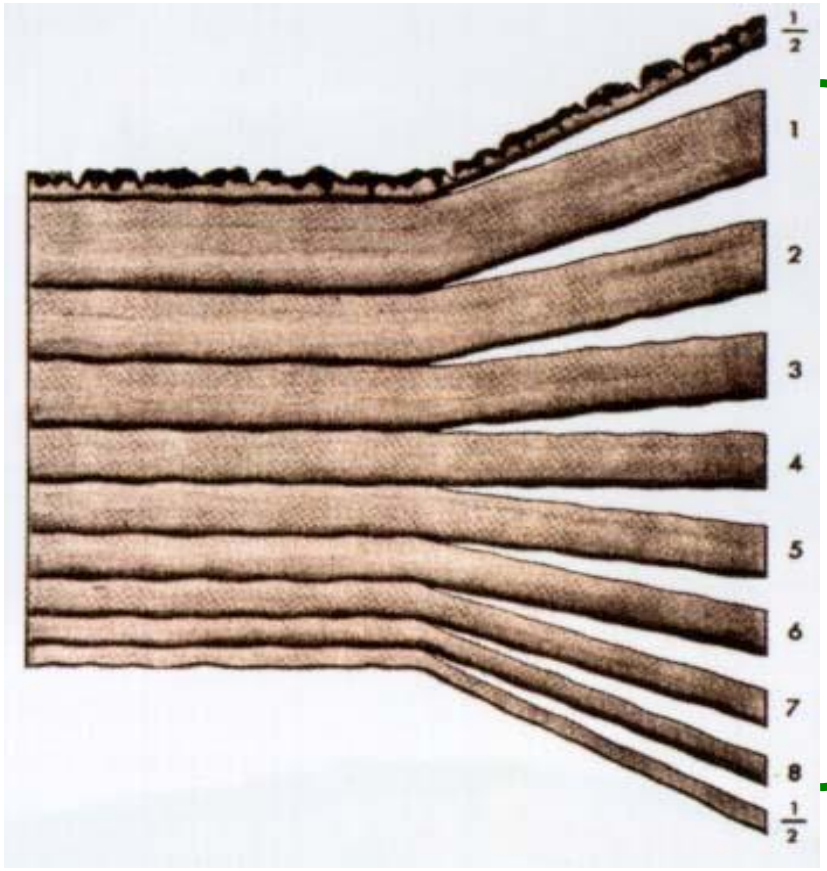
- ✓ Prediction of cork weight as a function of cork age

Modelling options - cork growth

Example with a cork with 9 years



1st half year

8 complete years

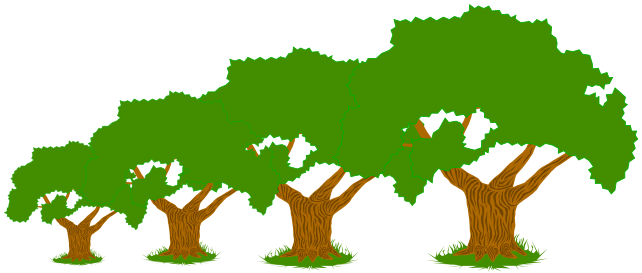
(cork growth index)

last half year

total cork thickness

Modelling options - cork growth

➔ Cork growth sub-models:

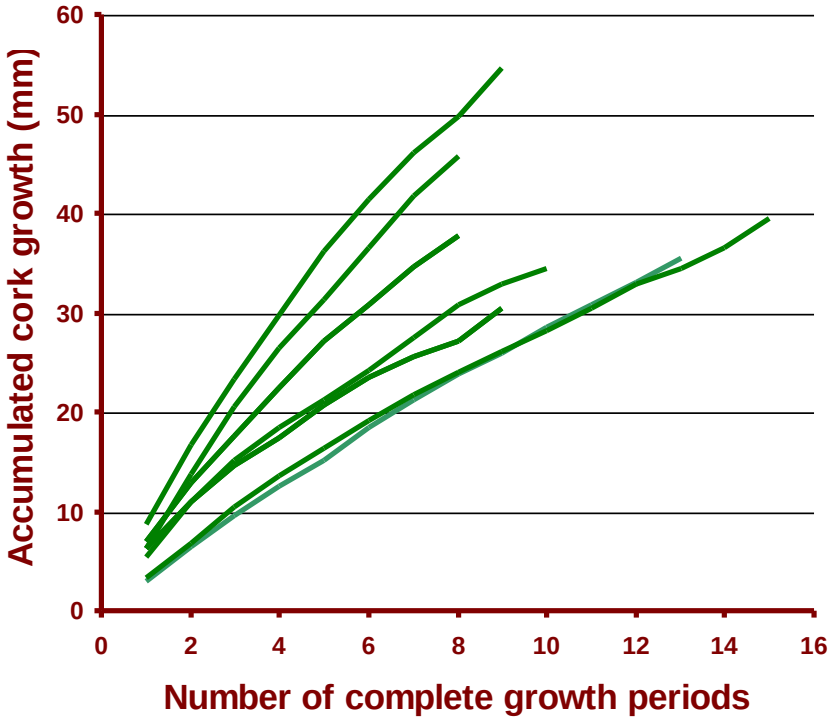


- juvenile stage
  - 1st cork thickness distribution
- intermediate and mature stages
  - cork growth prediction (complete years)
  - total cork thickness prediction

    (as a function of the thickness of complete years)
  - evolution of cork growth index through successive cork extractions
  - modification of cork growth index as a consequence of cork extraction intensity??? -> next topic!

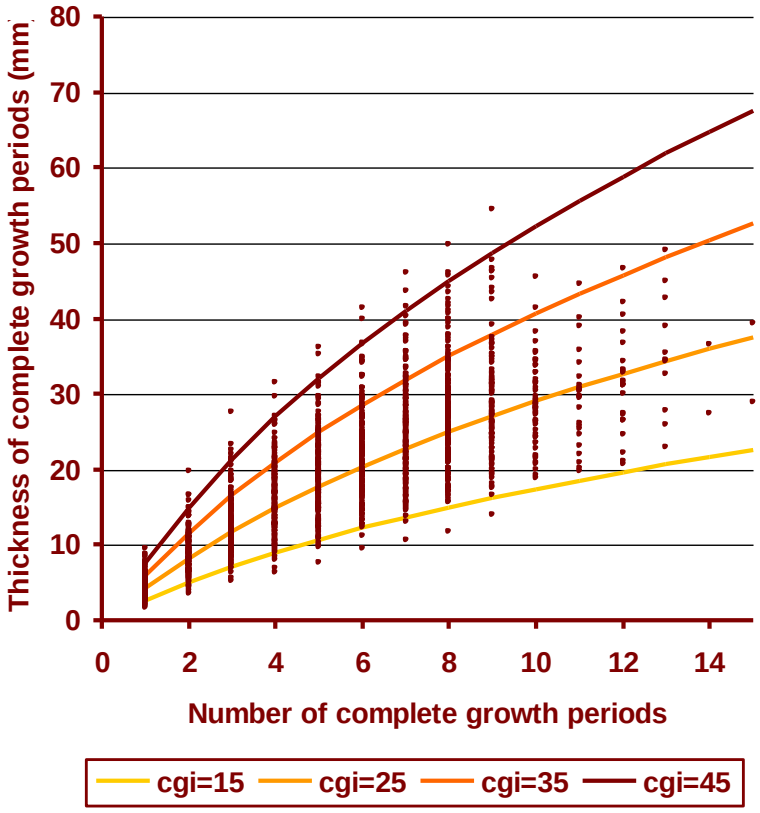
SUBER - cork growth

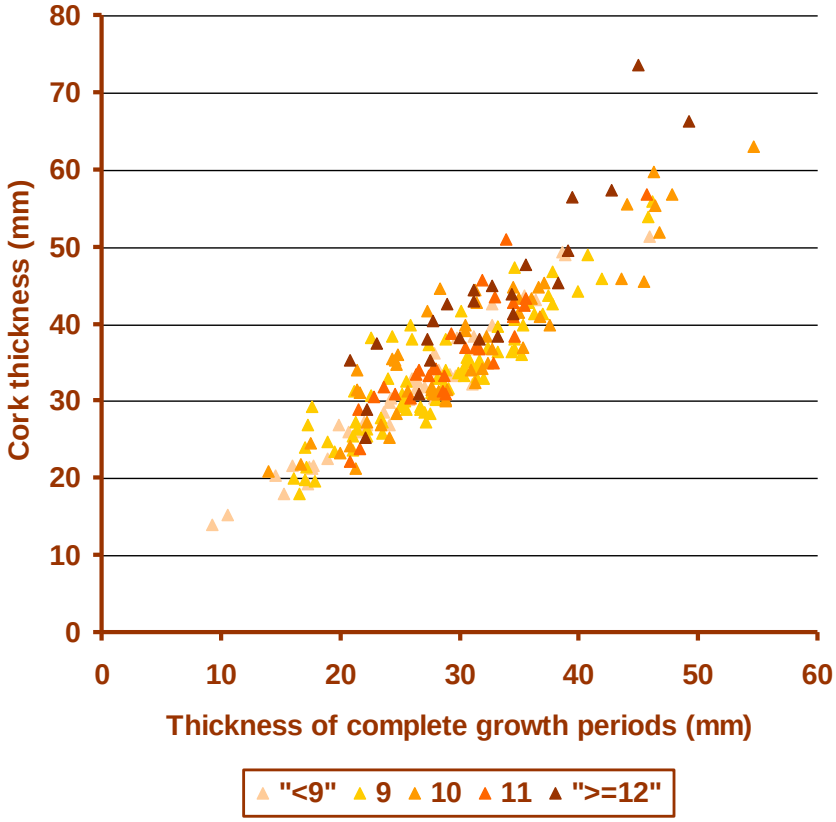
Data from cork ring measurements in cork samples with ages ranging from 7 to 16 years



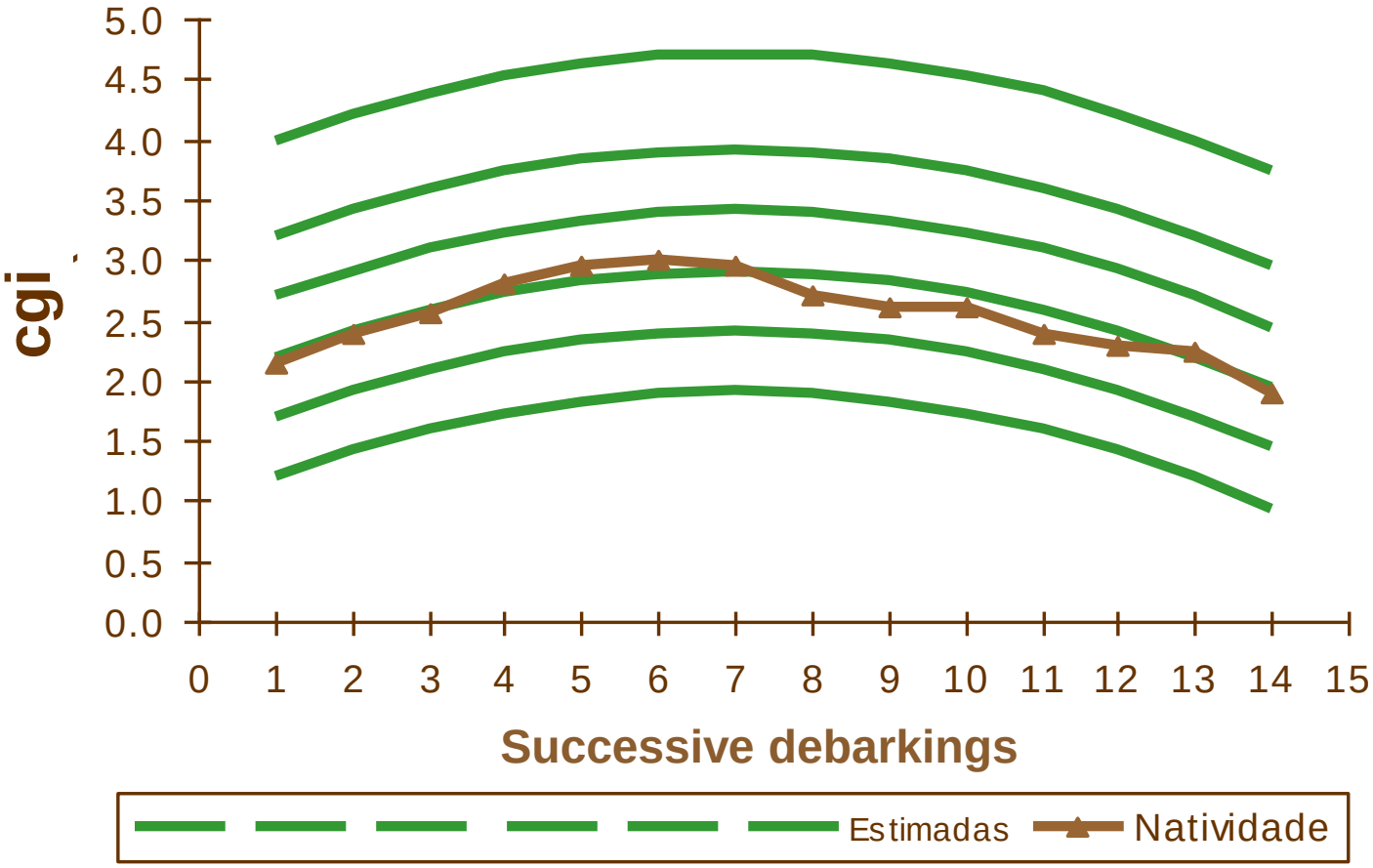
SUBER - cork growth

Data on the relationship between total cork thickness and thickness of complete rings





Evolution of cgi in sucessive debarkings



Prediction of cork weight using cork age

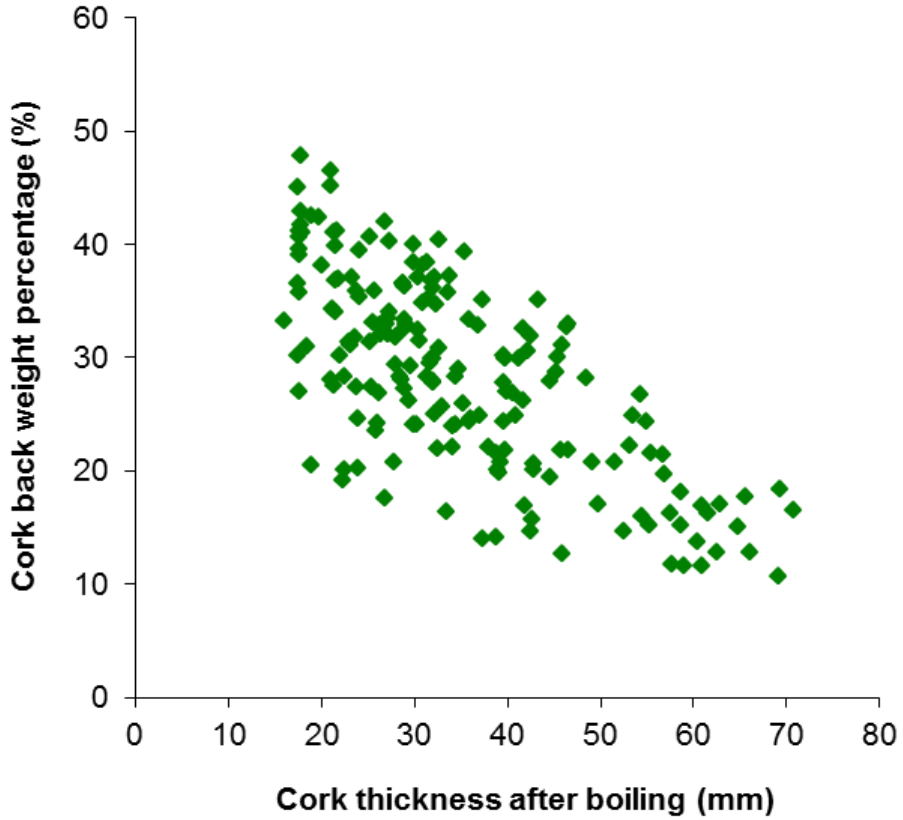
- Equation to predict cork weight for corks with 9 years
- Equation to predict % cork back weight at 9 years of age (cbp_9)
- Estimate the biomass of cork tissue free from the cork back

$$wcm_{9\_b} = wcm_9\left(1-\frac{cbp_9}{100}\right) = wcm_9 - \underbrace{wcm_9\frac{cbp_9}{100}}_{\text{biomass of cork back}}$$

- Estimate the cork biomass for t years of growth

$$wcm_t = \underbrace{wcm_{9\_b}\frac{ctab_t}{ctab_9}}_{\text{biomass of cork tissue}} + \underbrace{wcm_9\frac{cbp_9}{100}}_{\text{biomass of cork back}}$$

Percentage of cork back (in weight)



SUBER model – modules

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- ✓ Simulation of thinnings without using competition indices

Simulation of thinnings without CI

- The SUBER 3 model was used to simulate the development of several plots with alternative thinning strategies
- These simulated data were used to develop a model that predicts the probability of a tree being thinned (logistic regression):

$$p(\text{thinned}) = 1 - \frac{e^{\pi}}{1 + e^{\pi}}$$

$$\pi = -3.9800 + 0.00776 \ \text{du} + 6.8988 \ \text{Rdm} - 12.6742 \ \text{RCE}$$

- Trees are "thinned" with Monte-Carlo simulation
  - Uniform system: all trees at the same time
  - Selection system: by diameter class, towards a target distribution

SUBER model – modules

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- ✓ Simulation of thinnings without using competition indices
- ✓ Non-cork products and services

Non-cork products and services

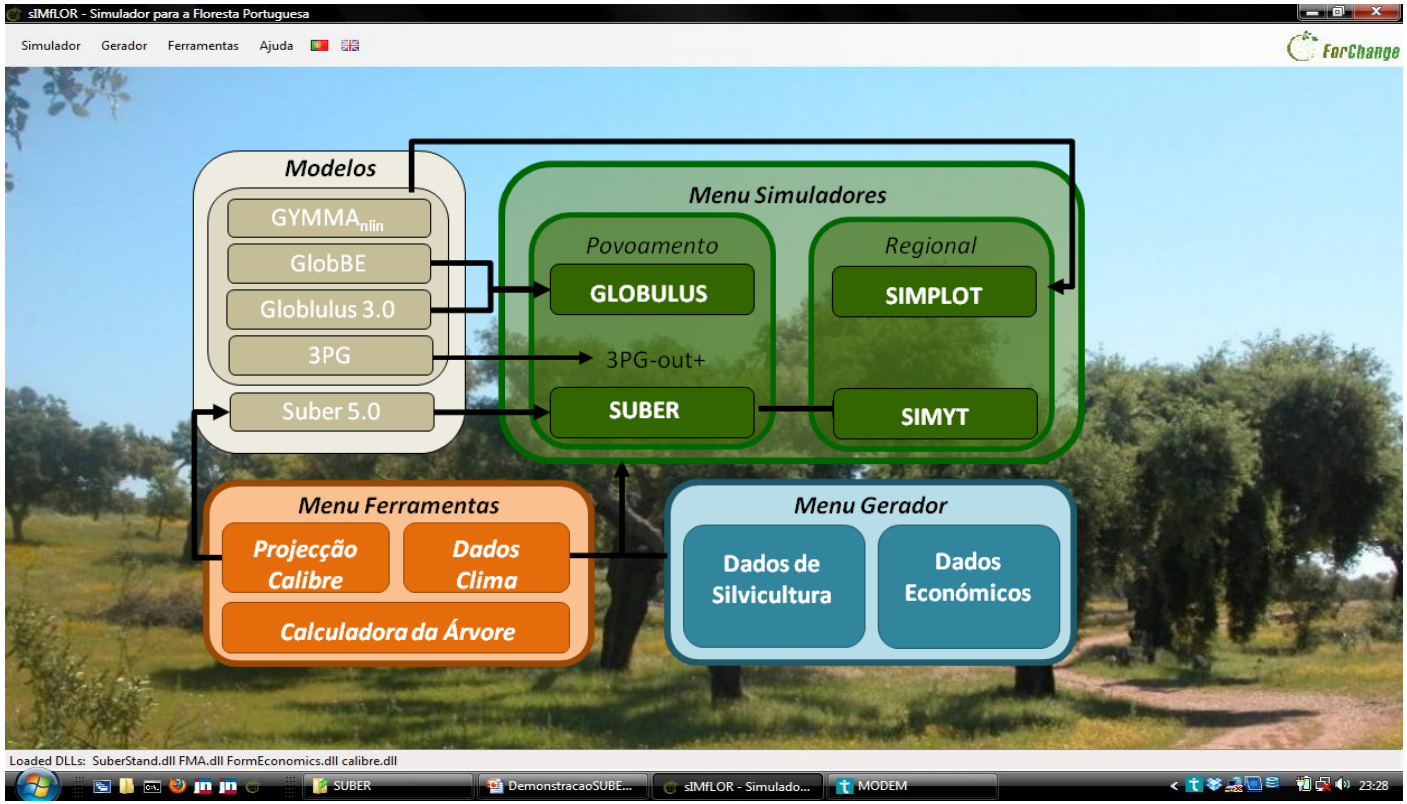
➔ **Products considered:**

- ✔ Wood from thinnings and harvests (under implementation)
- ✔ Total biomass by tree components
- ✔ Carbon (total and by tree components)

Just a few words on…

➔ sIMfLOR forest simulators platform

- ✔ www.isa.ulisboa.pt/cef/forchange/fctools



Just a few words on…

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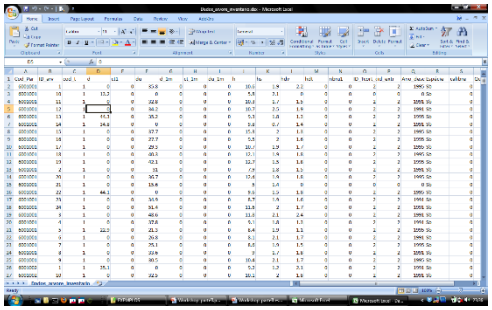
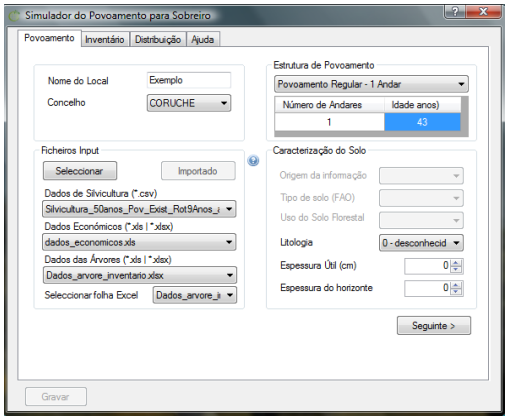
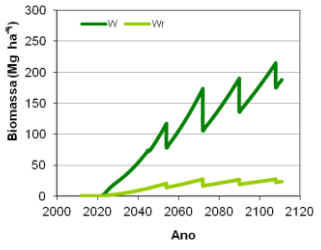
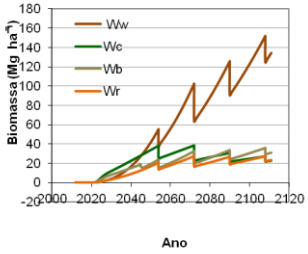
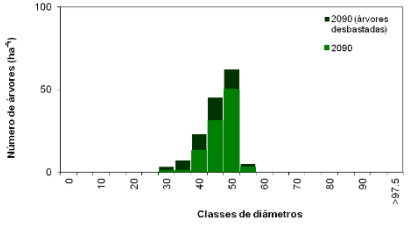
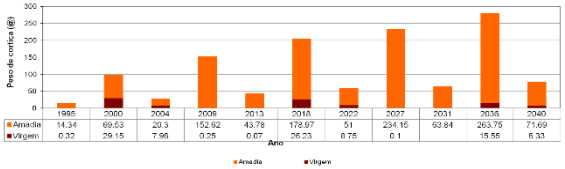












SUBER model – application

THE PROBLEM

- During the last decades cork oak stands have been used as a silvopastoral system with sheep grazing underneath the trees
- Some landowners think that grazing is no more profitable, so they are considering several alternatives:
  - Increase stand density at least for 50% crown cover (OPTION 1)
  - Maintain a lower stand density (40%) and move to a selection system (OPTION 2)
  - Maintain a lower stand density (40%) combined with read deer to increase the income (OPTION 3)

SUBER model – application

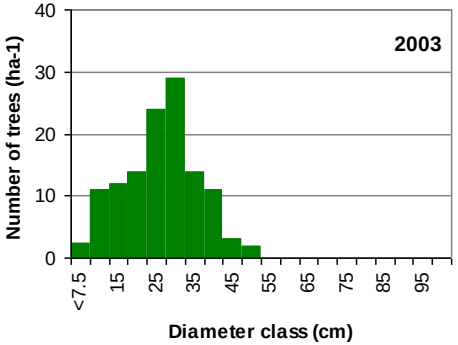
AN EXAMPLE

- Application to a stand with 252 ha
- Stand density: 136 ha^{-1}
- Basal area: 7.76 m^2 ha^{-1} (under bark)
- Quadratic mean dbh: 28 cm
- Crown cover: 40%

➔ It is a relatively young stand, “more or less” even-aged

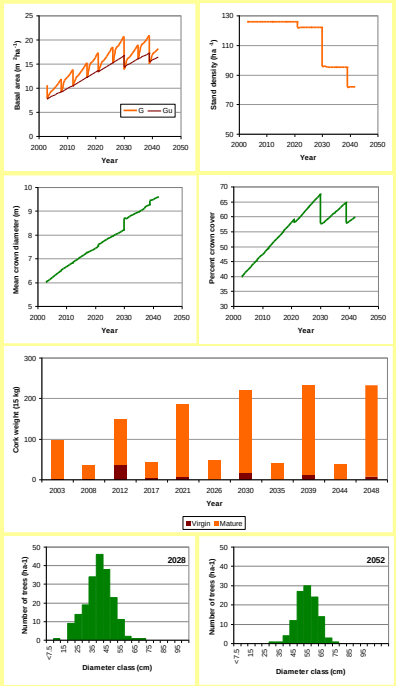
➔ Cork rotation is 9 years, with two extractions in a 9 years period (two cork ages)

Present status of the stand



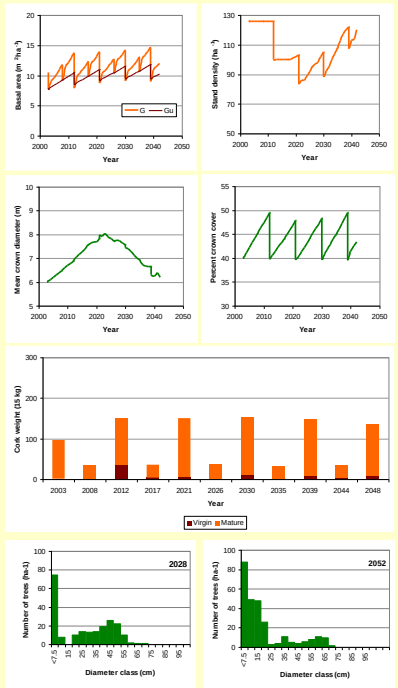
Net present value ha^{-1} 13975.1

OPTION 1



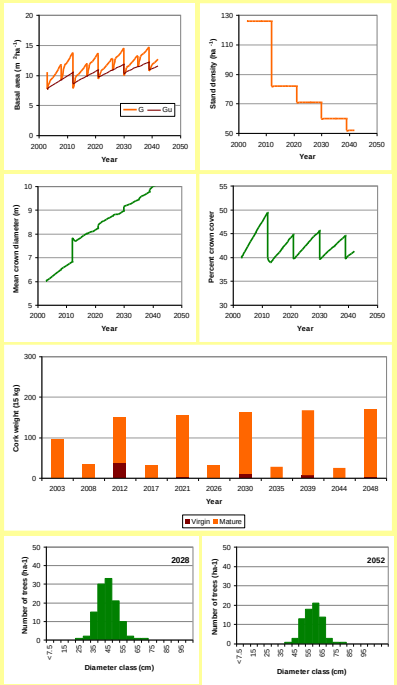
Net present value ha^{-1}=16238

OPTION 2



Net present value ha^{-1}=13539

OPTION 3



Net present value ha^{-1}=14174

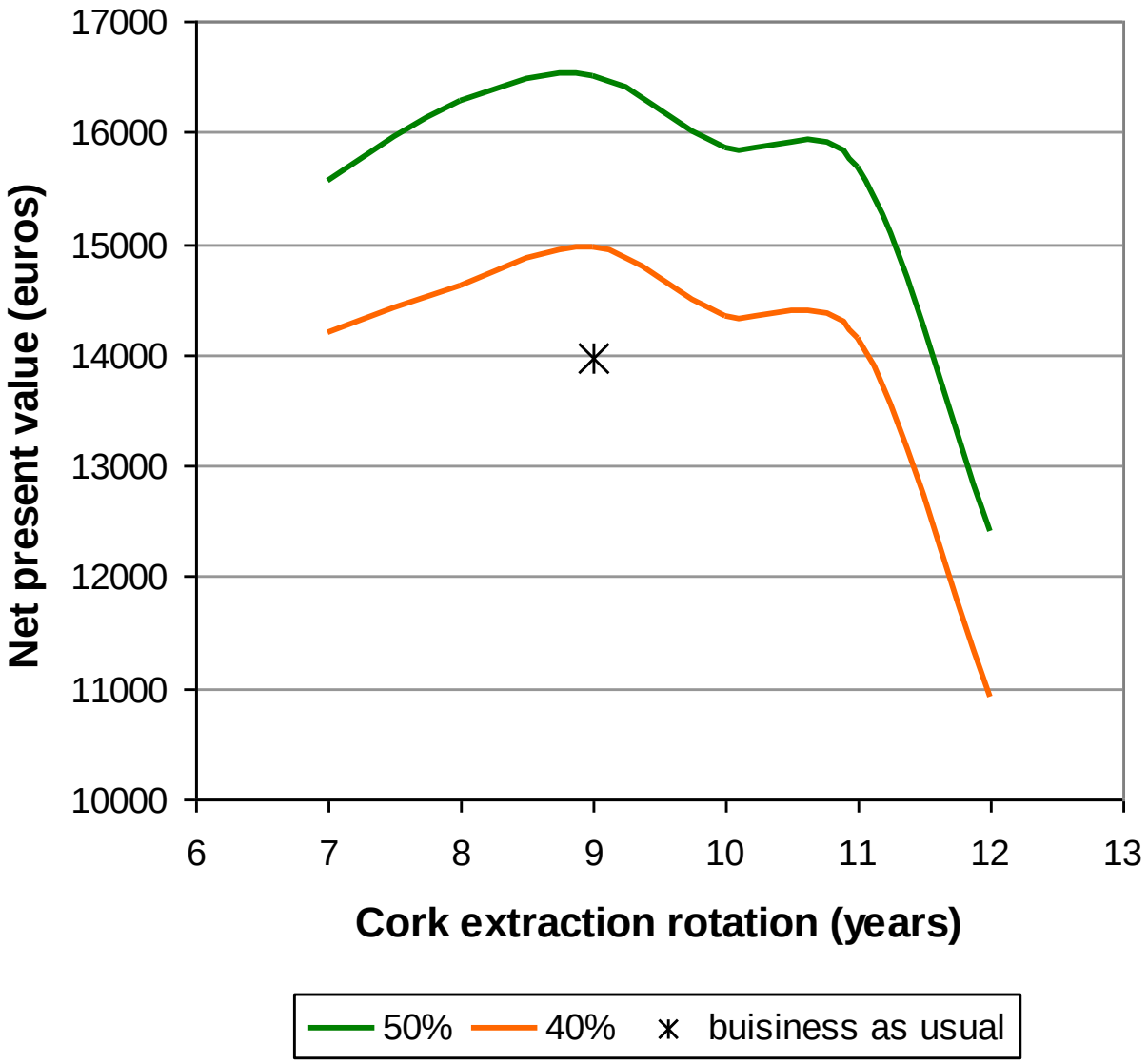
SUBER model – application

CONSEQUENCES

➔ After this first application the landowners put other questions:

- ✔ Is 9 years the best cork extraction rotation?
- ✔ Is it wise to concentrate cork extraction on every i^{th} year?
- ✔ Should cork extraction intensity be increased from now or from the next debarking?

➔ Again, the SUBER model was used to give answer to these questions


17000
16000
15000
14000
13000
12000
11000
10000
Net present value (euros)
6
7
8
9
10
11
12
13
Cork extraction rotation (years)
50%
40%
buisiness as usual


29
The END