**Instructions for the Forest Models Projects**

**2022/2023**

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# EUCALYPT

## Compare the simulations obtained with the GLOBULUS model with real data from Alto do Vilão spacing trial (Block 1)

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| --- | --- |
|  | The files for this project can be found in the folder AltoVilao and refer to a spacing trial described in the powerpoint available in the same folder (*altoVilao.ppt*). The EXCEL file *AltoVilao\_RealData.xlsx* contains the stand variables computed from the data from measurements in this trial. The trial was established in Óbidos in 1981 in a 6 years old stand. |

### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### Use the data from the 5 plots in block I to evaluate the GLOBULUS model. Repeat the following steps for each plot (you can run it in a single run):

1. Initialize the GLOBULUS with the data from the 1981 measurement
2. Prepare the FMA and the prescriptions to be used
3. Run the simulation until the age of the last remeasurement
4. Plot the observed and simulated data for the most important stand variables and for the diameter distributions
5. Discuss the results
6. Suppose you wanted to run AV07 into the second rotation assuming a shoots selection operation at age 2 leaving 2.1 shoots per stool and final harvest at age 13. What changes would you have to make to the simulation inputs previously used to guarantee you would be able to reproduce the management?

## Compare the simulations obtained with the GLOBULUS model with real data from Alto do Vilão spacing trial (Block 2)

|  |  |
| --- | --- |
|  | The files for this project can be found in the folder AltoVilao and refer to a spacing trial described in the powerpoint available in the same folder (*altoVilao.ppt*). The EXCEL file *AltoVilao\_RealData.xlsx* contains the stand variables computed from the data from measurements in this trial. The trial was established in Óbidos in 1981 in a 6 years old stand. |

### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### Use the data from the 5 plots in block I to evaluate the GLOBULUS model. Repeat the following steps for each plot (you can run it in a single run):

1. Initialize the GLOBULUS with the data from the 1981 measurement
2. Prepare the FMA and the prescriptions to be used
3. Run the simulation until the age of the last remeasurement
4. Plot the observed and simulated data for the most important stand variables and for the diameter distributions
5. Discuss the results
6. Suppose you wanted to run AV08 into the second rotation assuming a shoots selection operation at age 2 leaving 1.9 shoots per stool and final harvest at age 17. What changes would you have to make to the simulation inputs previously used to guarantee you would be able to reproduce the management?

## Use the GLOBULUS model in StandsSIM to estimate the loss in volume cause by a forest owner that disrespected a lease contract signed with a pulp and paper company.

The owner leased 62 ha covered with shrubs to a pulp and paper company (PPC) for a period of 23 years granting the late with the right to plant and manage the area defining the management operations and wood extraction terms as well as setting the price paid for the wood. According to the contract the owner would receive 45% of the income resulting from final harvest. Unfortunately, the forest owner disrespected the contract and will be taken to trial.

|  |  |
| --- | --- |
| Activities planned by the pulp and paper company: | Location: municipality of Grândola; altitude 53 m a.s.l.  Area: 62 ha  According to the contract:  1995: plantation  2005: final cut at age 10 and transition to coppice  2018: coppice final cut at age 12  2019: end of contract  The owner would receive 45% of standing volume paid at 18.5€/m3 (consider top diameter of 5 cm)    In 2005 when the stand was harvested, a total yield of 5000 m3 was available (standing volume overbark bark without stump) |

In 2007, the owner became unhappy with the pulp and paper company and decided to harvest 32 ha of the stand. In 18 ha out of the 32 ha, he destroyed the stumps leading to the following:

* 30 ha managed according to the contract
* 14 ha of coppice harvested at age 2 (no stump destruction)
* 18 ha of coppice harvested at age 2 with stumps destroyed (unforested area)

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|  | The pulp and paper company claims the forest owner caused them a major loss and demands a restitution of 140 thousand € |

### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### About the simulations:

1. To run this simulation which options of standsSIM.md could you choose? Yield table, existing stand or multiple stands. Justify
2. You are missing site index, how could you obtain it based on the data you've been provided?
3. Assume the pulp and paper company will not change the management originally defined in the contract and will manage according to the situations described in i), ii) and iii) for the 22 years. Consider a commonly used FMA for eucalypt and an interest rate of 3% and run simulations to determine if the amount the pulp and paper company claims is fair. (If you were unable to determine the site index in b) consider it = 19)
   * how many simulation runs do you have to make? Justify:
   * would you consider the same planning horizon (number of years of simulation) for situations i), ii) and iii). Justify.
   * Say if and what you would have to change in the files in the EXEMPLES folders to run StandsSIM.md simulations in economics, consumables, assortments
   * If you choose to use a previously prepared FMA, what will you have to guarantee to be able to simulate the given situation (think about the details of the operations and the list of operations to be carried out in particular for coppice in situations i), ii) and iii)
   * run the simulations and produce an estimate of the loss in terms of volume harvested for the total area of 62 ha comparing the forest management prescription originally planned and the present situation after the forest owner's interference.
   * Do you think the amount of money asked by the pulp and paper company is reasonable? Comment.
4. Prepare a prescription assuming the pulp and paper company would immediately replant the area where the stumps were destroyed (assume the same harvest age originally planned for the coppice ie 12 years)
5. What would you have to change in the previous prescription if the pulp and paper company would wish to anticipate harvest to receive the money from the wood sell before the end of the contract?

# MARITIME PINE

## Compare the simulations obtained with PINASTER model against real data from a thinning trial in Leiria National Forest

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| desb_tal_43444546 | The files for this project can be found in the folder MNL\_grupoA (talhão/stand 43 to 46). The EXCEL files *MNL\_A\_TreeData.xlsx* and *MNL\_A\_RealStandData.xlsx* refer to tree measurements and stand variables computed for 30 plots from a thinning trial established in Leiria National Forest. The codes used to classify the trees and measurements are explained in the files. |

The stand was regenerated in 1970 and the trial established in 1992, when the stand was 22 years old. The altitude of the site is 31 m and the closest meteorological stations is São Pedro de Moel. Each plot has a total area of 1000 m2 but just the central 500 m2 were considered for the computation of the stand variables, the outer part of the plots is considered as a border zone.

### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### Use the data from plot L2B101 to evaluate the PINASTER model and execute the following steps:

1. Initialize the PINASTER with the data from the 1992 measurement
2. Project the stand, applying thinnings with a severity similar to the one used for this plot (thinning criteria: Wilson Factor)
3. Plot the observed and simulated data for the most important stand variables and for the diameter distributions
4. Discuss the results
5. Repeat questions a) to d) for some plots with different stand density trajectories and discuss the results.
6. Prepare an FMA assuming a thinning based on a residual basal area of 18 m2. Assume the first thinning is to take place at age 15 and that the following will take place with a periodicity of 5 years.

## Compare the simulations of the PINASTER model with real data from a thinning trial in São Salvador

The files for this project can be found in the folder SaoSalvador and refer to a thinning trial described in the poster available in the same folder.

The EXCEL files *inv\_Pb\_SaoSalvador\_arv.xlsx* and *inv\_Pb\_SaoSalvador.xlsx* are the input files needed as input for the standsSIM forest simulator while the file *SSalvador\_RealData.xlsx* contain the evolution of diameter distributions and stand variables computed with the data from measurements in this trial. The trial was established in 1981 in a naturally regenerated stand that was 19 years old at the trial establishment. The experimental design is complete randomized blocks with 3 treatments: a control and 3 thinning severities: heavy, intermediate and light. Each plot has a total area equal to 1000 m2. Note that the codes used to classify the trees and measurements are explained in successive sheets of the EXCEL files.

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| São Salvador trial (2022):  E:\My_Stuff\My_fotos\2022_SaoSalvador_solos\P7080394.JPG |  |

### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### Use the data from the 4 plots in one block to evaluate the PINASTER model. Repeat the following steps for each plot:

1. Initialize the PINASTER with the data from the 1981 measurement
2. Project the stand, applying thinnings with a severity similar to the one used for each plot
3. Plot the observed and simulated data for the most important stand variables and for the diameter distributions
4. Discuss the results

## Analysis of different stand density measures for the data from the São Salvador thinning trial

The files for this project can be found in the folder SaoSalvador and refer to a thinning trial described in the poster available in the same folder.

The EXCEL file *SSalvador\_RealData.xlsx* contains the evolution of diameter distributions and stand variables computed with the data from measurements in this trial. The trial was established in 1981 in a naturally regenerated stand that was 19 years old at the trial establishment. The experimental design is complete randomized blocks with 3 treatments: a control and 3 thinning severities: heavy, intermediate and light. Each plot has a total area equal to 1000 m2. Note that the codes used to classify the trees and measurements are explained in successive sheets of the EXCEL file.

Use the data from all the plots and estimate the following stand density measures:

1. Stand density index
2. Relative spacing
3. Crown competition factor
4. Compare the values over time and for the different plots (with different thinning treatments) and discuss the results.

# CORK OAK

## Find the optimum age to start cork debarking in an average stand of the Mora county

Use the SUBER model to find the optimum age to start cork debarking in an average stand of the Mora county.

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### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### You should do the simulations taking the following steps:

1. Start by running the SUBER model for a new plantation without selecting the debarking operation. Assume the forest management approach described in the following table.

|  |  |  |  |
| --- | --- | --- | --- |
| Year of 1st occurence | Periodic (Y-yes; N-no) | Periodicity | Operation |
| 0 |  |  | Plantation |
| 1 | Y | 4 | Weed control (spacing 8x4) |
| 1 | N |  | Beating-up (20% of the trees) |
| 4 | N |  | Formation pruning (80% of the trees) |
| 5 | Y | 4 | Application of fertilizer |
| 8 | N |  | Formation pruning (30% of the trees) |
| 10 |  |  | Thinning (% crown cover = 35) |
| 12 | N |  | Formation pruning (10% of the trees) |
| 15 | N |  | Thinning (% crown cover = 35) |
| td [19;30] | Y | 9 | First debarking |
| td | N |  | Formation pruning (10% of the trees) |
| td | Y | 9 | Thinning (% crown cover=35) |
|  |  |  |  |

1. Find the age at which the dg is close to a perimeter of 70 cm.
2. Run the SUBER model for several alternative FMAs that differ among them by the age of the first debarking (td)
3. Make a graphic of the net present value (NPV) over the age of first debarking (td) in order to study the impact of this variable on NPV. The selected td age is the one that maximizes NPV.
4. Prepare a small report describing the work undertaken and discussing the results obtained.

## Find the optimum age to start cork debarking in an average stand of the Estremoz county

Use the SUBER model to find the optimum age to start cork debarking in an average stand of the Estremoz county.

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| --- | --- |
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### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### You should do the simulations taking the following steps:

1. Start by running the SUBER model for a new plantation without selecting the debarking operation. Assume the forest management approach described in the following table.

|  |  |  |  |
| --- | --- | --- | --- |
| Year of 1st occurence | Periodic (Y-yes; N-no) | Periodicity | Operation |
| 0 |  |  | Plantation (spacing 8X4) |
| 1 | Y | 4 | Weed control |
| 1 | N |  | Beating-up (40% of the trees) |
| 4 | N |  | Formation pruning (80% of the trees) |
| 5 | Y | 4 | Application of fertilizer |
| 8 | N |  | Formation pruning (30% of the trees) |
| 10 |  |  | Thinning (% crown cover = 35) |
| 12 | N |  | Formation pruning (10% of the trees) |
| 15 | N |  | Thinning (% crown cover = 35) |
| td [19;30] | Y | 9 | First debarking |
| td | N |  | Formation pruning (10% of the trees) |
| td | Y | 9 | Thinning (% crown cover=35) |
|  |  |  |  |

1. Find the age at which the dg is close to a perimeter of 70 cm.
2. Run the SUBER model for several alternative FMAs that differ among them by the age of the first debarking (td)
3. Make a graphic of the net present value (NPV) over the age of first debarking (td) in order to study the impact of this variable on NPV. The selected td age is the one that maximizes NPV.
4. Prepare a small report describing the work undertaken and discussing the results obtained.

## Find the optimum rotation for cork extraction in an existing stand (Herdade da Bolota)

The EXCEL file *HerdadeBolota.xlsx* contains the data obtained during a forest inventory carried on the Herdade da Bolota. Use the SUBER model to find the optimum rotation period for cork debarking.

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### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### You should do the simulations taking the following steps:

1. Start by running the SUBER model for a new plantation without selecting the debarking operation. Assume the forest management approach described in the following table.

|  |  |  |  |
| --- | --- | --- | --- |
| Year of 1st occurence | Periodic (Y-yes; N-no) | Periodicity | Operation |
| 0 |  |  | Plantation (spacing 8X4) |
| 1 | Y | 4 | Weed control |
| 1 | N |  | Beating-up (40% of the trees) |
| 4 | N |  | Formation pruning (80% of the trees) |
| 5 | Y | 4 | Application of fertilizer |
| 8 | N |  | Formation pruning (30% of the trees) |
| 10 |  |  | Thinning (% crown cover = 35) |
| 12 | N |  | Formation pruning (10% of the trees) |
| 15 | N |  | Thinning (% crown cover = 35) |
| td [19;30] | Y | 9 | First debarking |
| td | N |  | Formation pruning (10% of the trees) |
| td | Y | 9 | Thinning (% crown cover=35) |
|  |  |  |  |

1. Find the age at which the dg is close to a perimeter of 70 cm.
2. Run the SUBER model for several alternative FMAs that differ among them by the age of the first debarking (td)
3. Make a graphic of the net present value (NPV) over the age of first debarking (td) in order to study the impact of this variable on NPV. The selected td age is the one that maximizes NPV.
4. Prepare a small report describing the work undertaken and discussing the results obtained.

# STONE PINE

The file *Herdade\_Pinhão.xls* contains the tree measurements carried out in 2000 m2 plots established in a pure even-aged stone pine stand. The stand located in Portugal, close to Evoramonte, was planted in 1998 and had 18 years of age by the time the inventory took place. The stand had had a weed control operation the year before the inventory and a formation pruning at age 15.

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### Describe the model answering the following questions:

1. Is the model empirical or process based? Justify.
2. Classify the model according to the primary unit of simulation (stand model, stand model with simulation of diameter distributions, individual tree model). Justify.
3. Identify the state variables considered by the model and classify them as principal and derived variables
4. Find the equation/modules used to simulate growth of each one of the principal variables and analyze which variables (tree/stand variables, environmental variables, etc) that are used in the equation/module, describing the role of each one in the growth prediction
5. Can you find information about the thinning algorithms used by the model?
6. Are you able to describe the regeneration module (if it exists)?

### Simulate the growth using PINEA model considering 2 alternative management objectives: fruit production and wood production

1. Generate two alternative Forest Management Approaches for fruit production and wood production according to the table below

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Final harvest age** | **Thinning residual basal area** | **Age of 1st thinning** | **Age of last thinning** | **Thinning periodicity (years)** | **Weed control periodicity** |
| Fruit | 120 years | 15 m2 ha-1 | 10 | 90 | 10 | Every 5 years |
| Wood | 120 years | 25 m2 ha-1 | 10 | 90 | 10 | Every 5 years |

1. Simulate the growth of each plot with the PINEA model using StandsSIM simulator considering both FMAs and plot the evolution of the following sustainability indicators: *Carbon stock*, *Carbon sequestered*, *harvested volume*, *fruit production*. For the simulation:

* plot 1 has 35 trees and plot 2 has 34 trees
* use the climatic data from the closest meteorological station (Évora)
* consider an altitude of 275 m
* use the economics and the consumables default files
* update the assortments file: wood price (m3) =32€ and pine cone price (kg) = 1.2€

1. Analyze the Net Present Value in the output and indicate which FMA would you recommend and justify why

# EUCALYPTUS – 3PG MODEL

## Impact of different climatic scenarios in the productivity of eucalyptus in the Chamusca county

Use the 3PG model to study the impact of different climatic scenarios in the eucalyptus productivity in the Chamusca county. You should go through the following steps:

1. Get climatic data for the Chamusca county: averages of the last 30 years and at least two future scenarios for the next 30 years. For that you can use the climate picker tool of the FCTOOLS web site.
2. Obtain the range of site indices for the Chamusca county. You can use the WebGlobulus tool available from the FCTOOLS website.
3. Run the WebGlobulus tool for the range of site indices (at least 5: very low, low, average, high, very high) to find the values of biomass that correspond to each one of these site classes.
4. Test different combinations of: soil texture, fertility rating and maximum available soil water to reproduce, using the average climate of the last 30 years, the biomass production for each one of the site classes defined in c)
5. Repeat the simulations for each one of the site classes selected in c) but using the two climatic scenarios selected in a).
6. Prepare a small report describing the work undertaken and discussing the results obtained.

## Impact of different climatic scenarios in the productivity of eucalyptus in two regions with contrasting climates

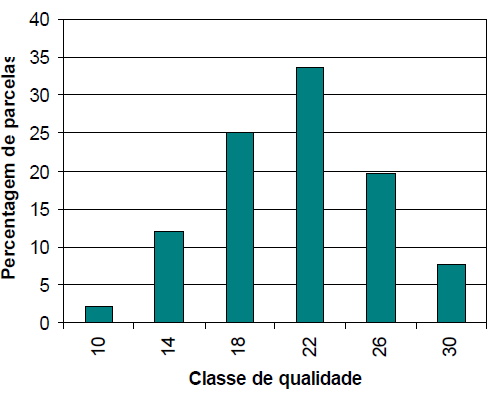
Use the 3PG model to study the impact of different climatic scenarios in the eucalyptus productivity in two contrasting regions: the Braga and the Odemira counties. You should go through the following steps:

1. Get climatic data for the Braga and Odemira counties: averages of the last 30 years and at least two future scenarios for some 30 years period (for instance 2030-2060 and 2060-2090). For that you can use the climate picker tool of the FCTOOLS web site.
2. Obtain the average site index for each of the counties. You can use the WebGlobulus tool available from the FCTOOLS website.
3. Run the WebGlobulus tool for the average site index of each one of the counties to find the values of biomass that correspond to each one of them.
4. Test different combinations of: soil texture, fertility rating and maximum available soil water to reproduce, using the average climate of the last 30 years, the biomass production for each one of the counties
5. Repeat the simulations for each one of the counties but using the two climatic scenarios selected in a).
6. Prepare a small report describing the work undertaken and discussing the results obtained.

## Impact of climate change on the productivity of eucalyptus in the Chamusca county

Use the 3PG model to analyze the impact of climate change in the productivity of eucalyptus stands located in the Chamusca county. For that you should:

1. Obtain two scenarios of climate data for the Chamusca county: i) average climate of the last 30 years; ii) two climate change scenarios. Suggestion: use the climate picker tool from sIMfLOR that includes the HadRM3Q0 A1B2 climate scenarios for the period 1951 to 2099, using climate from different periods to simulate the different climate scenarios.
2. Find the range of site indices in the county by analysis of forest inventory data represented in figure below.



Percentage of plots

Site index

1. Consider that the more frequent texture of the soils in Chamusca is sandy.
2. Consider a value of FR=0.5.
3. Consider a number of trees at planting equal to 1250 and that each seedling has the following biomass (g): wr=0.2278; wl=2.6300; wwoody=0.2035.
4. Use the 3PG model and the climate equal to the average of the last 30 years to find ASW values appropriate to simulate stands with productivities equivalent to the different site indices present in the county.
5. Repeat the exercise using the ASW value found in e) and predict the productivity under two alternative climate scenarios.
6. Discuss the results.

# Maritime pine – 3PG model

## Compare the simulations of the 3PG model with real data from a thinning trial in São Salvador

The files for this project can be found in the folder SaoSalvador and refer to a thinning trial described in the poster available in the same folder.

The EXCEL file SSalvador\_RealData.xlxs contains the evolution of diameter distributions and stand variables computed with the data from measurements in this trial. The trial was established in 1981 in a naturally regenerated stand that was 19 years old at the trial establishment. The experimental design is complete randomized blocks with 3 treatments: a control and 3 thinning severities: heavy, intermediate and light. Note that the codes used to classify the trees and measurements are explained in successive sheets of the EXCEL files.

Use the data from the 4 plots in one block to evaluate the 3PG model. Repeat the following steps for each plot:

a) Initialize the 3PG model with the data from the 1981 measurement

b) Project the stand, applying thinnings with a severity similar to the one used for each plot

c) Plot the observed and simulated data for the most important stand variables and for the diameter distributions

d) Discuss the results

# R projects

## Estimate carbon stocks in eucalyptus stands

The objective of this project is to develop all the models needed to estimate stand biomass in a set of eucalyptus stands and, from there, to estimate carbon stocks by assuming that 50% of the biomass is carbon.

For that, the students have 3 tasks:

1. To use data from pure even-aged stand of eucalyptus from the 5th Portuguese NFI in order to develop a h-dbh curve for the species (file NFI5\_Ec\_pure\_even.xlsx)

STEPS TO FOLLOW:

* Calculate the stand variables that have impact on the parameters of the height-dbh curve
* Select a h-dbh relationship as an example (in a real problem you should select several h-dbh curves and compare them in order to select the one that better fits to your data)
* You may want to force the h-dbh curve to go through the point (ddom, hdom)
* Fit the selected equation to your data and try alternative ways to express the parameters as a function of the stand and site variables

1. To develop an allometric model to estimate individual tree biomass (file Ec\_TreeBiomass.xlsx)

STEPS TO FOLLOW:

* Fit the allometric model to the data from the trees sampled
* Check if the model fit improves when expressing some of the parameters as a function of stand and site variables

1. Use the models developed in 1 and 2 to process the data from the 5th Portuguese NFI (pure stand of eucalyptus) to estimate carbon stocks (average value per ha) in the eucalyptus stands (file NFI5\_Ec\_pure\_even.xlsx)

STEPS TO FOLLOW:

* Using the h-dbh curve developed in 1. estimate the height of the trees which height has not been measured
* Use the allometric equation developed under 2. to estimate the total aboveground biomass of each tree
* Aggregate the biomass data per plot and expand the values obtained for each plot to the hectare
* Calculate the mean value per ha of the C stock

## Develop site index curves for eucalyptus in Portugal

The objective of this project is to develop site index curves for eucalyptus stands in Portugal, comparing two alternative methods:

1. Difference equations method

In this method one growth function formulated as a difference equation is used to fit an equation that allows the prediction of hdom at age t2 as a function of hdom at age t1

1. Parameter prediction method

This method starts from estimating the site index (S) for each one of the plots, so that this variable can be used to express the impact of site index in the growth function parameters

The data to be used in this project can be found in file Ec\_StandGrowth\_Without\_S.xlsx.

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## Develop compatible models to initialize and project stand basal area

The objective of this project is to develop two equations for basal growth prediction of eucalyptus stands:

1. A growth function formulated as a difference equation to project the stand from age t1 to age t2; the parameters should reflect the impact of stand density and site quality

STEPS TO FOLLOW:

* Transform the data file in a paired data file that can then be used to fit the growth function formulated as a difference equation
* Select one growth function and one of its formulations as a difference equation (in a real problem, you should compare several growth functions and all its formulations as difference equations)
* Fit the selected growth to the data
* Express some of the parameters as a function of stand and site variables

1. The same growth function in its integral form to be used in the model initialization module

STEPS TO FOLLOW:

* The growth function as an integral form must be fitted with the original data set
* The parameters common to the difference formulation used in 1. must be set to the values obtained in 1., so that the two functions are compatible
* Now you should fit the growth function with just the free parameter to estimate
* Express the free parameter as a function of stand and site variables

The data to be used in this project can be found in file Ec\_StandGrowth.xlsx.

Table 1 (Annexed to this text) shows the most used forest growth functions and its formulation as difference equations. Note that if you will express a parameter as a function of variables that change over time, then you will have to take this into account in the respective difference equation. Using the Lundqvist-k function for basal area (G) as an example:

If we want to express the *m* parameter as a function of stand density (*m=m0+mN N*), the correct expression is:

Table 1 (Annexed to this text) shows the most used forest growth functions and its formulation as difference equations.

# ANNEX 1 – Growth functions formulated as difference equations

Table 1. Different formulations of the theoretical growth functions as difference equations. The different formulations are indexed by the site-specific parameter.

|  |  |
| --- | --- |
| **Function** | **Mathematical expression** |
| Lundqvist-A  (Schumacher-A if n=1) |  |
| Lundqvist-k  (Schumacher-k if n=1) |  |
| Richards-A  (Monomolecular-A if m=0) |  |
| Richards-k  (Monomolecular-k if m=0) |  |
| Richards-m |  |
| McDill-Amateis |  |