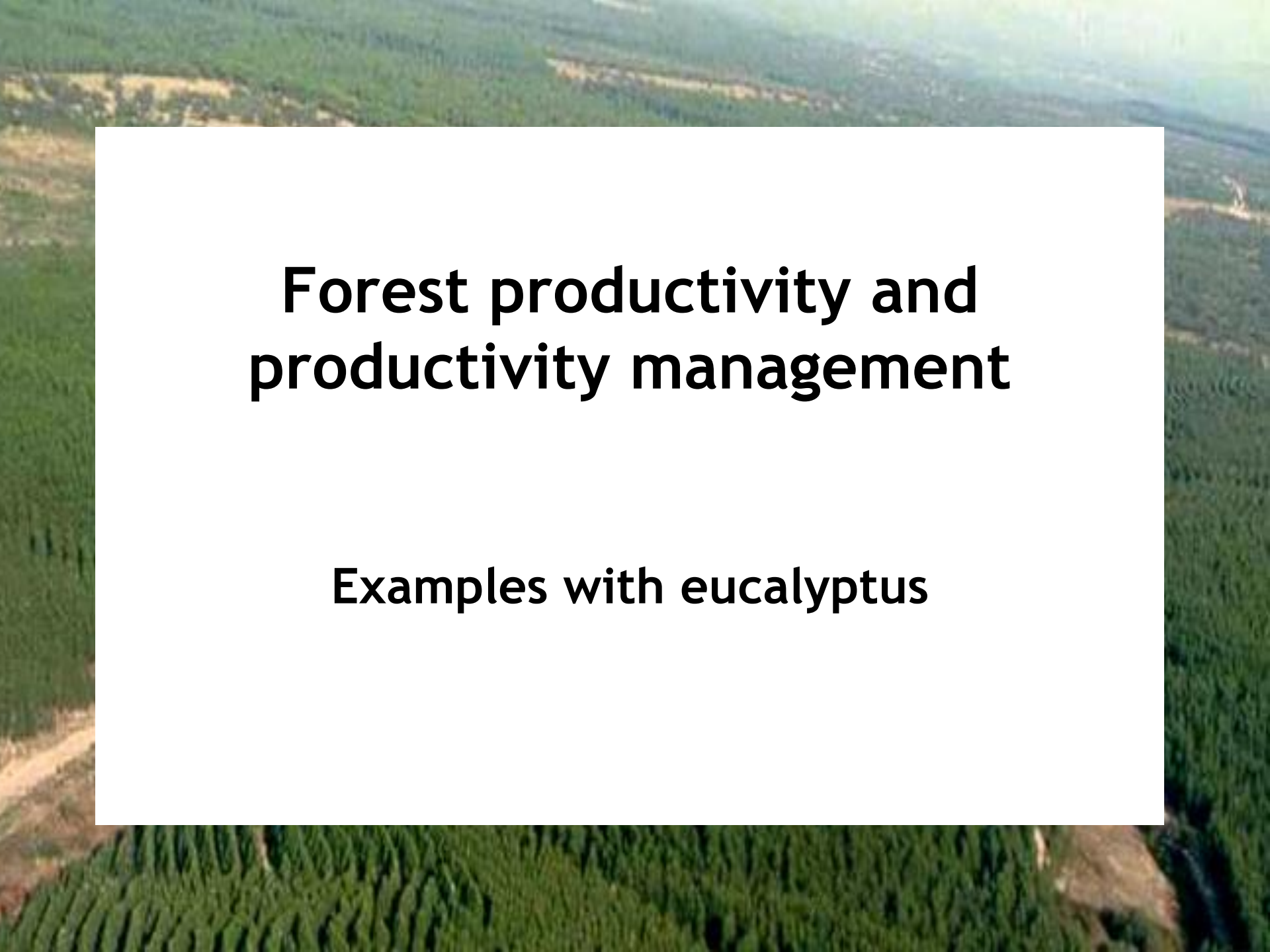


Forest productivity and productivity management

Examples with eucalyptus

summary

- **Potential and Actual productivity of a site**
- **Limiting factors – altering productivity**
  - Climate
  - Soil
- **Management of forest productivity – examples**
  - Alto do Vilão Trial – spacing
  - Optimization Trial – fertilization and irrigation
  - Agolada Trial – spacing and genetic material

Site productivity

- Site productivity may be defined as the potential net primary production of biomass or the accumulation of biomass/unit area/unit time
- It includes accumulation of tree biomass as well as all other plant and animal life in the site
- In complex systems NPP is distributed among the different species present in the system, while simple systems allow for the concentration of NPP in the desired species as well as in the desired product
- The potential production is achieved when the stand attains the maximum leaf area

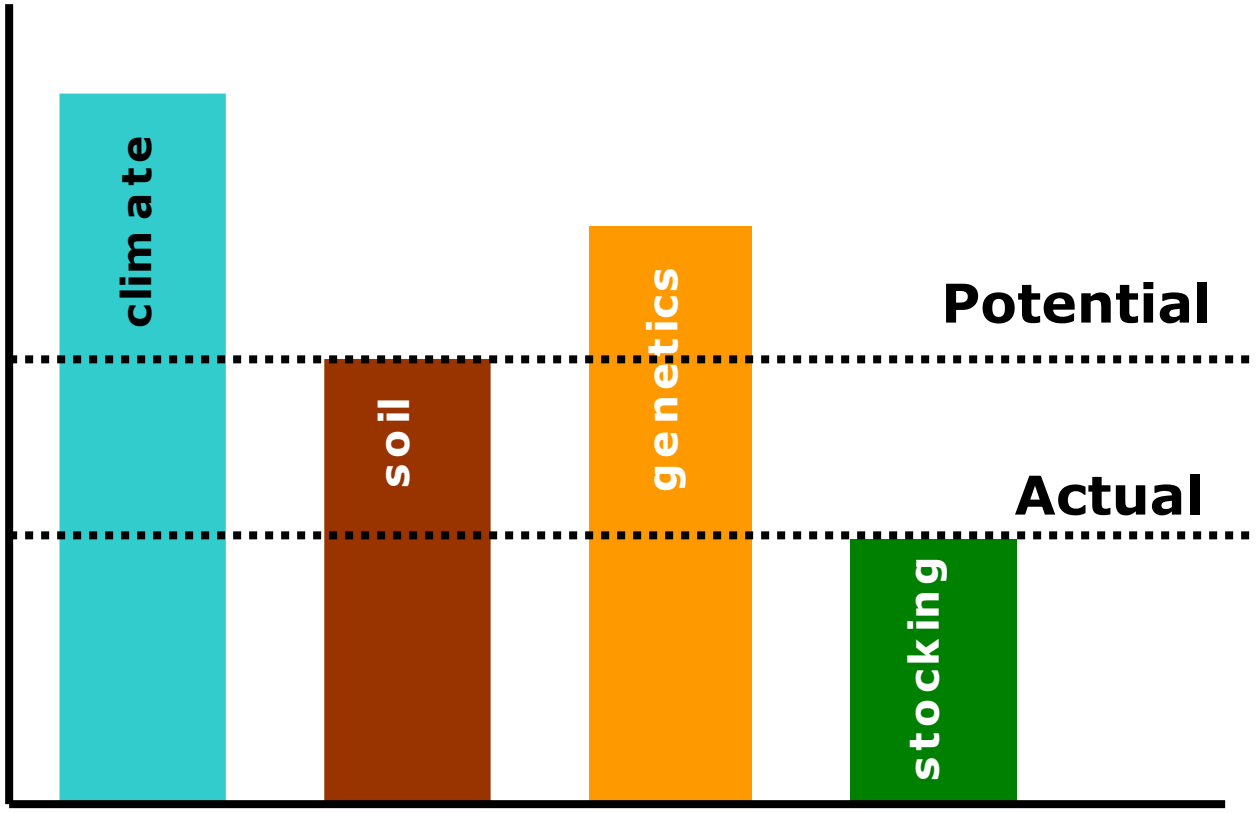
Site productivity - potential productivity

- Soil and climate determine the limits to the potential productivity of a site (PPS)
- Genetic potential (species and genetic material) determine the biological limits of PPS
- Management (spacing, weed control) determine to which point is the PPS attained. Management may also, obviously, change PPS (e.g. fertilization and/or irrigation)
- A site's maximum leaf area capacity may take more or less time to be achieved as a consequence of management and genetic potential

Site productivity

actual and potential productivity

Site productivity limited by stocking

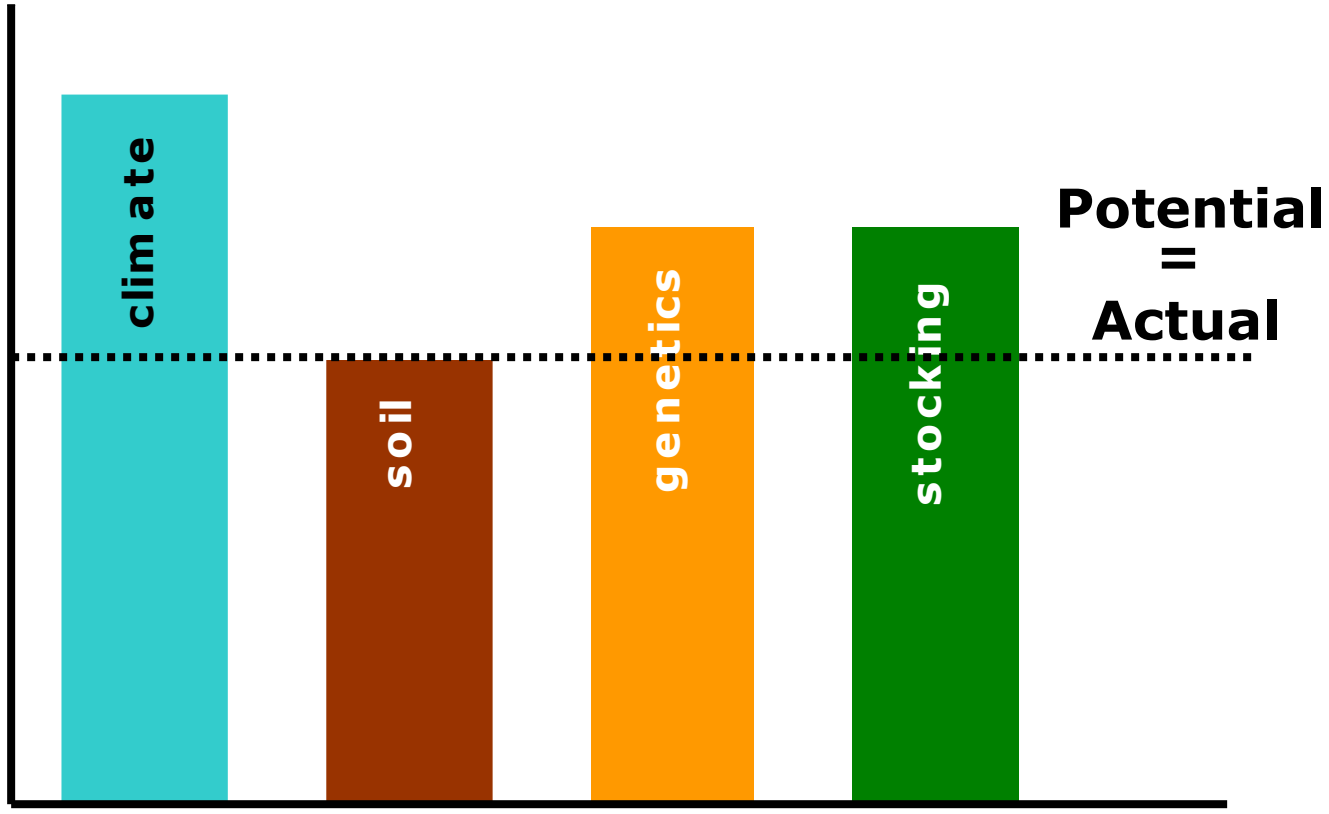


Adapted from Powers, 1999

Site productivity

actual and potential productivity

Increasing stocking ⇗ soil the limiting factor

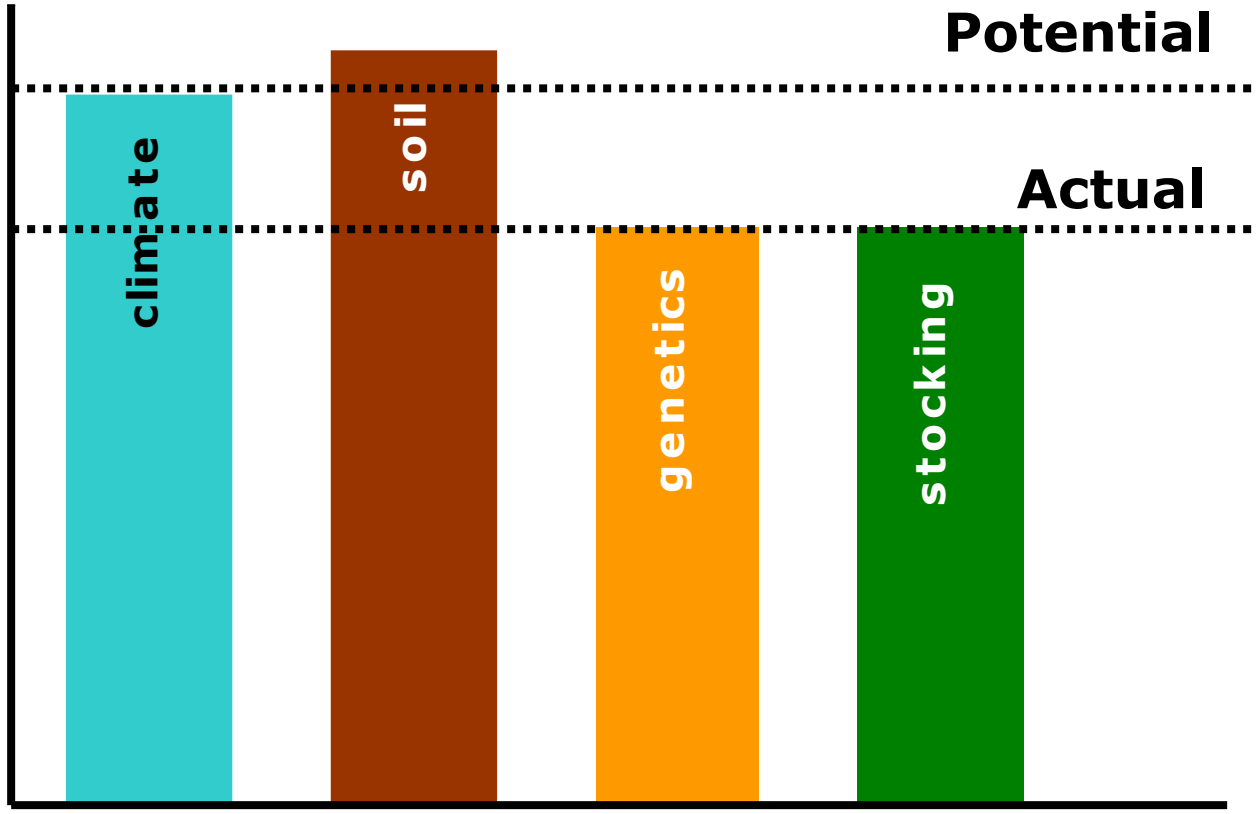


Adapted from Powers, 1999

Site productivity

actual and potential productivity

Soil amelioration ⇨ new limit set by climate

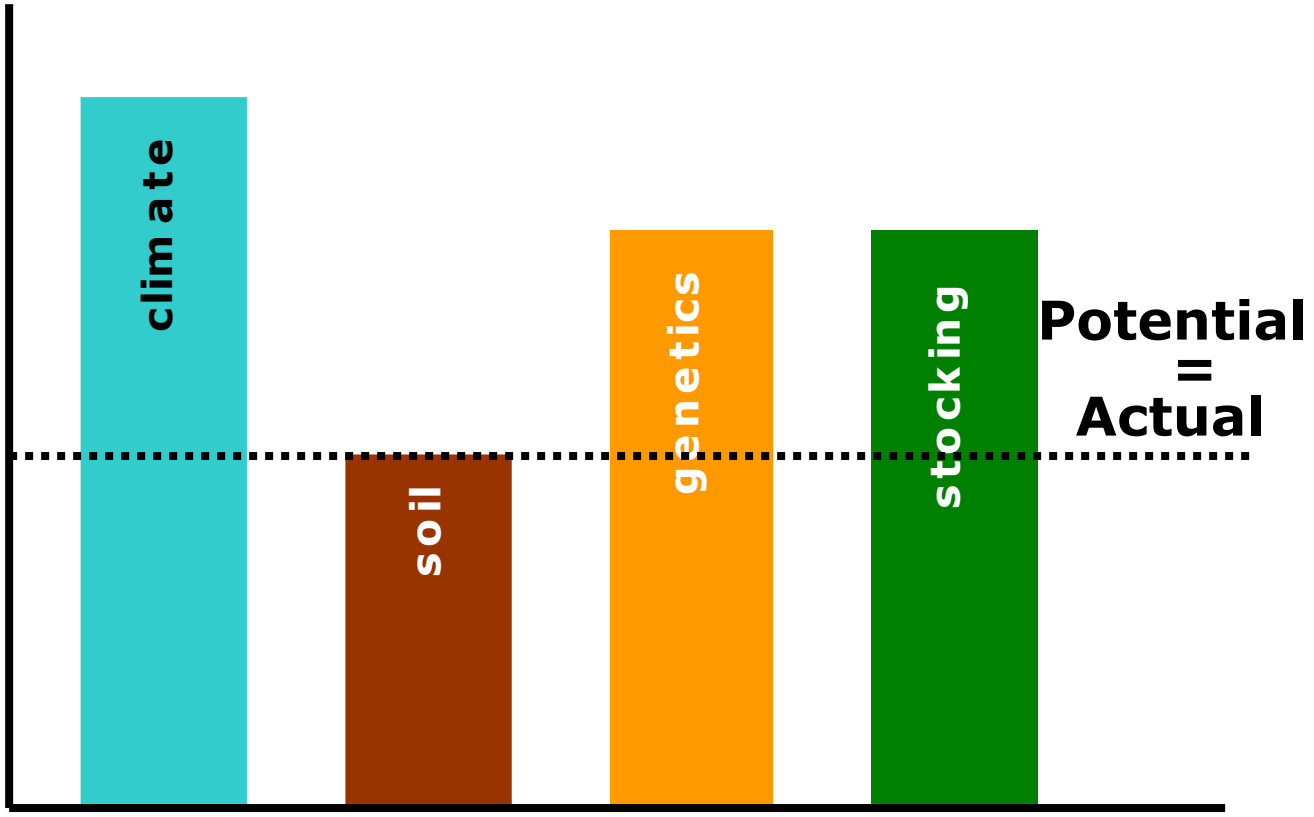


Adapted from Powers, 1999

Site productivity

actual and potential productivity

Soil degradation ⇒ new limit set by soil

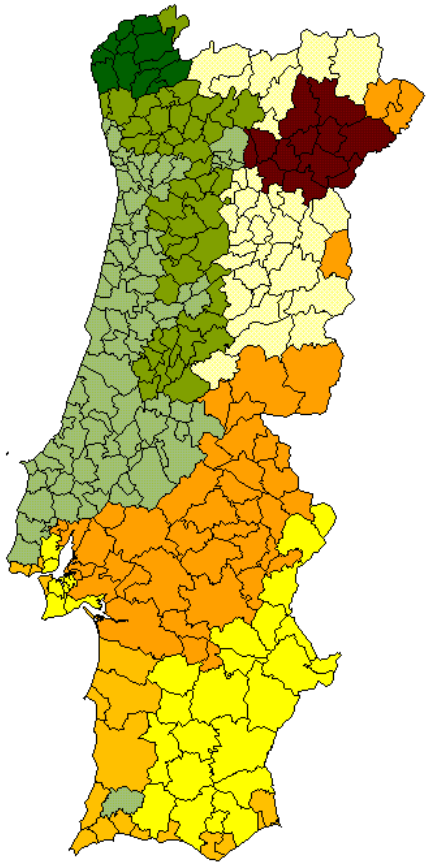


Adapted from Powers, 1999

Site productivity - Portugal

influence of climate in E. globulus plantations

Climatic classification of Portugal - 8 regions

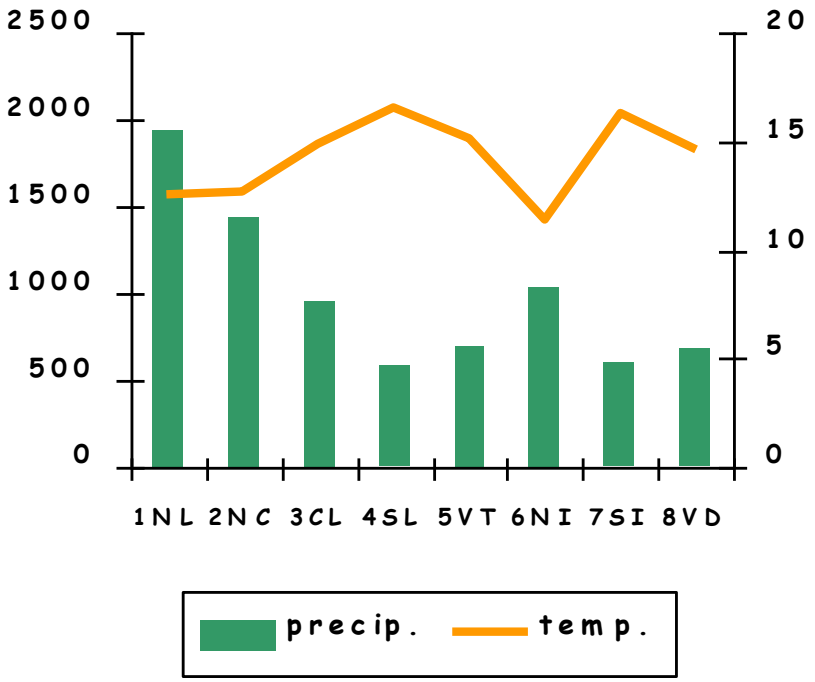


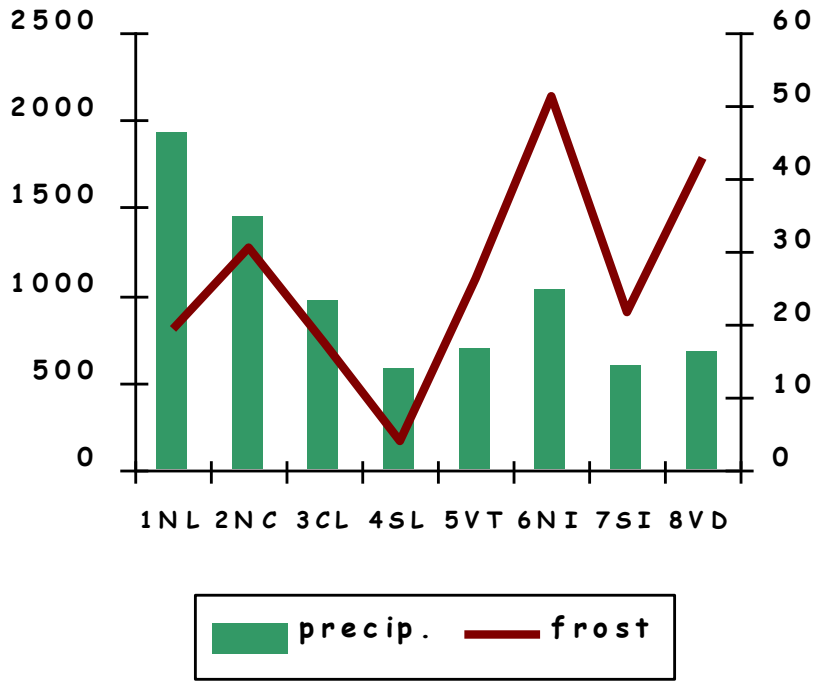
1 North Litoral
2 North/centre Litoral
3 Centre Litoral
4 South Litoral
5 Tagus Valley
6 North Interior
7 South Interior
8 Douro valley

Site productivity - Portugal

influence of climate in *E. globulus* plantations

Climatic classification of Portugal - 8 regions



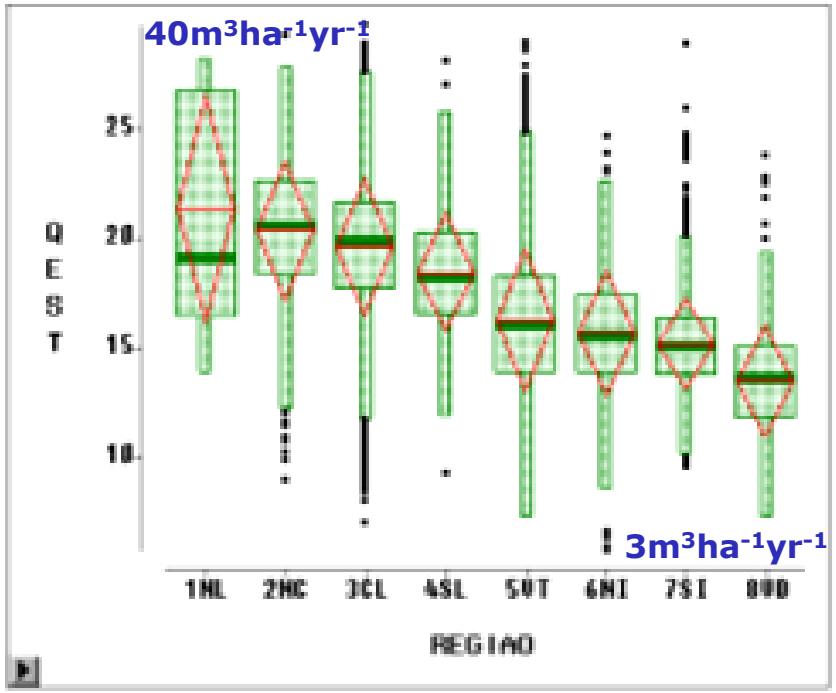


Site productivity - Portugal

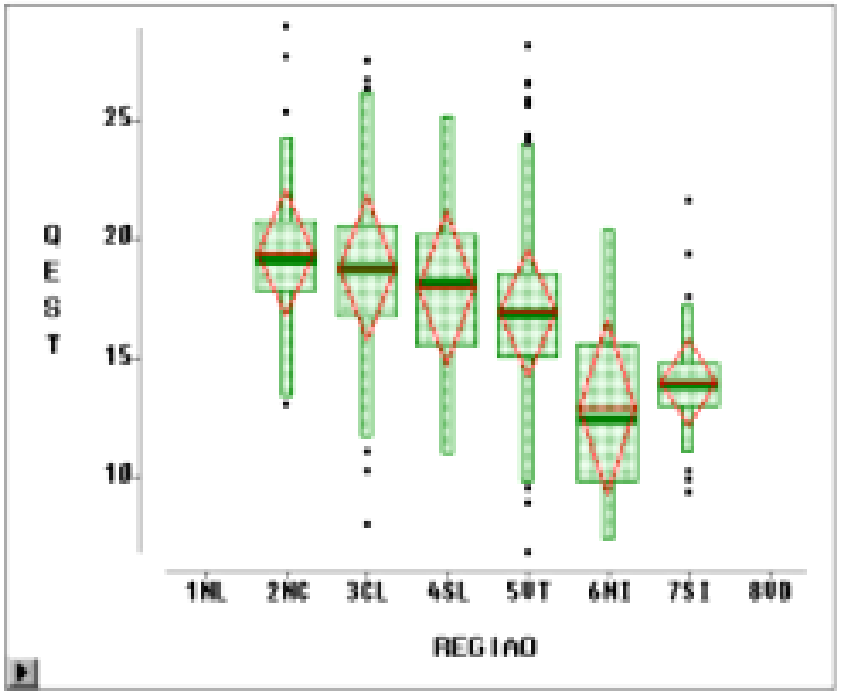
influence of climate in *E. globulus* plantations

Yield (site index, base age 10) in the 8 regions

1st rotation



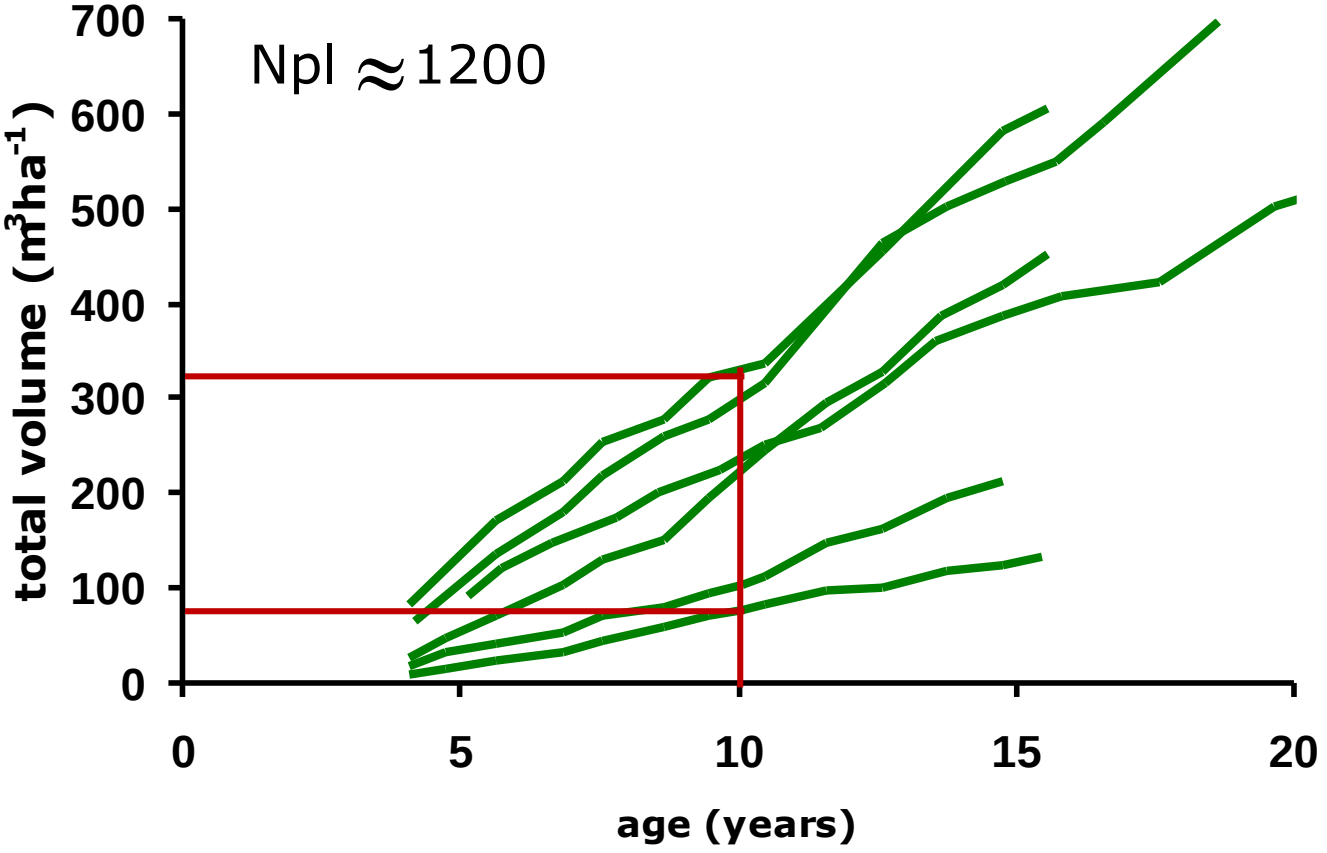
coppice



Site productivity - Portugal

influence of microsite in *E. globulus* plantations

Yield for plots located in the same farm



Management of forest productivity
EXAMPLES

Management of site productivity

- Foresters can manipulate tree growth by modifying the growing environment in order to optimize the quantity and quality of the desired product

- Modifications may include
  - appropriate silvicultural practices
  - management of site potential productivity
  - use of appropriate genetic material

- The success of such manipulation depends of course of a thorough knowledge of the processes that drive tree growth

ALTO DO VILÃO trial

spacing

Research team (CELBI, ISA)

Margarida Tomé, Paula Soares (ISA)
Luís Leal, João P. Pina, C. Araújo (CELBI)

Alto do Vilão trial - objectives

- Main objective
  - Evaluate the impact of initial spacing on productivity of *Eucalyptus globulus*
- through
  - The installation of a trial with different spacings
  - Annual monitorization of the trial to measure plant growth

Ensaio do Alto do Vilão

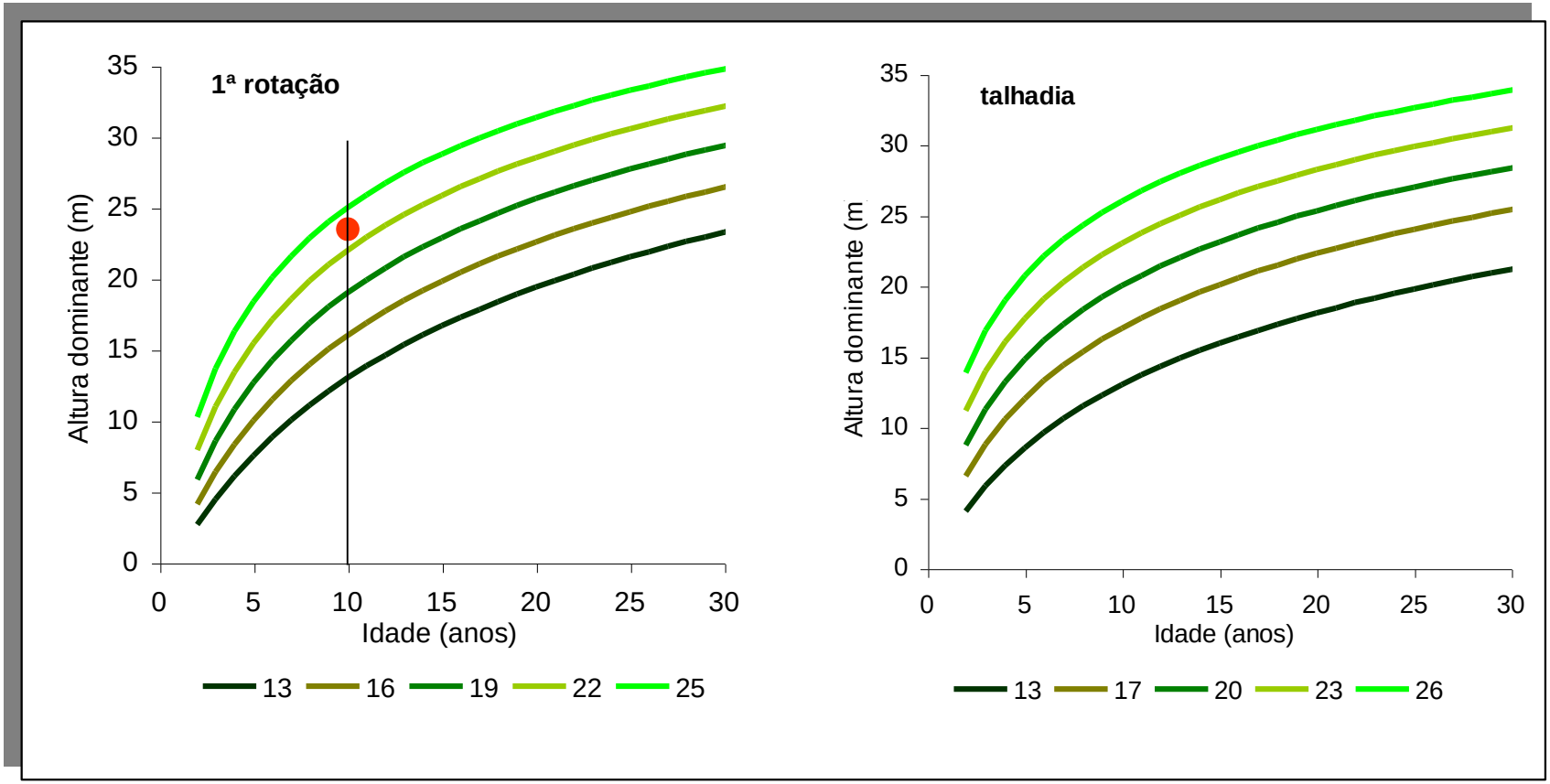
- Localization
  - Near to Óbidos, centre of Portugal, 10 km from Atlantic Ocean, elevation of 30 m
- Climate
  - Mean annual temperature: 15.2 ºC
  - Mean annual precipitation: 607 mm
  - Frost occurrence: not frequent
  - Dry season: June to September
  - Fog during summer, attenuating the effect of drought
- Plantation date
  - March 1975

Alto do Vilão trial

- Genetic material
  - Seedlings
- Fertilization at planting
  - Commercial fertilizer
- Productivity
  - According to the climate classification of Portugal of Ribeiro and Tomé (2000) it belongs to the “Centro Litoral” (CL) region
  - Site index (base age 10) is between 21 and 24, close to the 99% percentile for the region

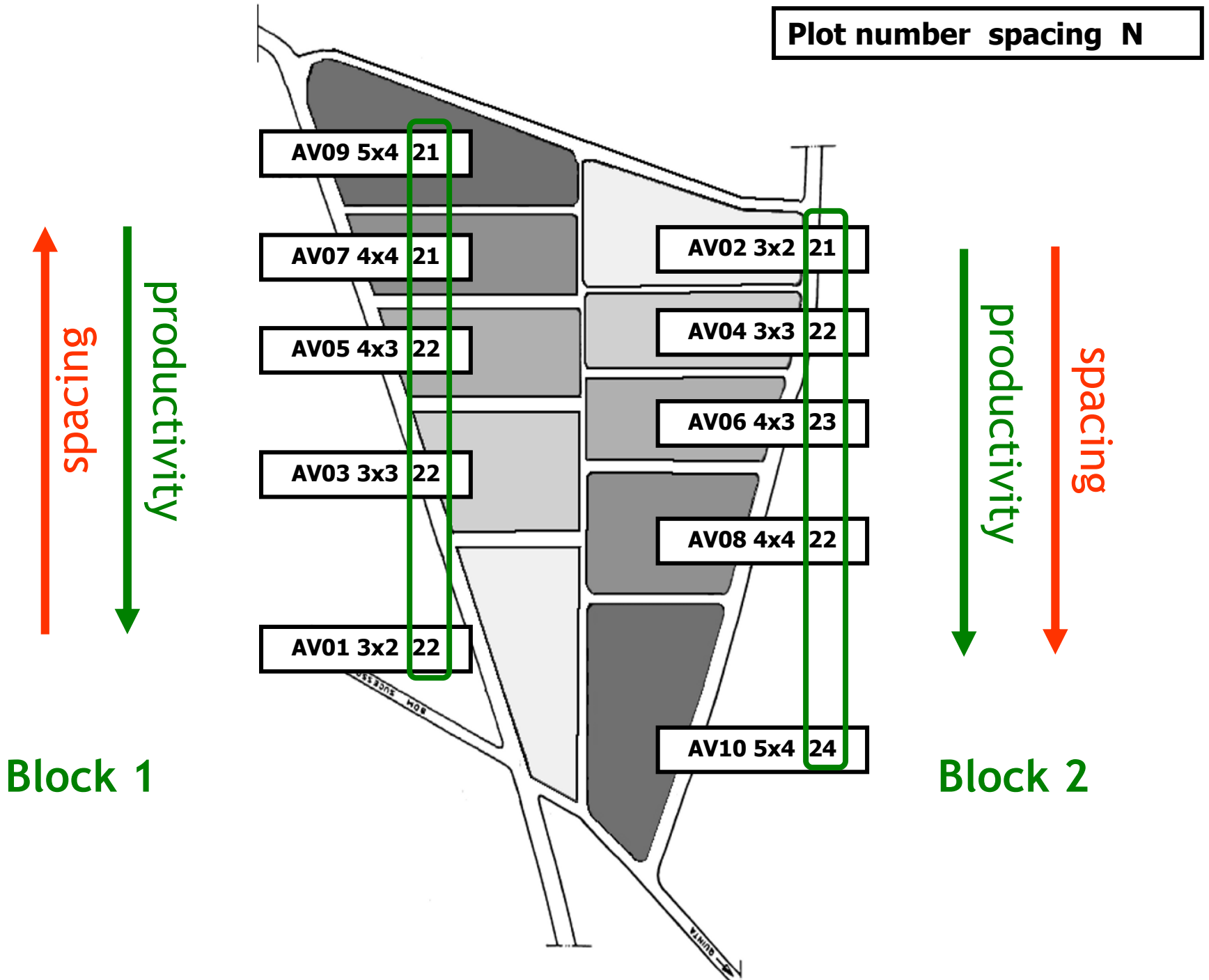
Alto do Vilão trial

Site index “location” within the CL region



Alto do Vilão trial

Experimental design – map of the trial

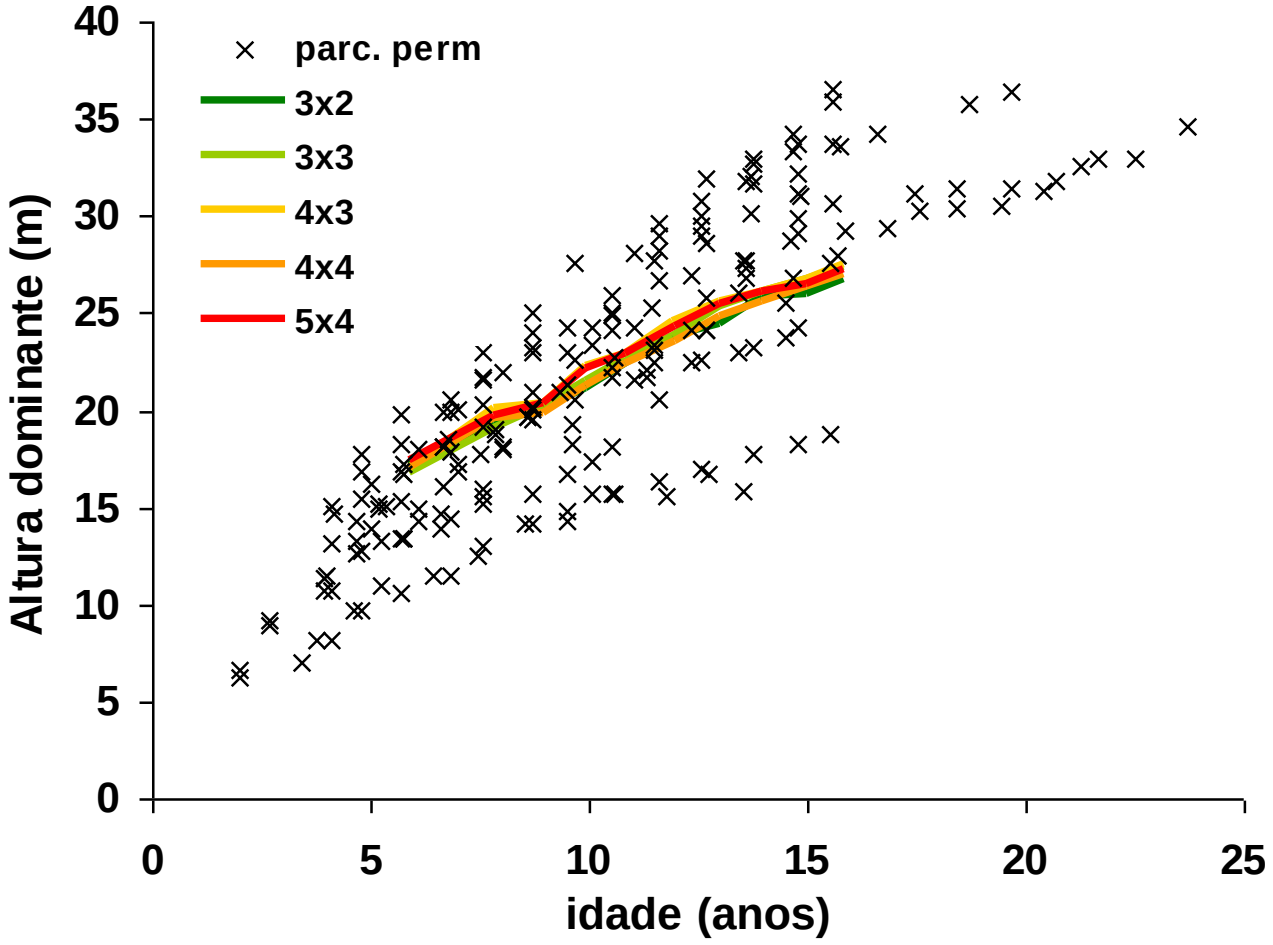

Plot number spacing N
AV09 5x4 21
AV07 4x4 21
AV05 4x3 22
AV03 3x3 22
AV01 3x2 22
AV02 3x2 21
AV04 3x3 22
AV06 4x3 23
AV08 4x4 22
AV10 5x4 24
spacing
productivity
productivity
spacing
Block 1
Block 2

Alto do Vilão trial

Some results

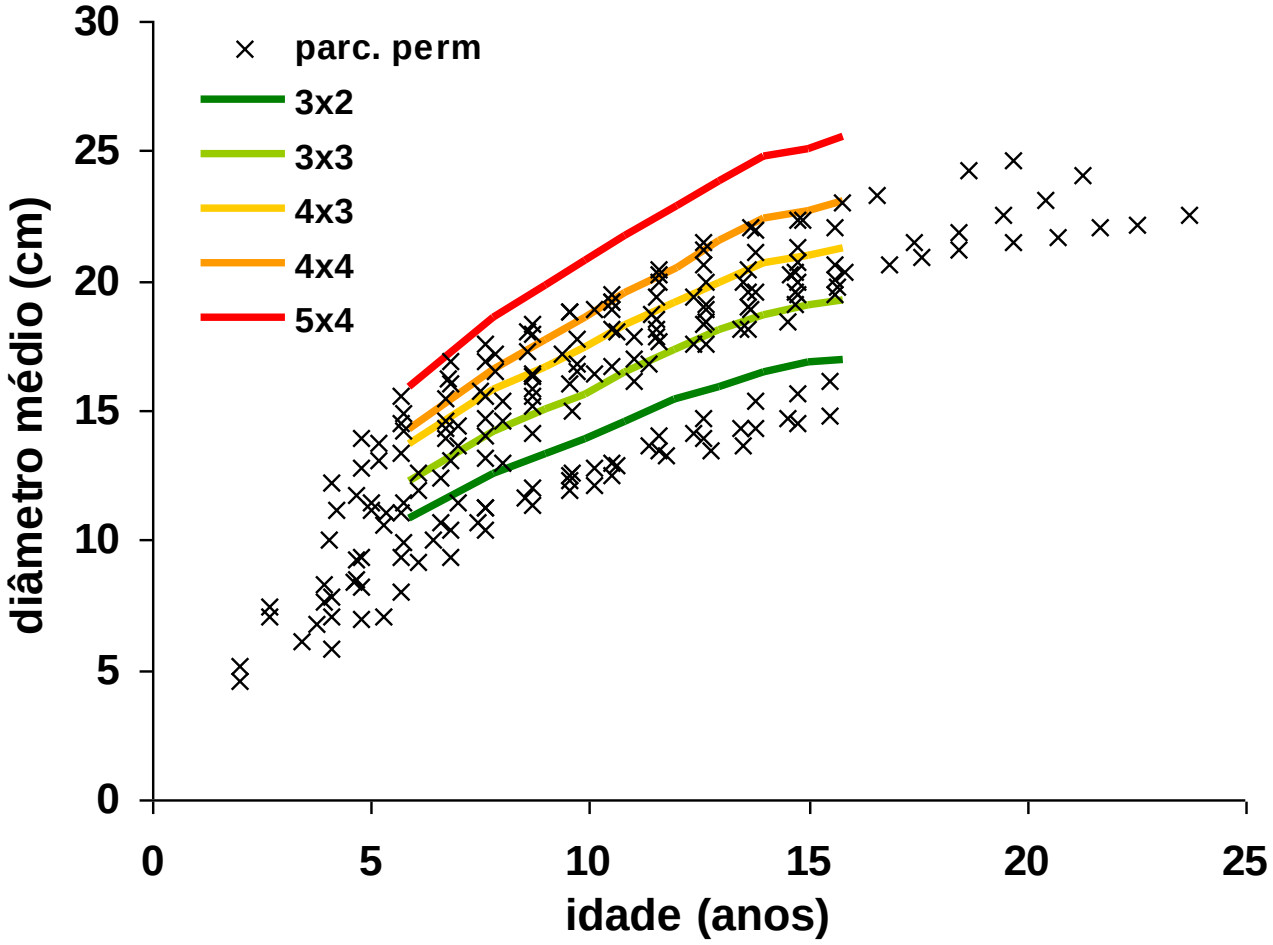
Alto do Vilão trial

dominant height in the trial "over" permanent plots 3x3 (x)



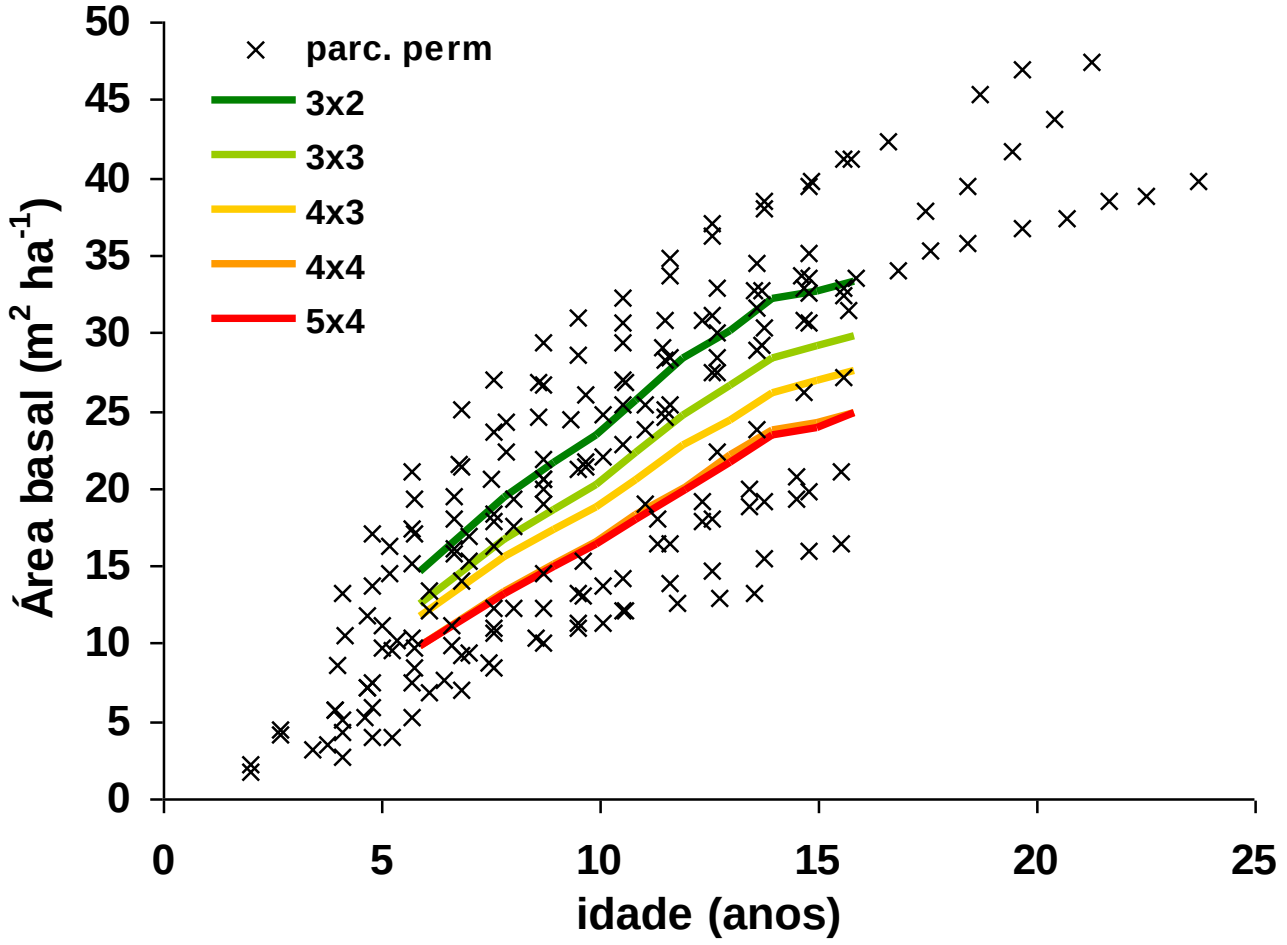
Alto do Vilão trial

quadratic mean diameter in the trail "over" permanent plots 3x3 (x)



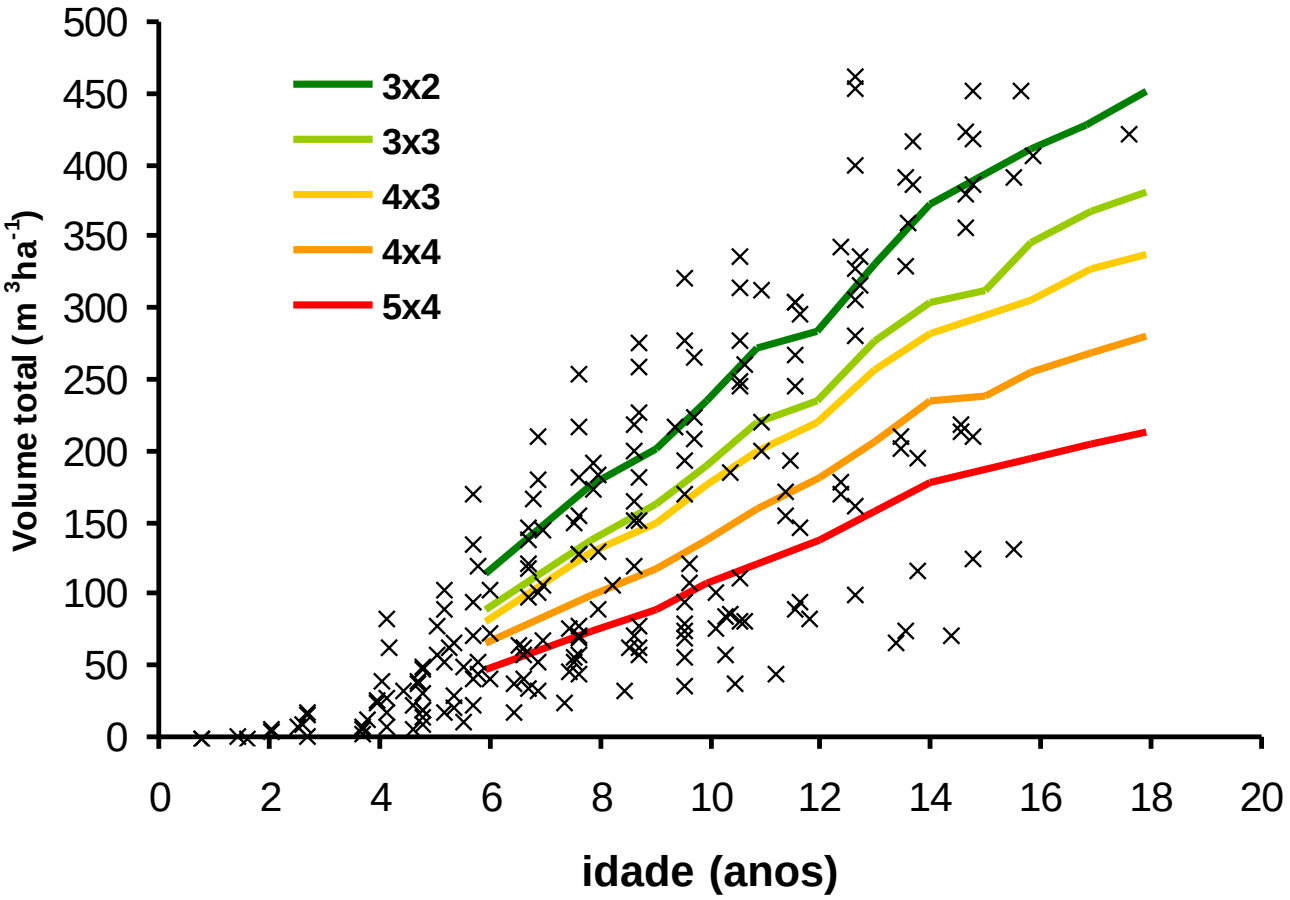
Alto do Vilão trial

basal area in the trial "over" permanent plots 3x3 (x)



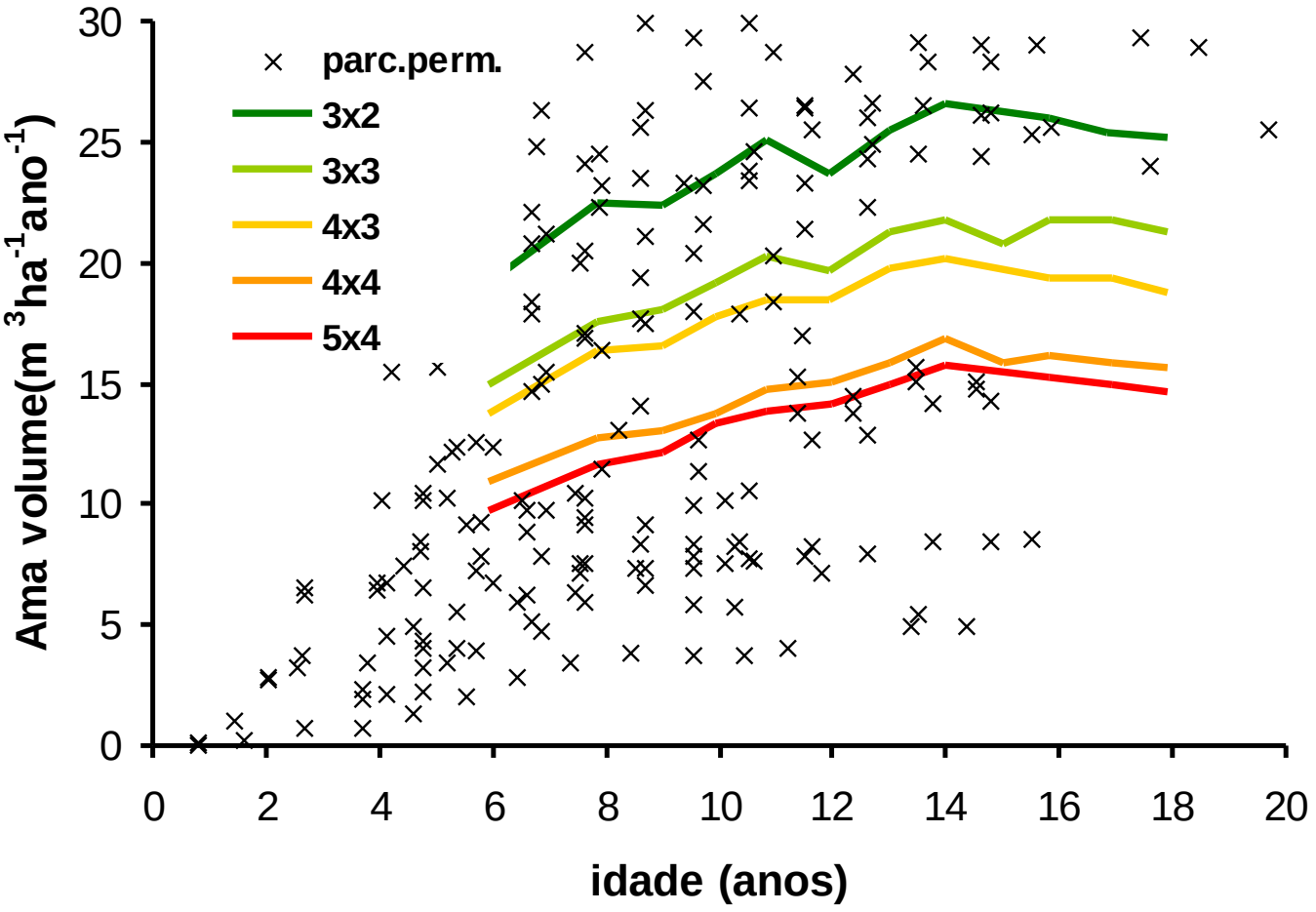
Alto do Vilão trial

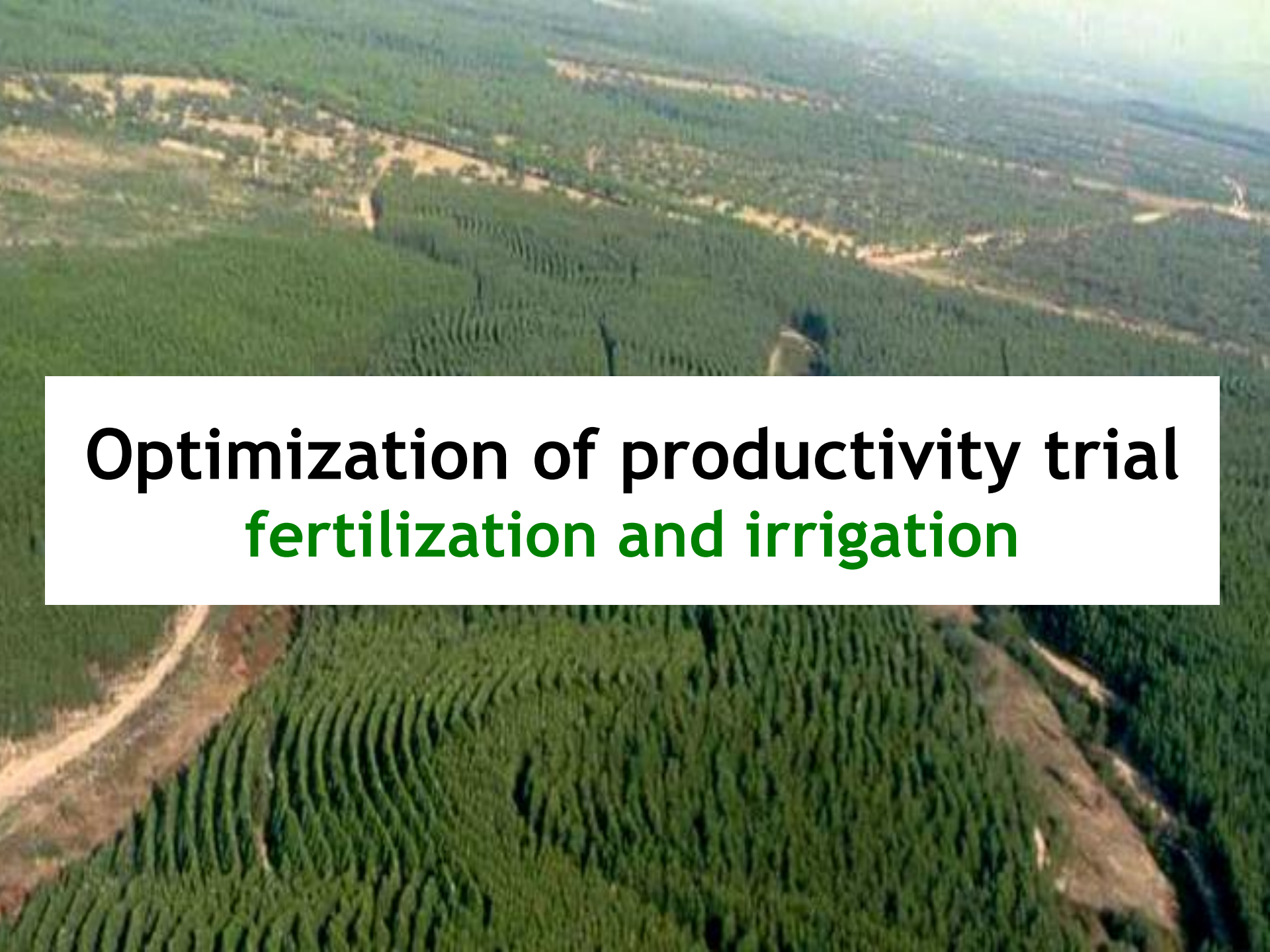
volume in the trial "over" permanent plots 3x3 (x)



Alto do Vilão trial

mai in volume in the trial "over" permanent plots 3x3 (x)





Optimization of productivity trial

fertilization and irrigation

Research team
(CELBI, Univ. Uppsala, ISA)

Coordination:

João S.Pereira, Sune Linder (physiology)
M. Madeira, A. Fabião, T. Ericsson (soils)
Margarida Tomé, Clara Araújo (biometry)

Optimization of productivity - objectives

- Main objective
  - Evaluate the effect of optimum availability of water and nutrients in *Eucalyptus globulus* productivity to establish the limits of biomass production in the Atlantic areas with Mediterranean influence
- Through
  - The establishment of a trial with different treatments of irrigation and fertilization
  - Intensive monitorization of the trials, including climate, plant growth, physiological parameters, nutrients in the soil and in the plant, etc

Optimization of productivity trial

- Localization
  - Close to Óbidos, centre of Portugal, 10 km from the Atlantic Ocean, elevation of 30 m
- Climate
  - Mean annual temperature: 15.2 ºC
  - Mean annual precipitation: 607 mm
  - Frost occurrence: not frequent
  - Dry season: June to September
  - Fog during summer, attenuating the effect of drought
- Plantation date
  - March 1986

Optimization of productivity trial

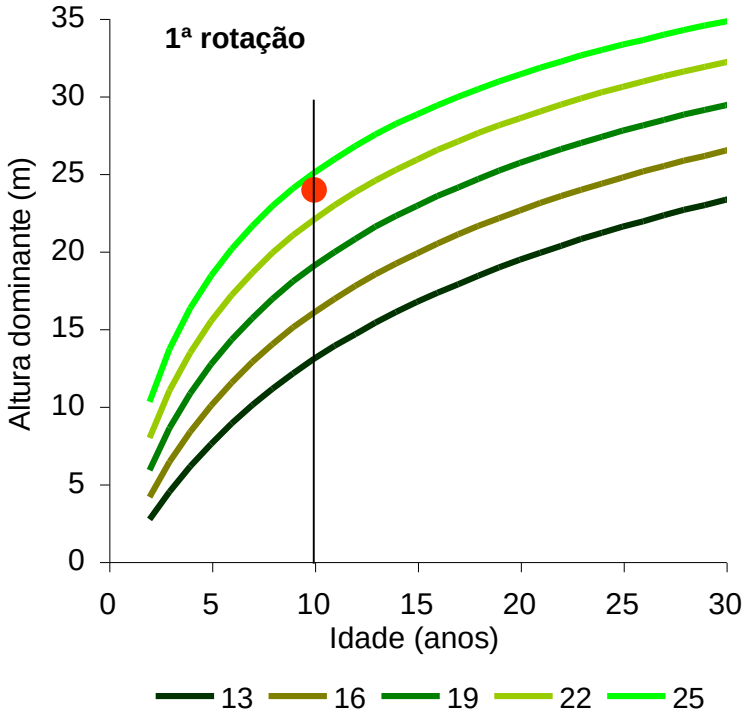
- Soil
  - Spodosols (FAO/UNESCO, 1994)
  - Sandy texture with a low amount of clay to 170 cm of depth, except in a small part of the trial where slightly higher clay content could be observed from 90 cm
  - Low organic matter content (0.4 a 0.5 %) at planting
- Site preparation
  - ploughing till 80 cm of depth
- Spacing at planting
  - Spacing of 3x3 m in the main plot (no harvest of trees) and of 1.5x1.5 m in the plot for destructive sampling, thinned at the age of 2 years to 3x3 m

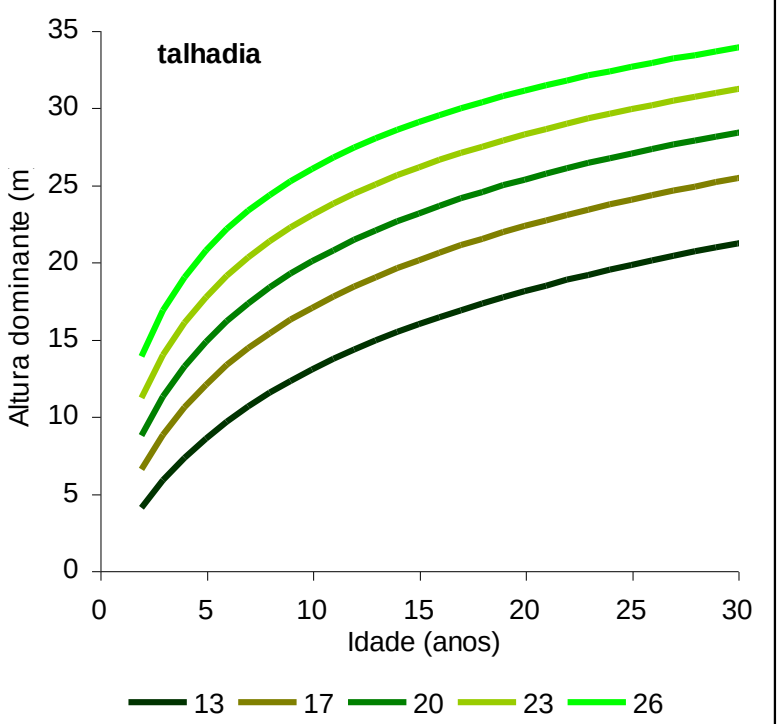
Optimization of productivity trial

- Genetic material
  - Seedlings (genetically improved)
- Fertilization at planting
  - Commercial fertilizer (31 kg ha^{-1} N, 42 kg ha^{-1} K, 26 kg ha^{-1} P) + 1.5 t ha^{-1} of dolomitic calcarium (66.5% de Ca CO_3, 32.5% de Ng CO_3)
- Productivity
  - According to the climatic classification of Portugal by Ribeiro e Tomé (2000) the trial is located in the "Centro Litoral" (CL) region
  - Site index in the control plots is 23.2 and 24.6, respectively in blocks 1 and 2, close to the 99% percentile for the region

Optimization of productivity trial

Site index of the trial within the CL region





Optimization of productivity trial

- Experimental design - treatments

  - Control:
    - No irrigation and just the “normal” fertilization at planting
  - Solid fertilization:
    - (N, P, K, Ca, Mg) applied in March and October of each year, with the amount estimated using the Ingestad’s theory
  - Irrigation
    - Drip irrigation between April and October in order to maintain water content at least at 80% of field capacity
  - Irrigation + fertilization:
    - Irrigation as in the irrigation treatment + weekly application of liquid fertilizer jointly with the irrigation

Optimization of productivity trial

- Experimental design - design

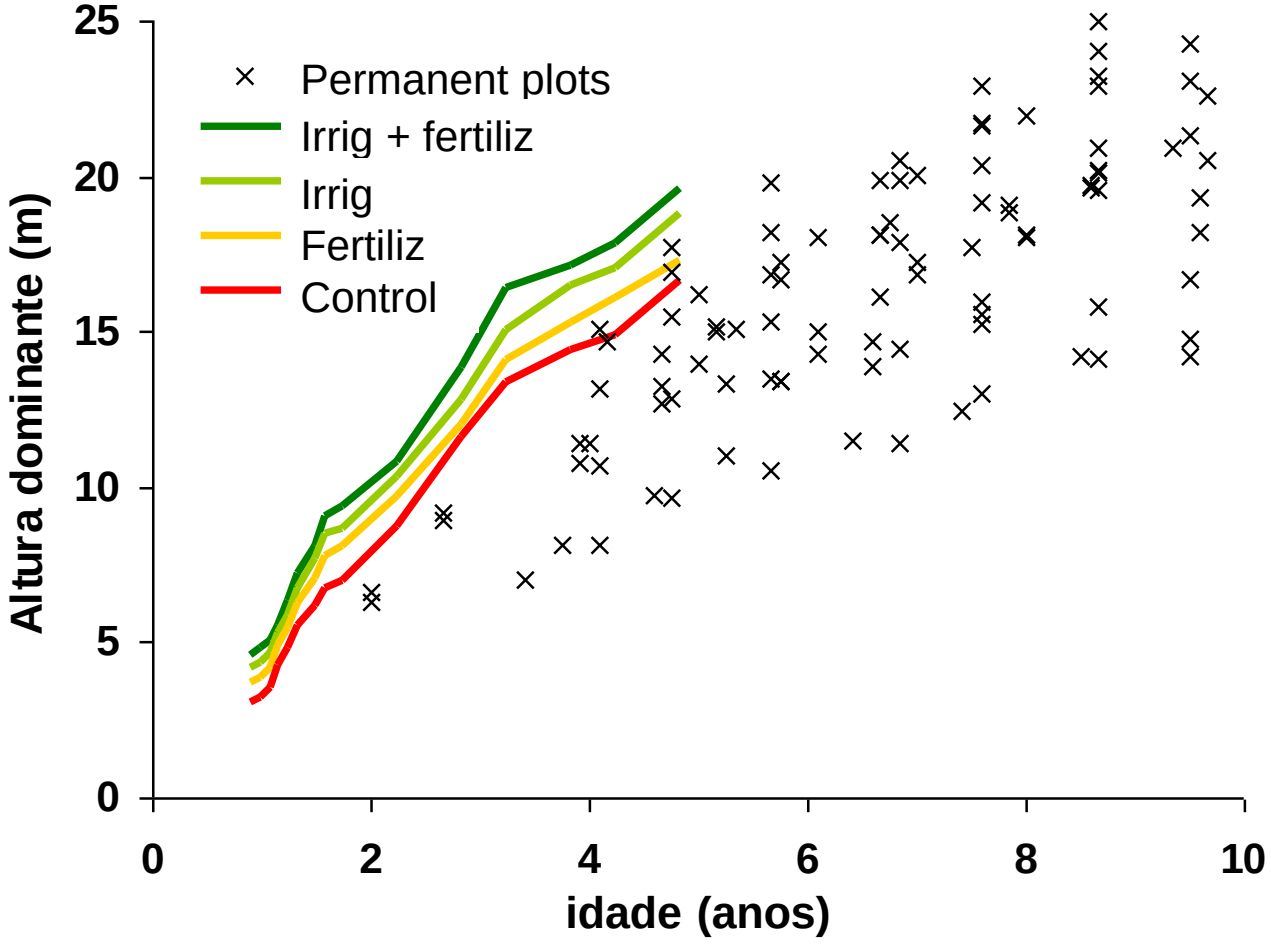
  - Complete randomized blocks with 2 replicates
  - Each main plot includes 121 (11x11) trees, plus a border line (area: 1089 m^2)
  - Contiguous to each plot a smaller plot was established for destructive samplings, initially with a 1.5x1.5 m spacing, later reduced to a 3x3 m spacing and receiving the same treatment
  - The total area of the trial was approximately 1 ha

Optimization of productivity trial

Some results

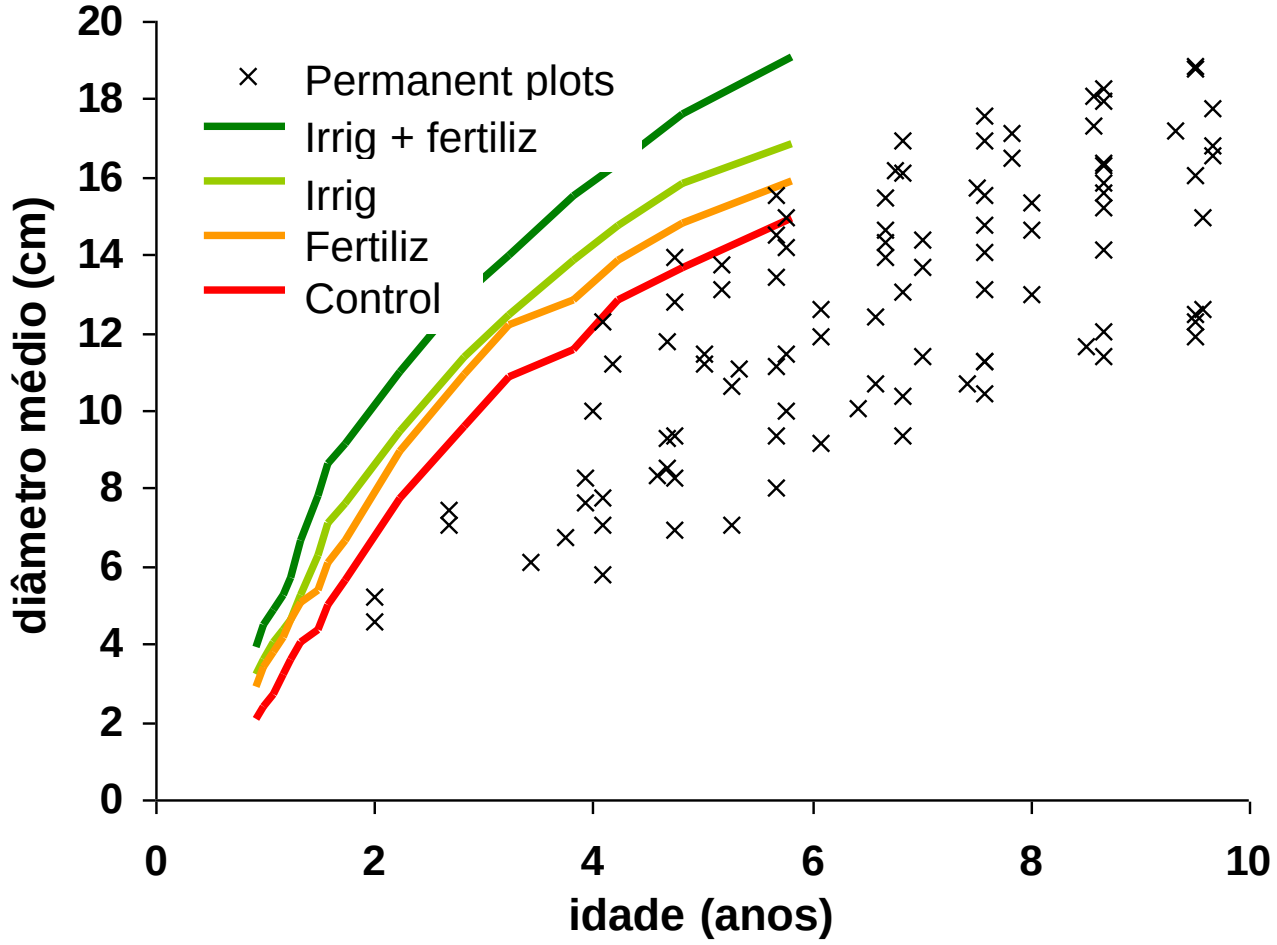
Optimization of productivity trial

dominant height in the trial “over” permanent plots 3x3 (x)



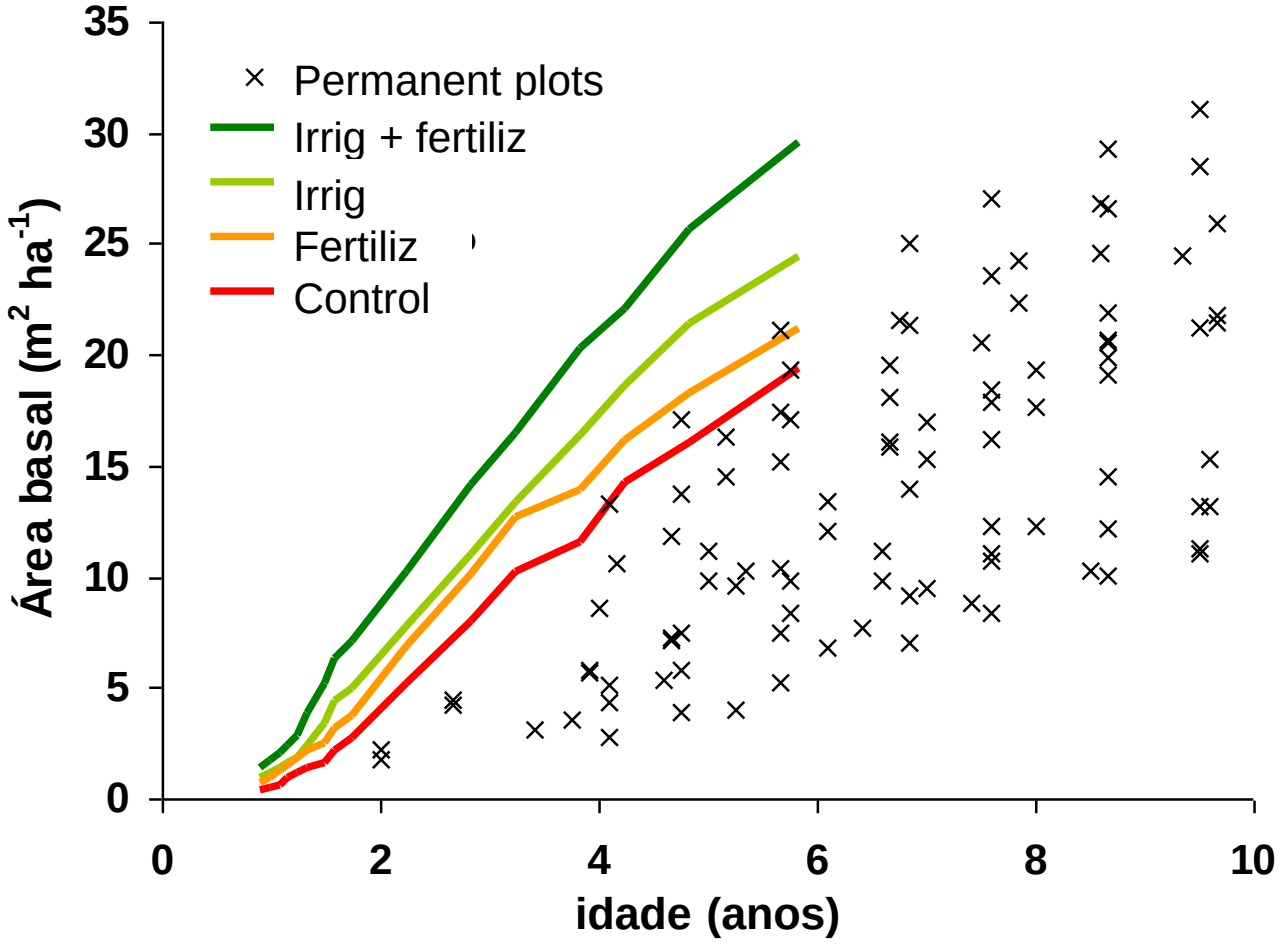
Optimization of productivity trial

quadratic mean diameter in the trial "over" permanent plots 3x3 (x)



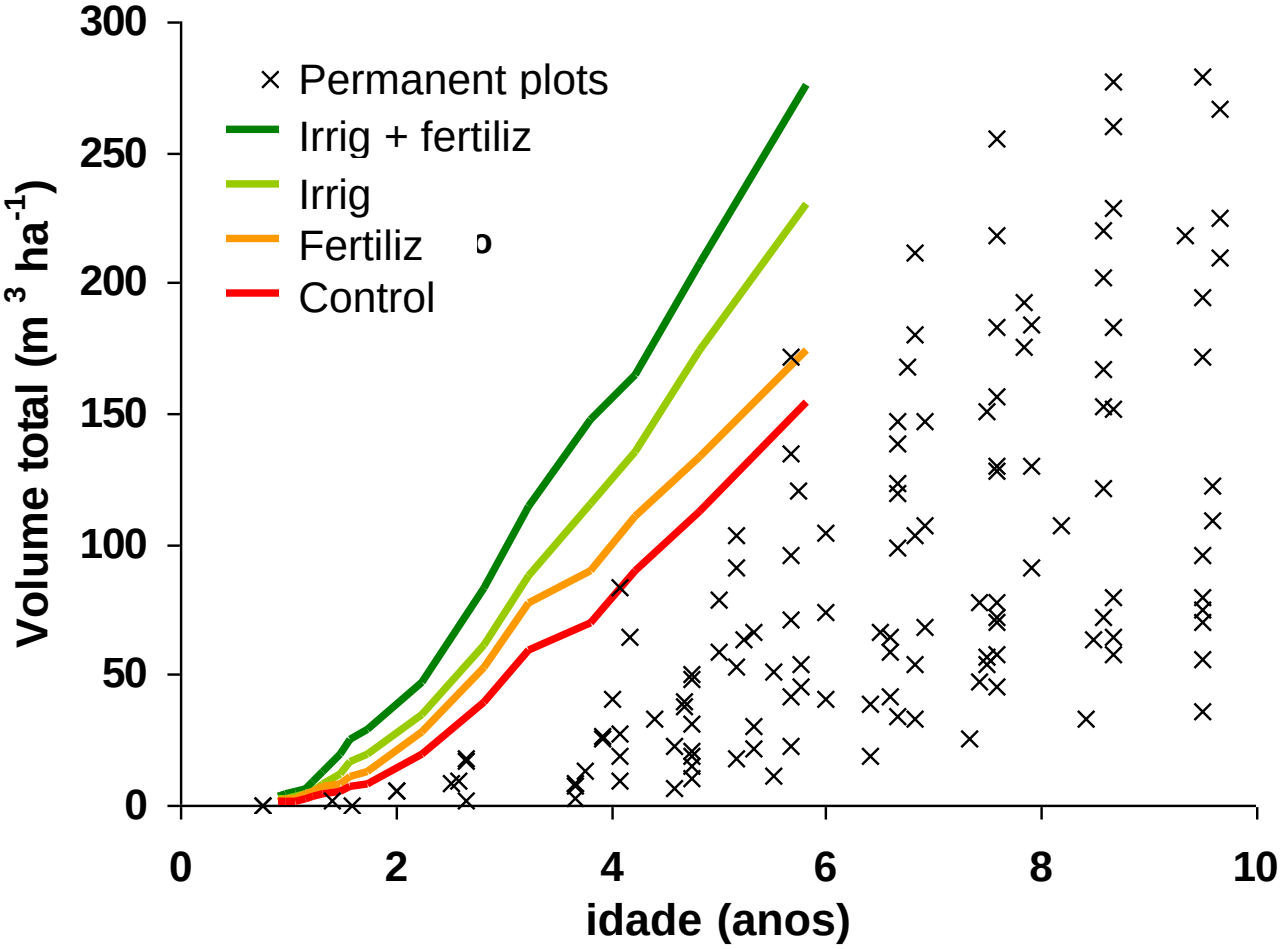
Optimization of productivity trial

basal area in the trial "over" permanent plots 3x3 (x)



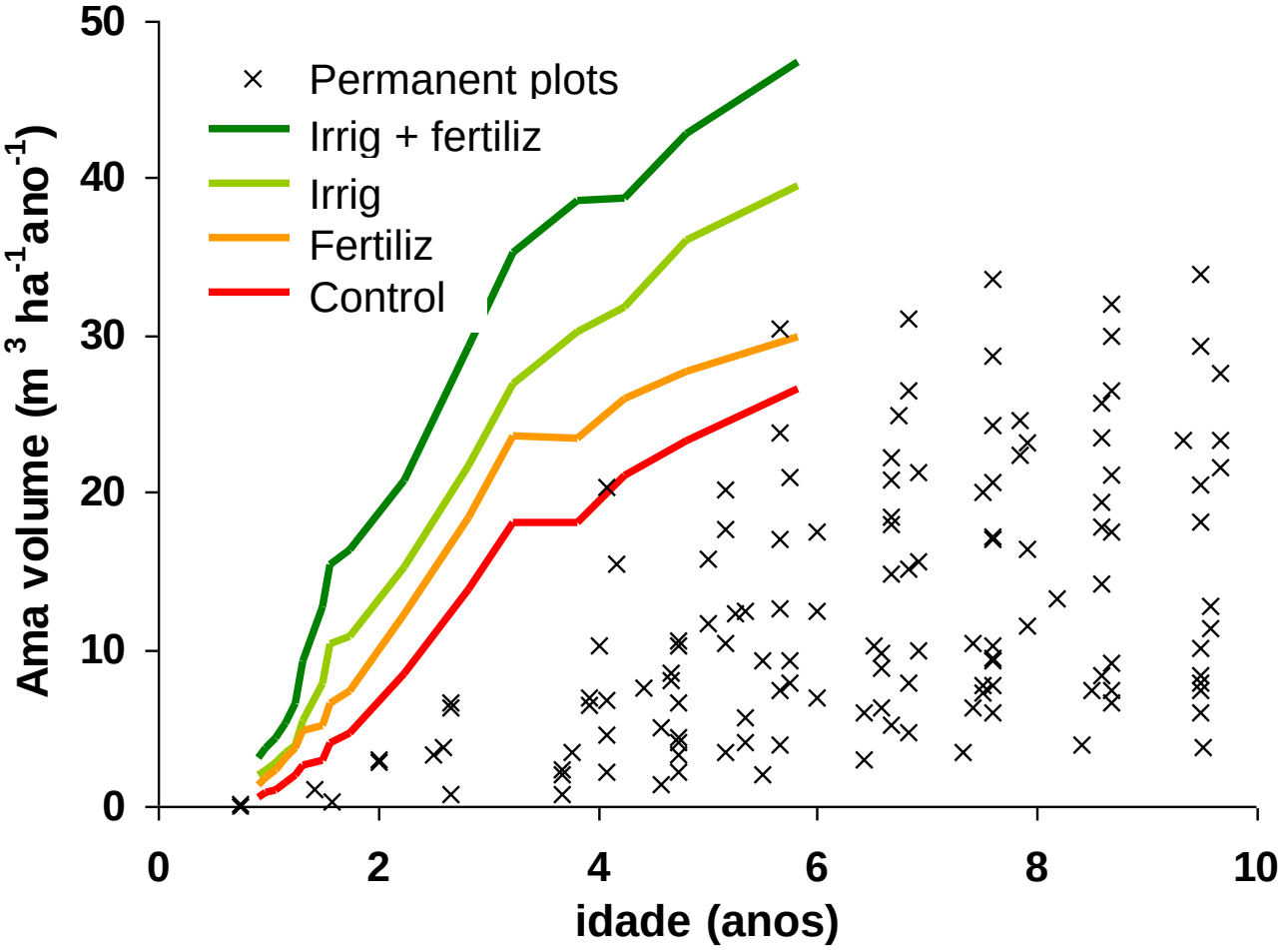
Optimization of productivity trial

volume in the trial "*over*" permanent plots 3x3 (x)



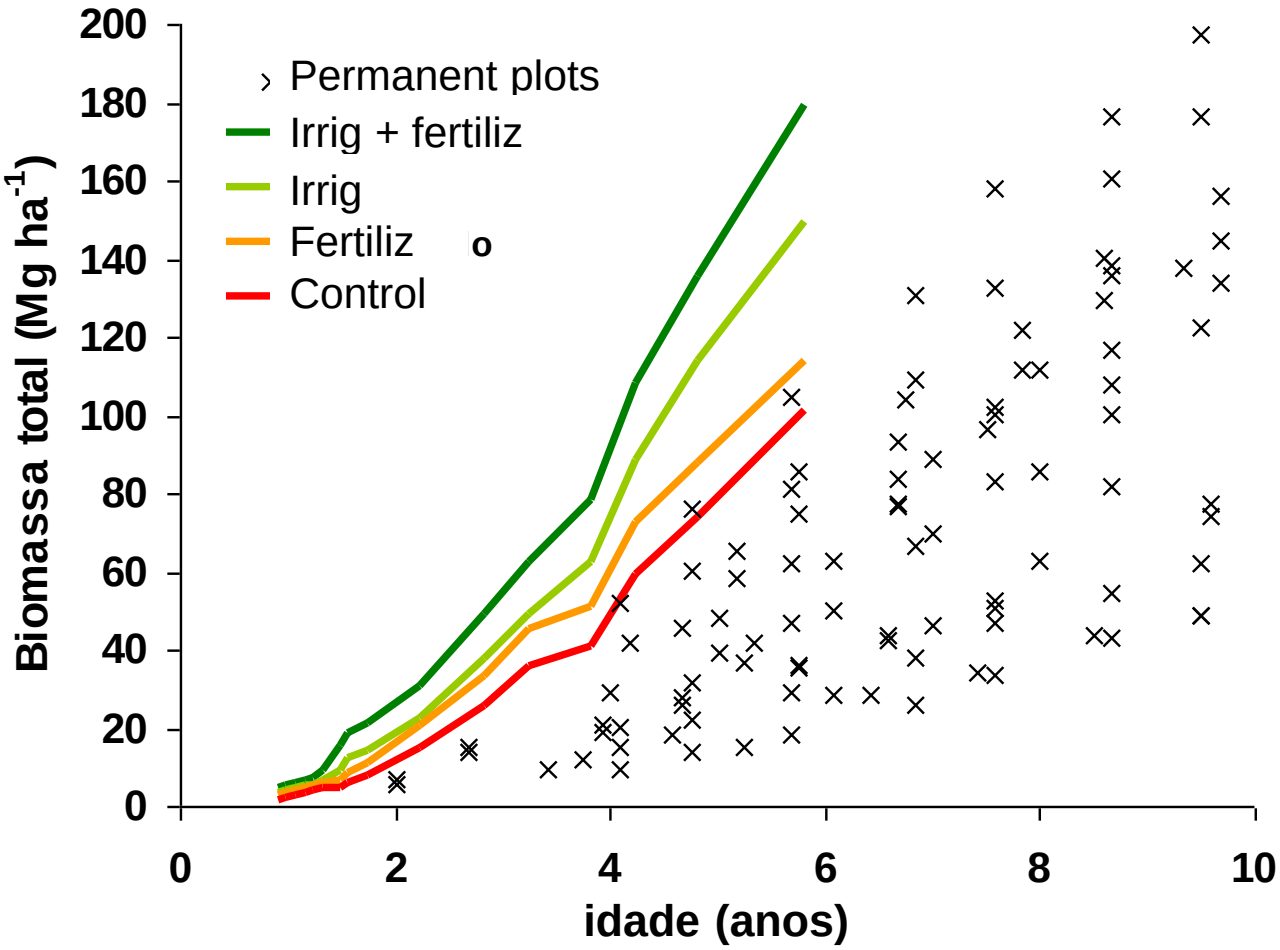
Optimization of productivity trial

mai in volume in the trial “over” permanent plots 3x3 (x)



Optimization of productivity trial

biomass in the trial "over" permanent plots 3x3 (x)



AGOLADA trial

spacing and genetic material

Research team

Coordination:

Carlos Arruda Pacheco (soil)
José A. Tomé (physiology)
Margarida Tomé (biometry)

Agolada trial - objectives

- Main objective
  - Contribute to the understanding of water and nutrients use by *Eucalyptus globulus* and its relationship with biomass growth and yield
- through
  - The establishment of trials with variability in terms of water and nutrients availability and stand density
  - Intensive monitoring of these trials including climate, plant growth, physiological parameters, available soil water, nutrients content in the soil and the plant, etc

Agolada trial

- Location
  - 5 km from Coruche, within an eucalyptus management area with ≅ 600 ha
- Climate
  - Mean annula temperature: 21.5 ºC
  - Mean annual precipitation: 737 mm
  - Dry season: May to October
  - Low relative humidity in summer, corresponding to high levels of evapotranspiration (annual average is 79%, 90% in winter and 70% during the dry period)
  - High insolation values, achieving 2900 horas per year, 67% of light hours

Agolada trial

- Soil
  - Ludvic Arenosols (FAO/UNESCO, 1994)
  - Sandy layers in combination with layers with some clay and loam, with a high % of quartz gross elements
  - These layers cover compact sandstone rock sometimes strongly cemented by iron oxides, with ca. 3% of clay, 30% of elements with diameter > 2 mm and ≅ 65% of coarse sand

- Previous soil use
  - Eucalyptus plantation in a 6^{th} (?) cutting cycle

Agolada trial

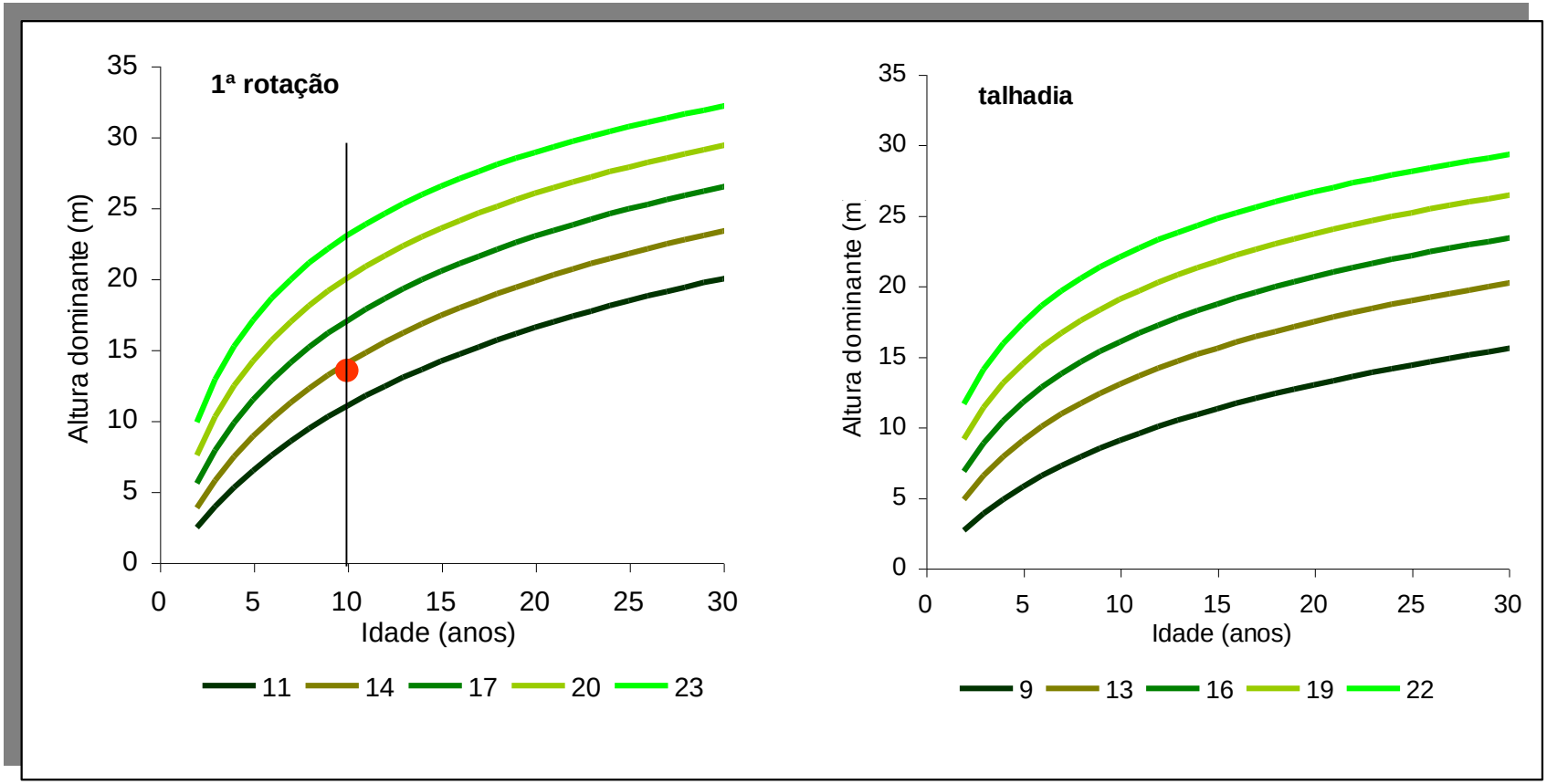
- Site preparation
  - Similar to the one selected by PORTUCEL for the stand in which the trial is included
  - Harvest and extraction of the previous stand, extraction, gathering and burning of the stumps
  - Ripping till 0.8 to 0.9 m (distance between tooth ripper of 0.7 m), followed by harrowing
- Date of planting
  - November 1994
- Other silvicultural operations in the trial
  - Weed control by the end of summer 1995 and 1996 (if needed)

Agolada trial

- Genetic material
  - Three clones selected by PORTUCEL, Espirra, corresponding to different productivities, coded as Cl1, Cl2 and Cl3
- Fertilization at planting
  - 30 g of Osmocote 11+22+9+6 MgO per seedling
- Productivity
  - According to the climatic classification of Portugal by Ribeiro e Tomé (2000) the trial locates in the “Vale do Tejo” (VT) region

Agolada trial

Site index of the trial within the VT region



Agolada trial

- Experimental design - treatments
  - fertilization:
    - Just at planting
    - Additional fertilization with NPK (100:150:150) by the end of 1995
  - Spacing at planting

spacing	Trees ha^{-1}
1x1	10000
2x1	5000
2x2	2500
4x1.5	1667
4x2	1250
3x3	1111
4x4	625

  - clones Cl1, Cl2 and Cl3

Agolada trial

- Experimental design - design
  - split-split-plot with two replicates

    main treatment - fertilization

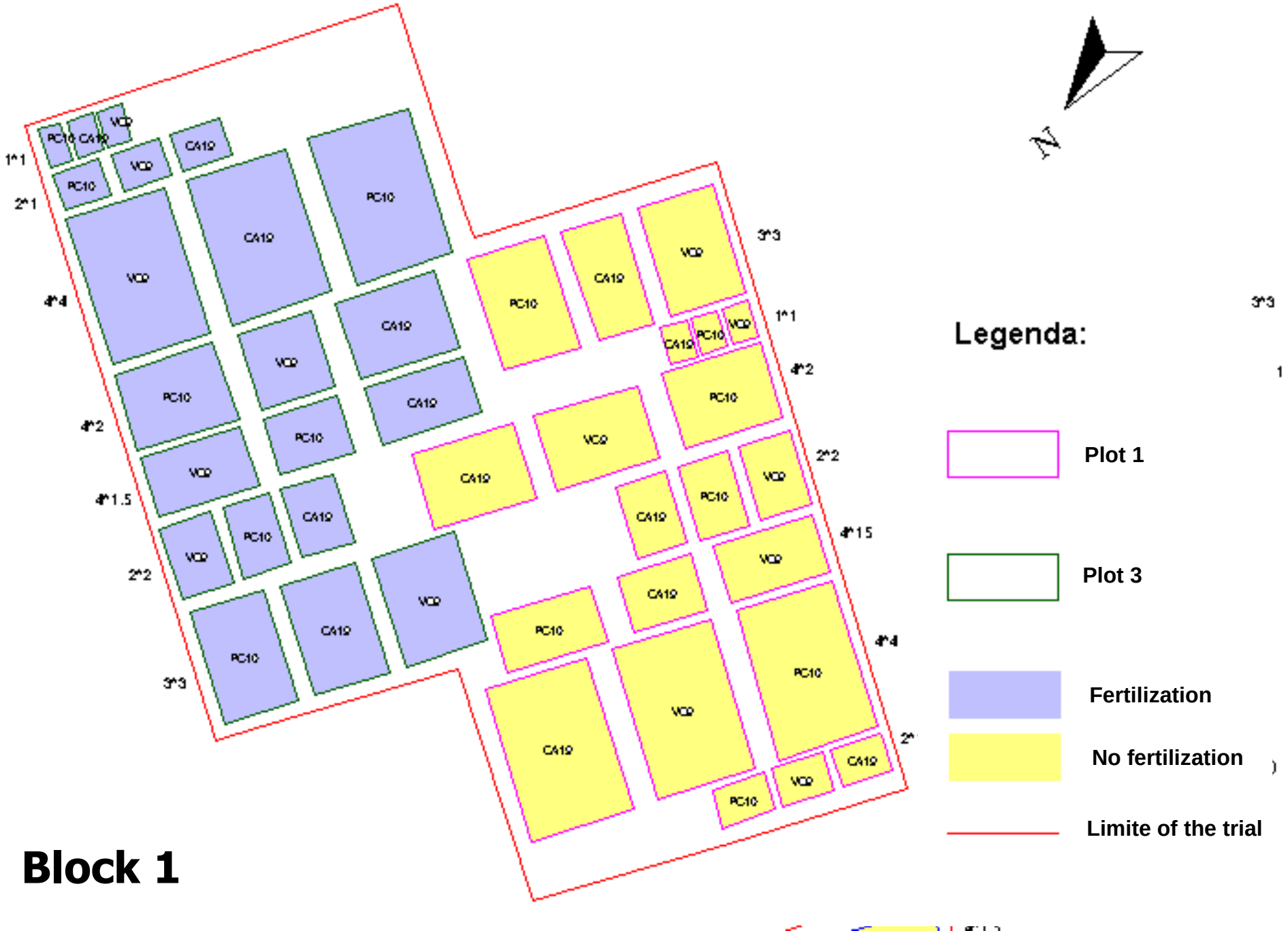
    treatment in the sub-plots – spacing at planting

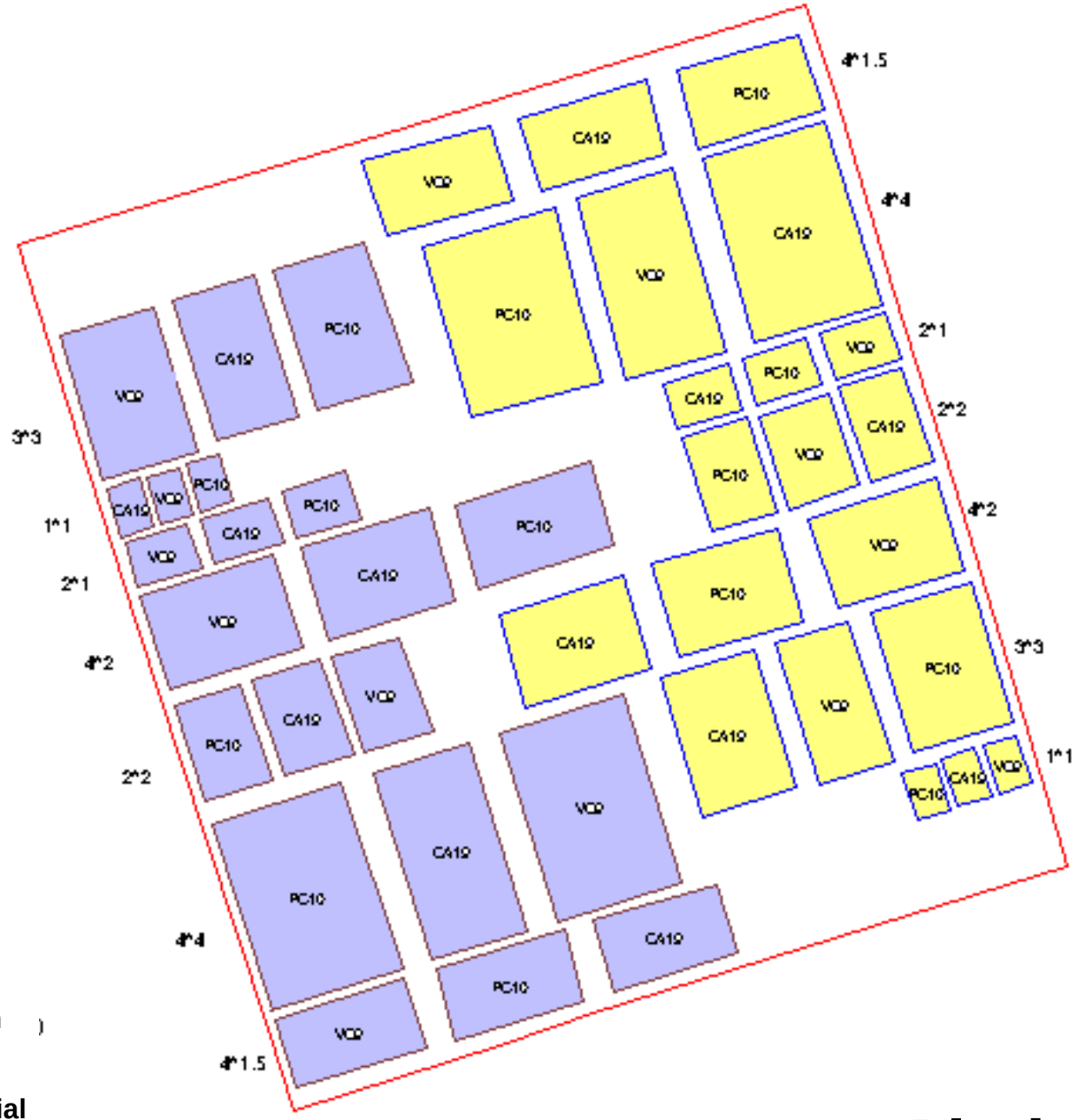
    treatment in the sub-sub-plots - clone

  - Each sub-sub-plot includes 35 (7x5) plants, just 15 (5x3) considered for intensive measurement (other are border trees)
  - The area of the sub-sub-plots depends on the spacing at planting from 15 to 240 m^2
  - Total area of the trial is 2 ha

Agolada trial

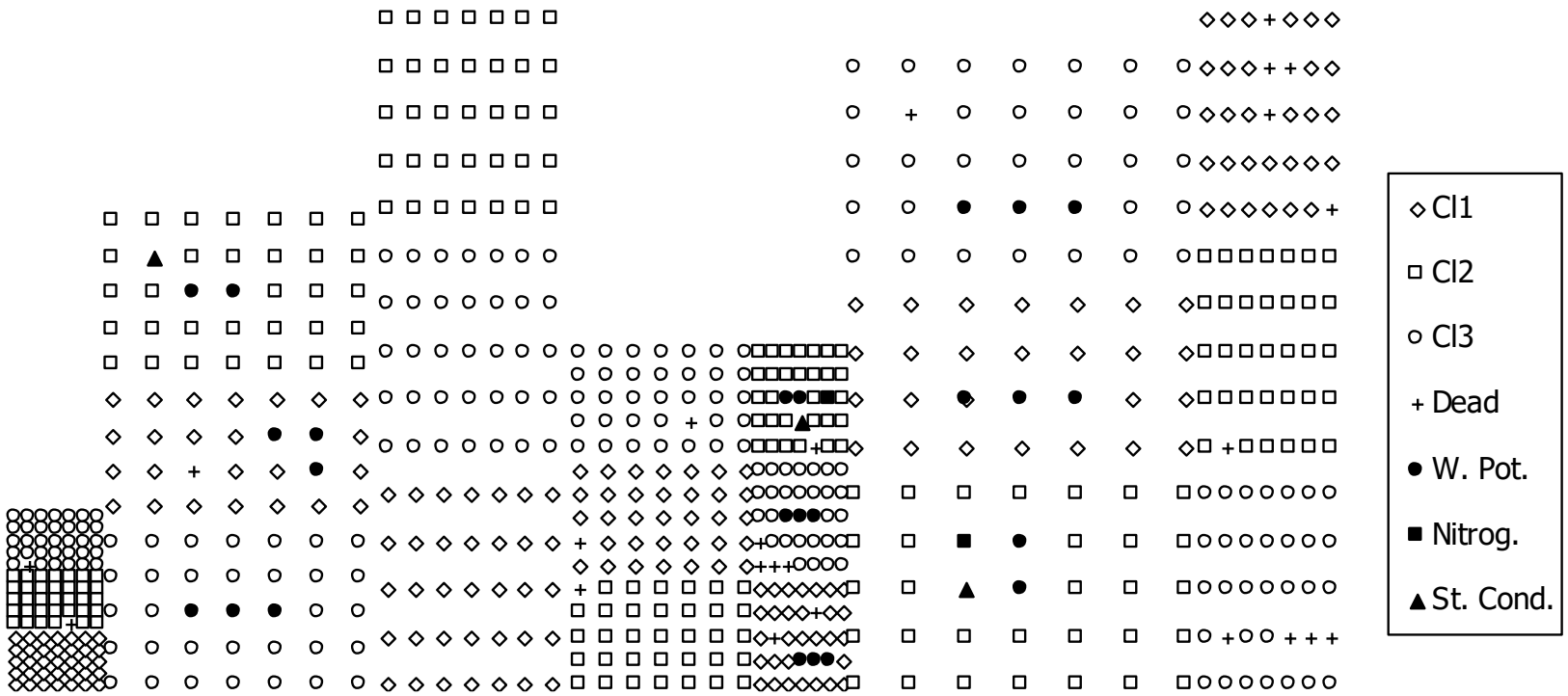
Experimental design – map of the trial


N
Legenda:
Plot 1
Plot 3
Fertilization
No fertilization
Limite of the trial
Block 1


N
Legenda:
Plot 1
Plot 3
Fertilization
No fertilization
Limite of the trial
Block 2
4*1.5
4*4
2*1
2*2
3*3
4*2
1*1
PC10
CA19
VCP

Agolada trial

Experimental design - detail of one plot

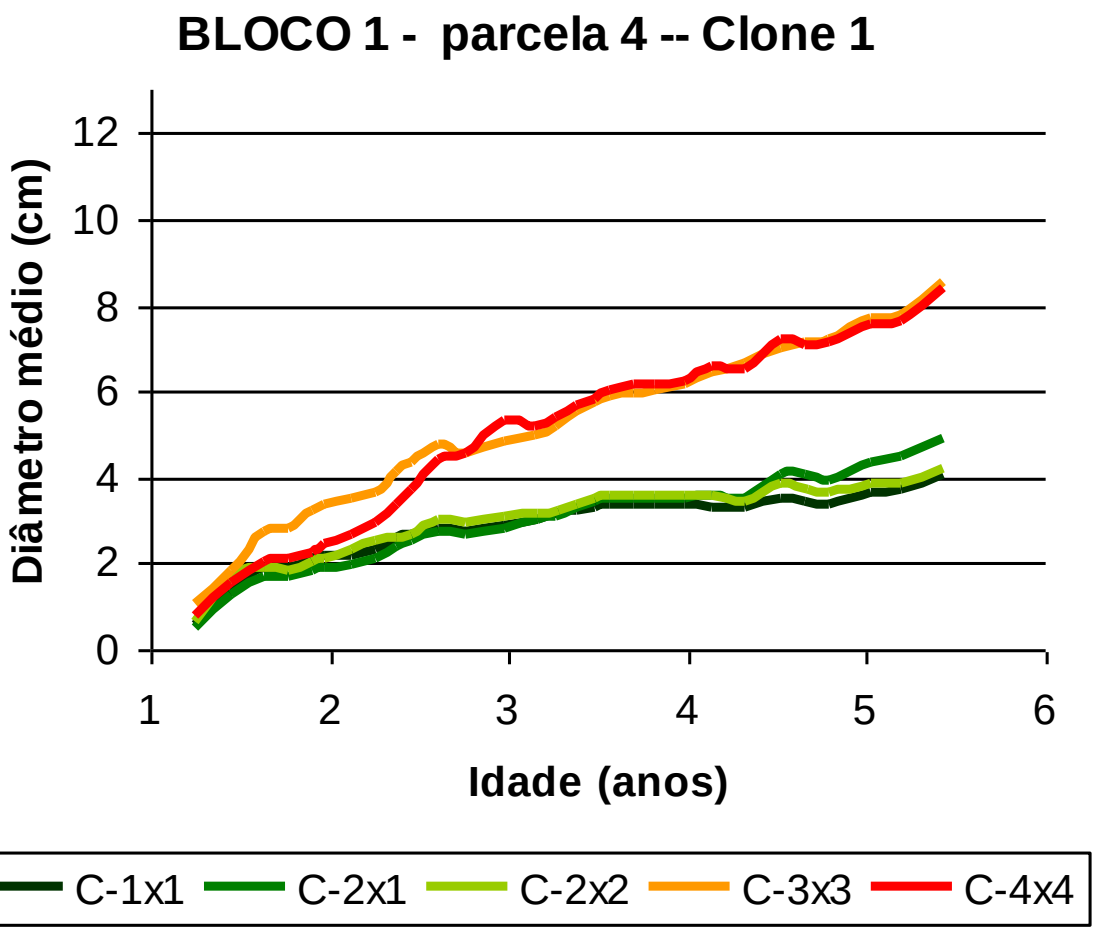


Agolada trial

Some results

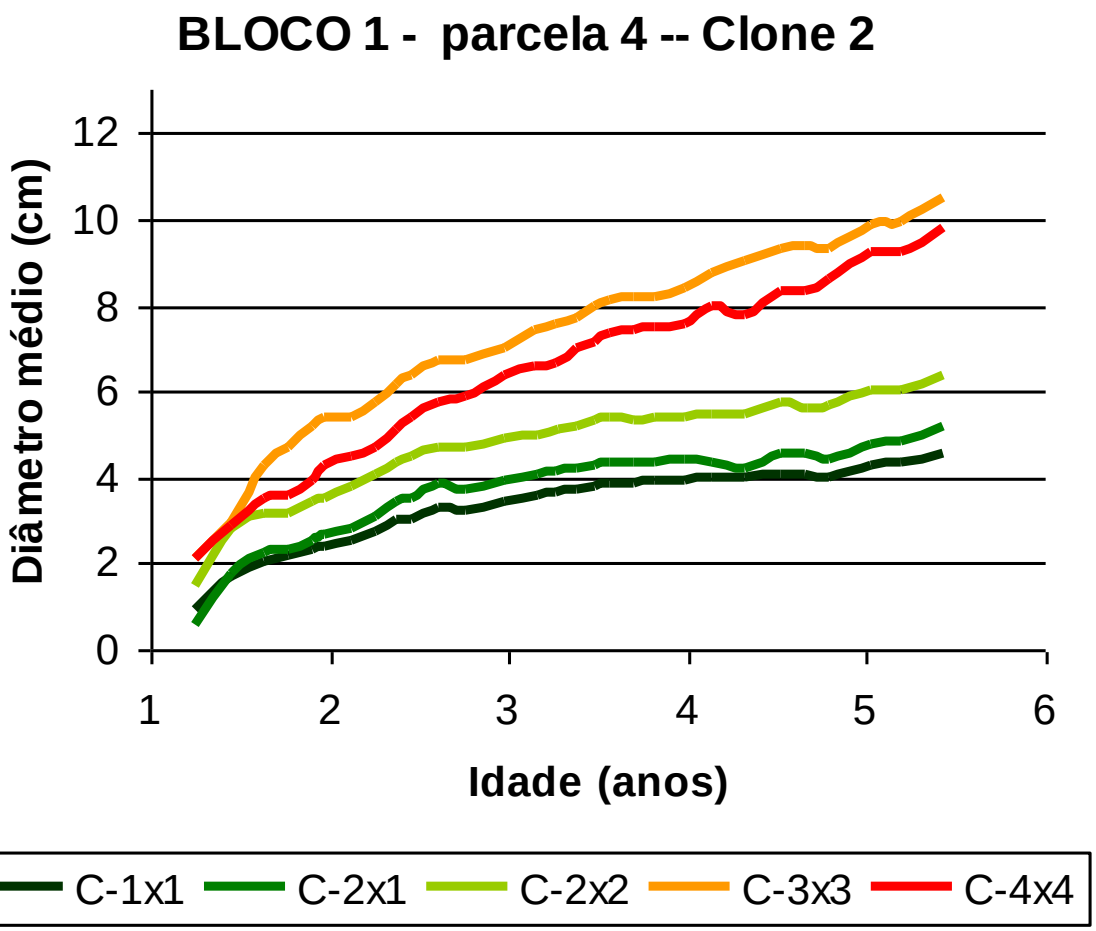
Agolada trial

quadratic mean diameter



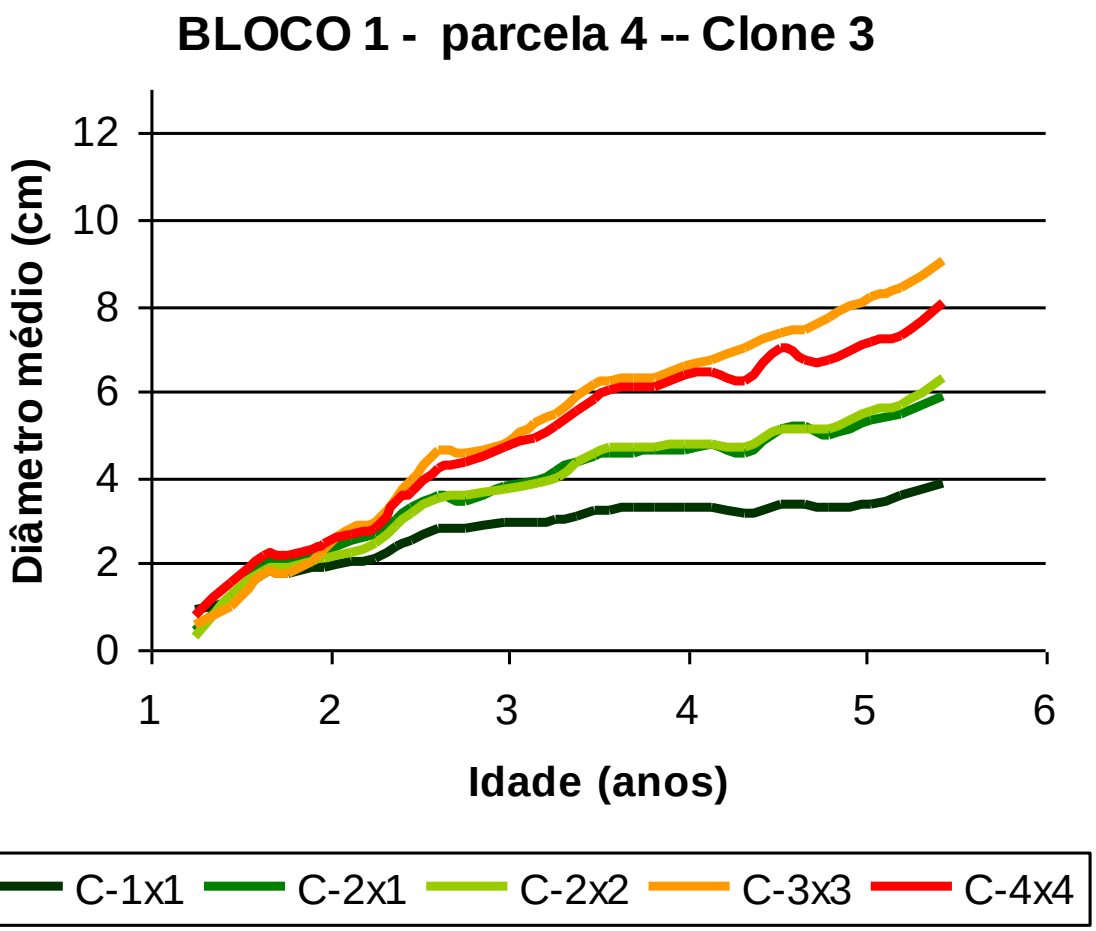
Agolada trial

quadratic mean diameter



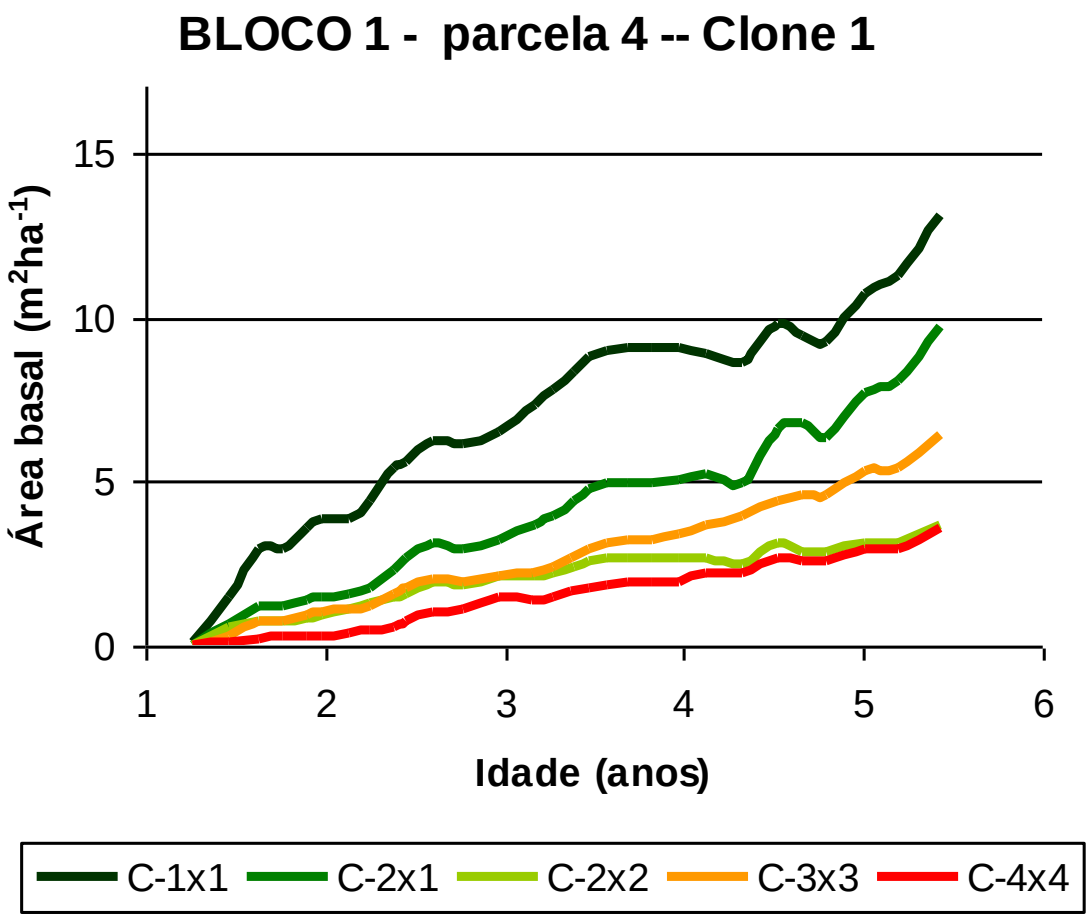
Agolada trial

quadratic mean diameter



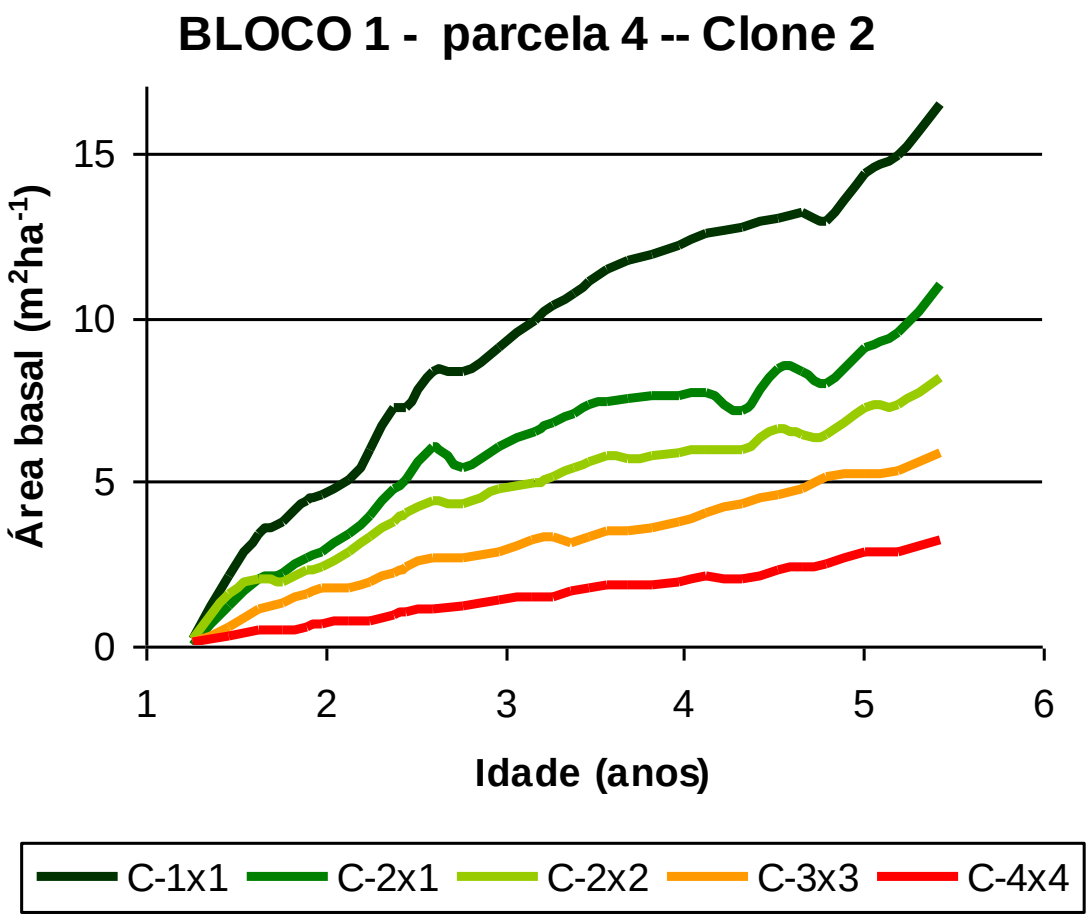
Agolada trial

basal area



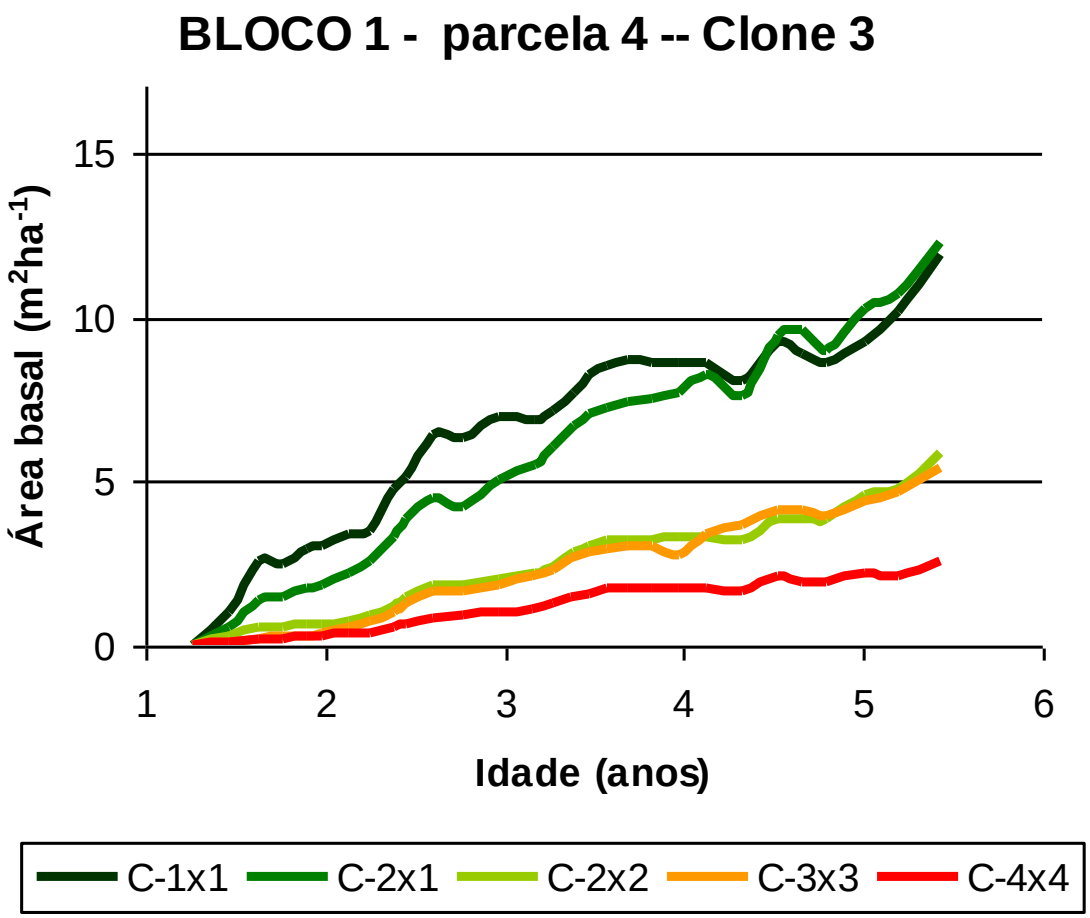
Agolada trial

basal area



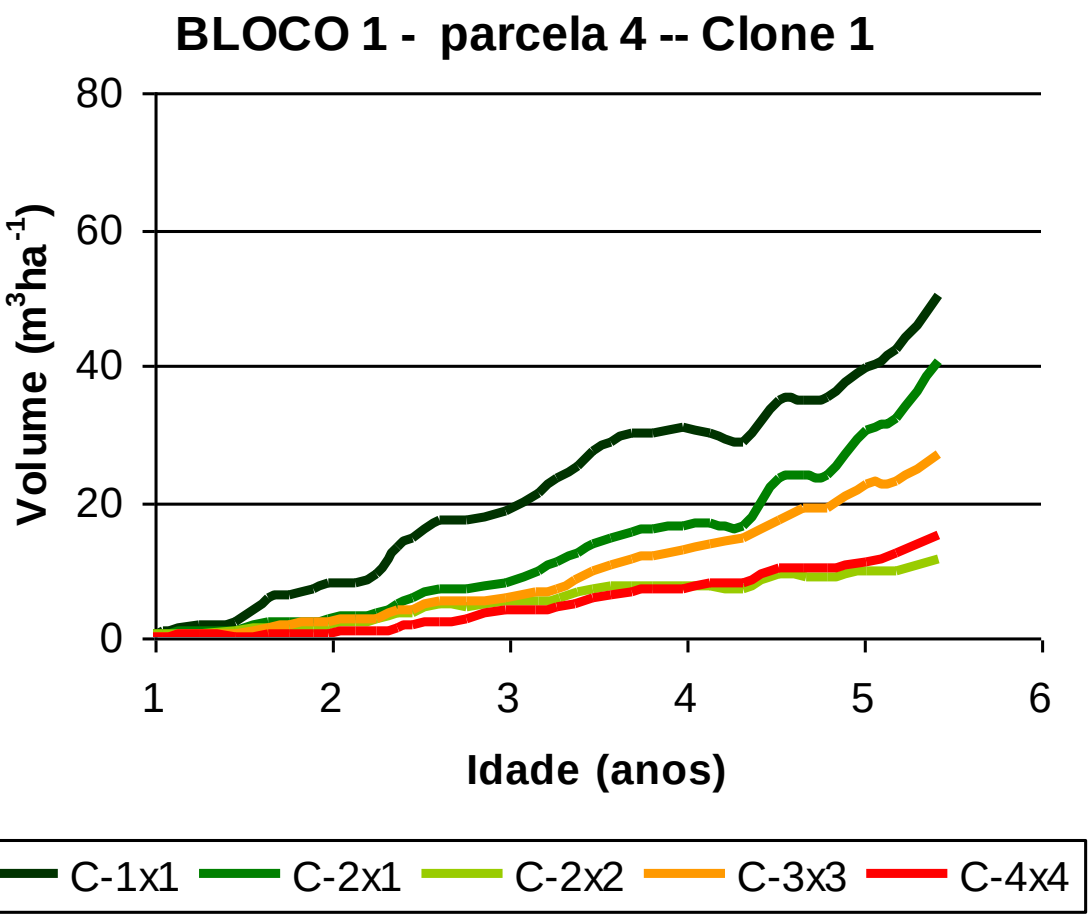
Agolada trial

basal area



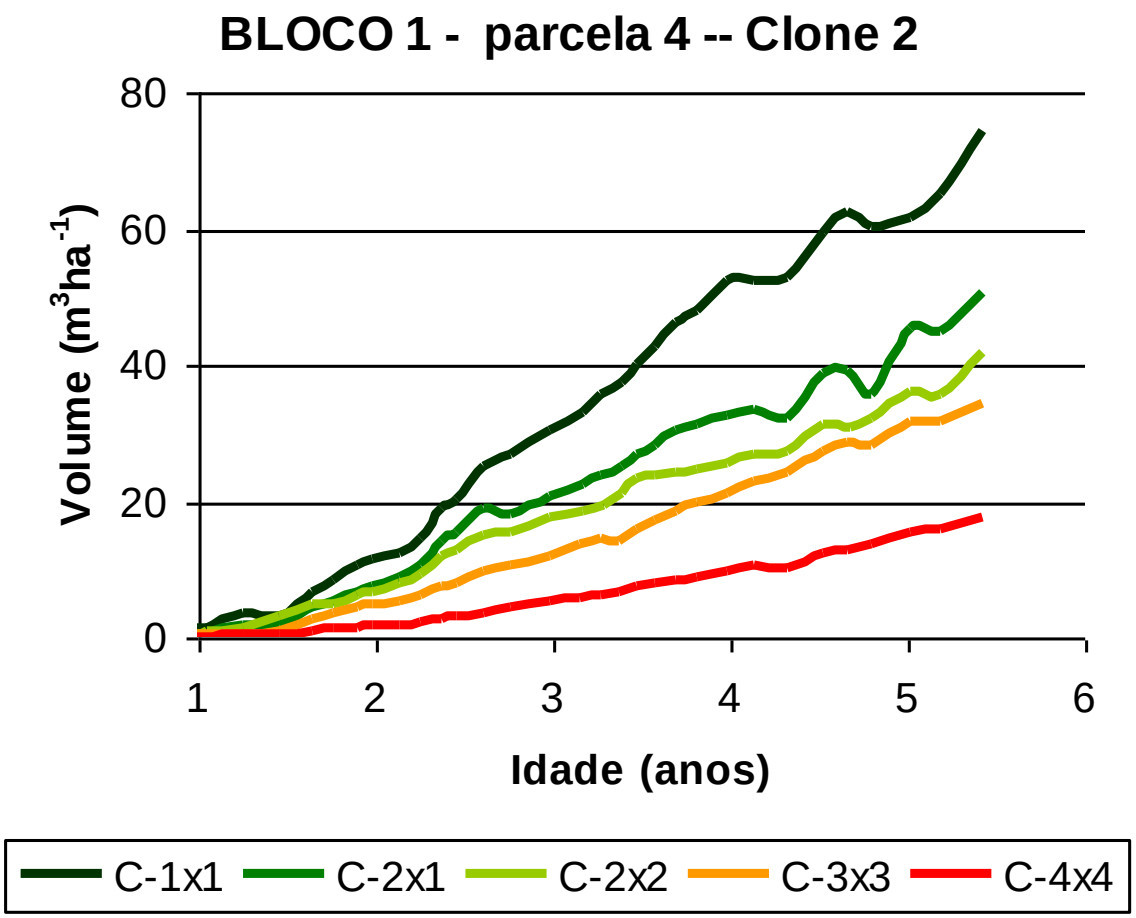
Agolada trial

volume



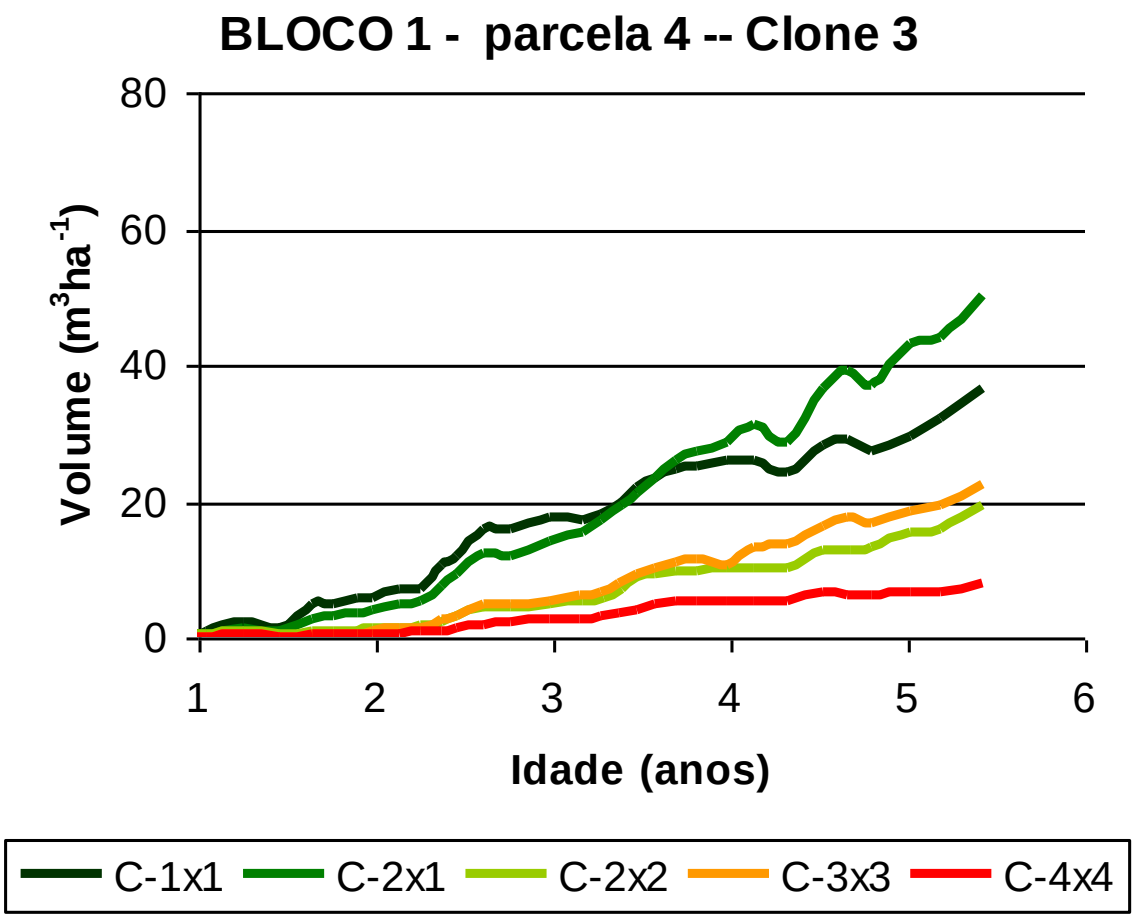
Agolada trial

volume



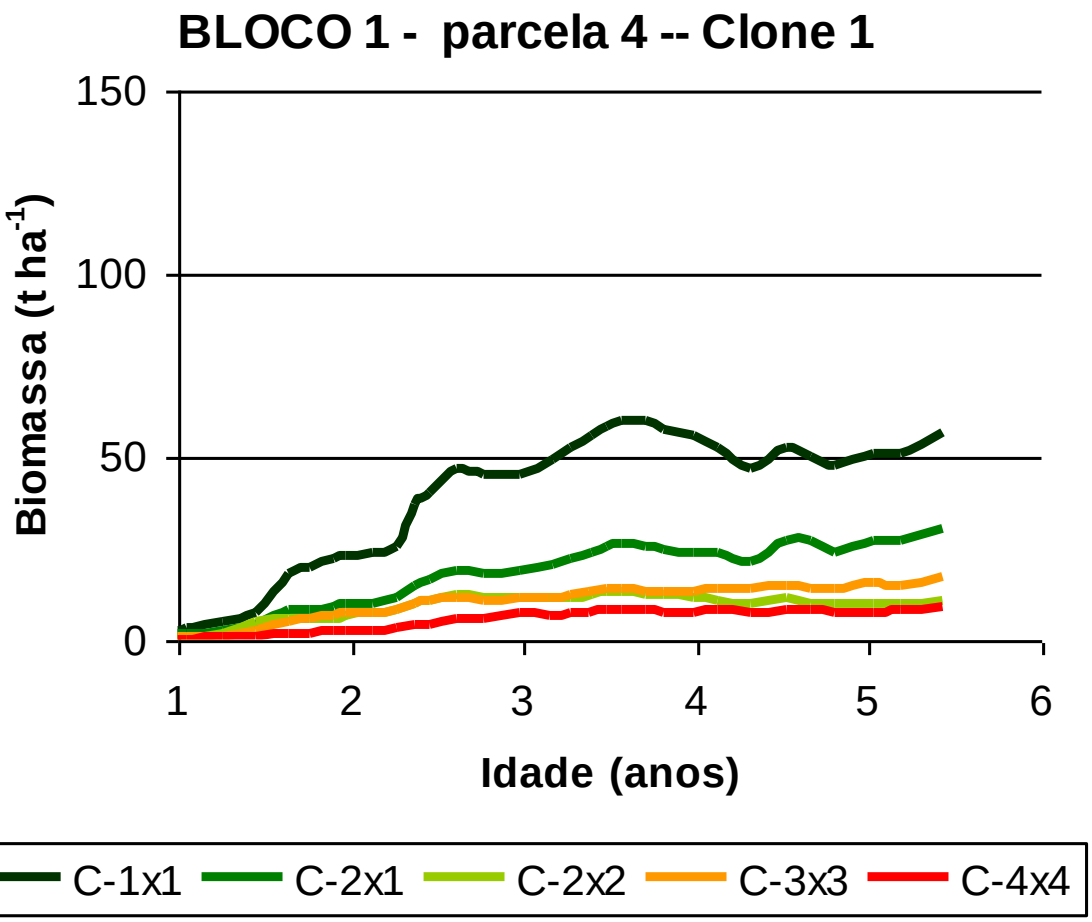
Agolada trial

volume



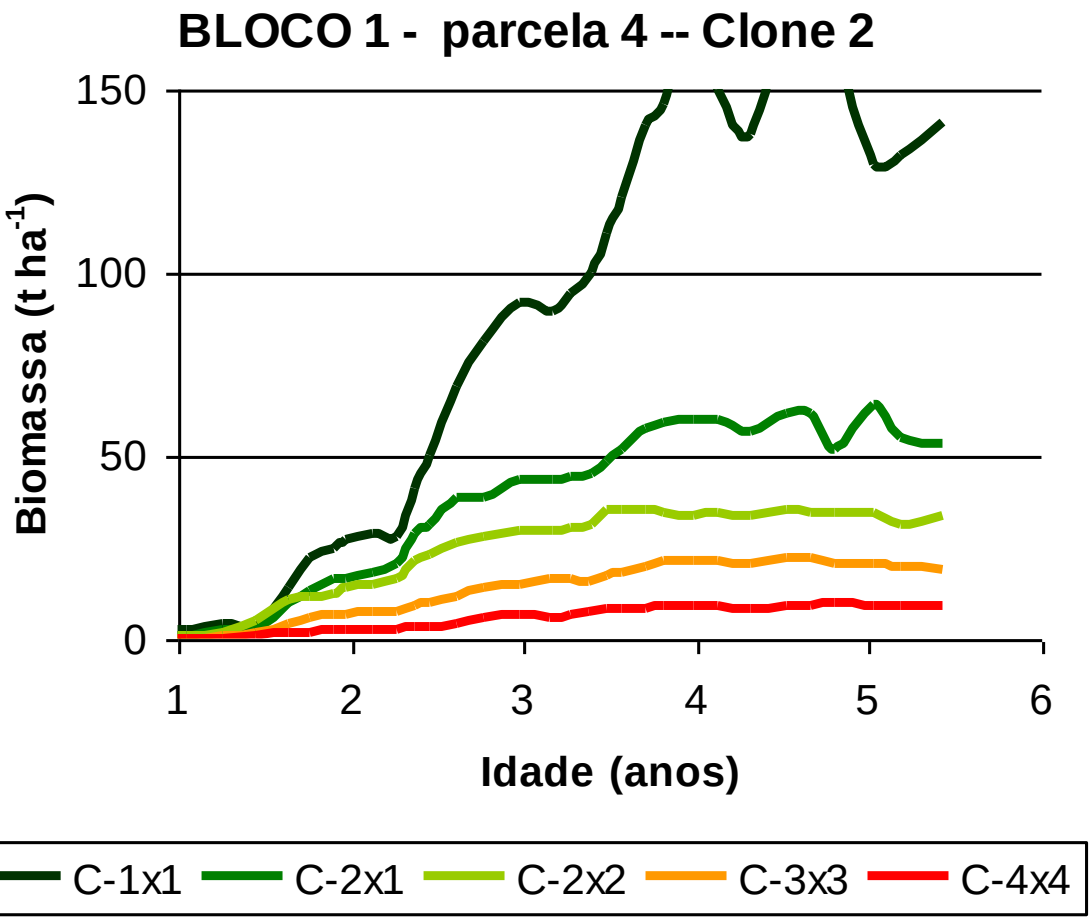
Agolada trial

biomass



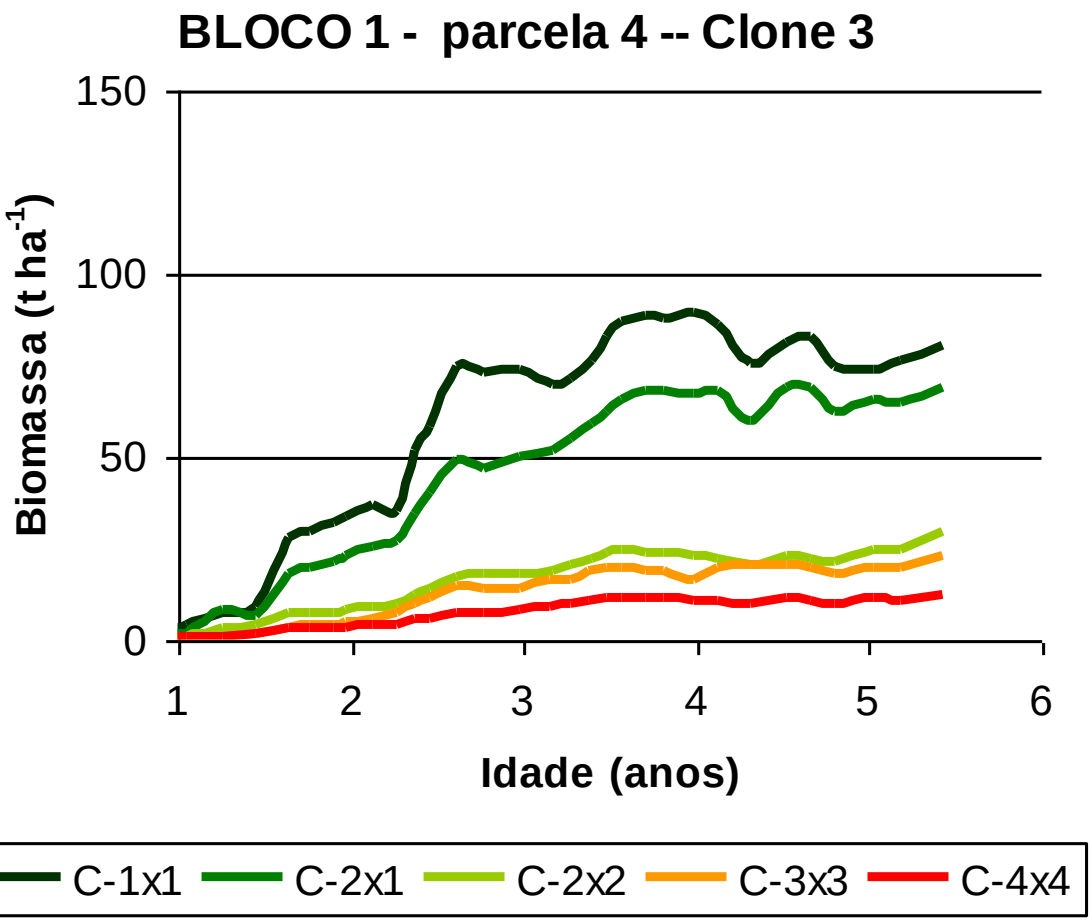
Agolada trial

biomass



Agolada trial

biomass



Some final coments

- Productivity of eucalypt in Portugal may achieve very high values by optimizing all the factors that control PPS:
  - Water and nutrients availability
  - Genetic material
  - Density at planting
  - Weed control
- Are we doing a good job?
- Or is there still a “world” to explore?
- Is it possible to produce more in the same area?


The
end!!