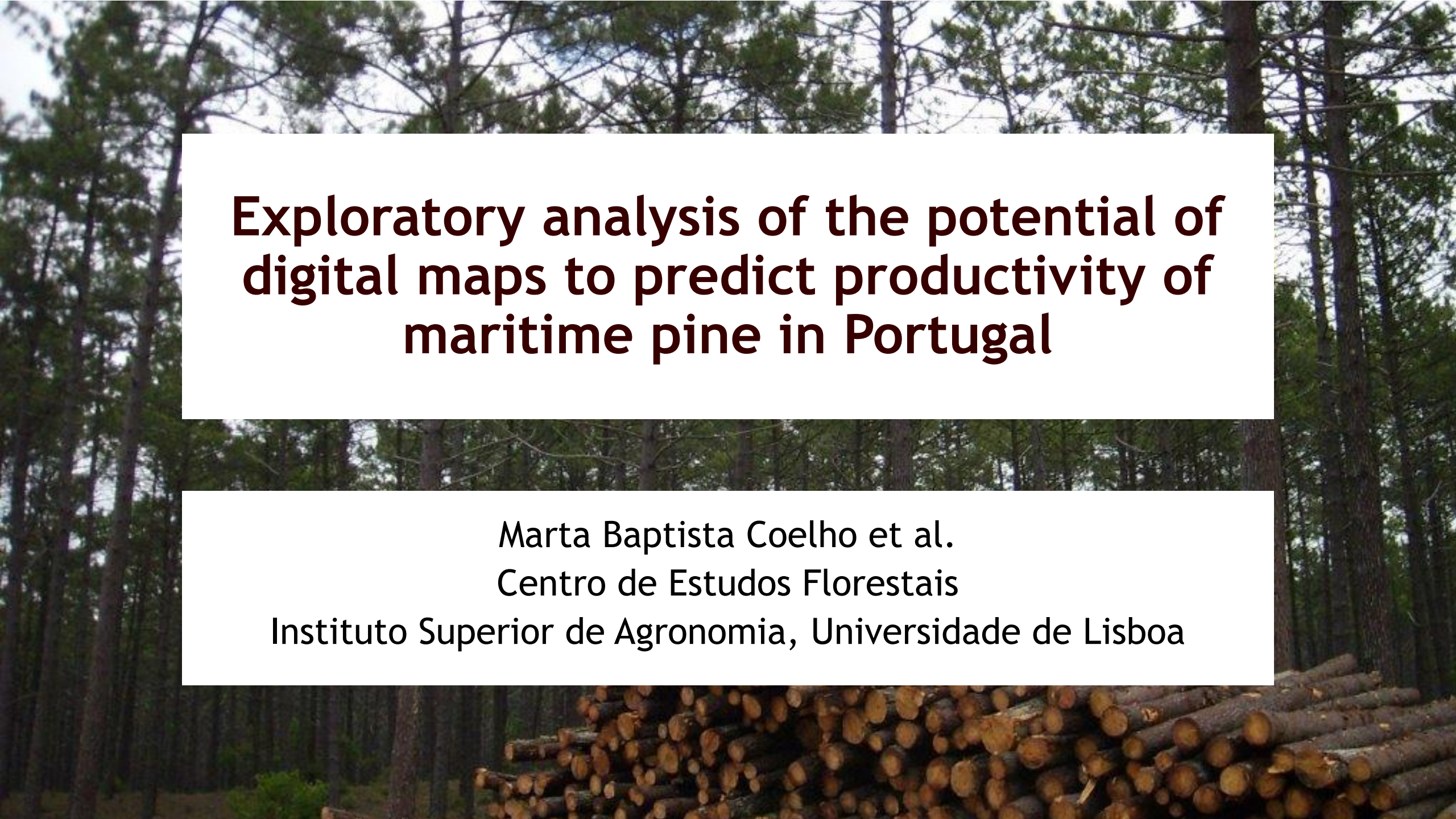


Exploratory analysis of the potential of digital maps to predict productivity of maritime pine in Portugal

Marta Baptista Coelho et al.
Centro de Estudos Florestais
Instituto Superior de Agronomia, Universidade de Lisboa

Margarida Tomé

Susana Barreiro

Marta Baptista-Coelho

António Correia

Instituto Superior de Agronomia
Centro de Estudos Florestais
Universidade de Lisboa

Motivation: the ARF project










ARF@Pt

A tool to suport landowners' and policy decisions in Portugal

ARF@PT - a participatory task force

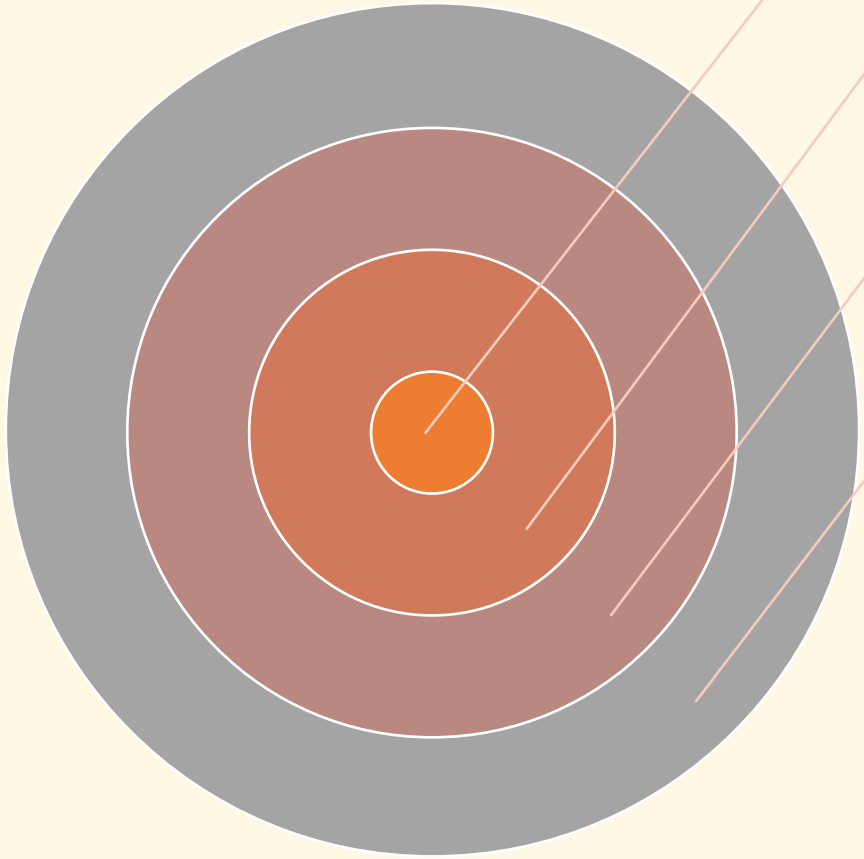
- ✔ The ForChange group has provided several tools (among which forest simulators) in the FCTOOLS website

  https://www.isa.ulisboa.pt/cef/forchange/fctools/en/home (write FCTOOLS in google)

- ✔ Some of the simulators (SUBER and standsSIM) include economic analysis among the output, but they are so flexible that the users find them “too difficult” to use

- ✔ **The aim of ARF@ptis to develop a tool that will be liked by the landowners and other stakeholders**

Organization of the task force



Coordination comittee

Technical team

Consultation board with species-specific comittees

Users

ARF@pt project steps

- ✔ **Ecological envelopes** for each species (EES)
- ✔ **Models for the estimation of site index** (S) for the species that can be selected for a particular site
- ✔ Define, for each “site condition”, the **silvicultural systems** and the **associated operations** along the planning horizon
- ✔ **Identification**, for each site condition, of all the **forest operations** during the planning horizon
- ✔ Adoption of **cost and prices** to be used in the economic analysis
- ✔ Develop a **user-friend platform** that the stakeholders like and use

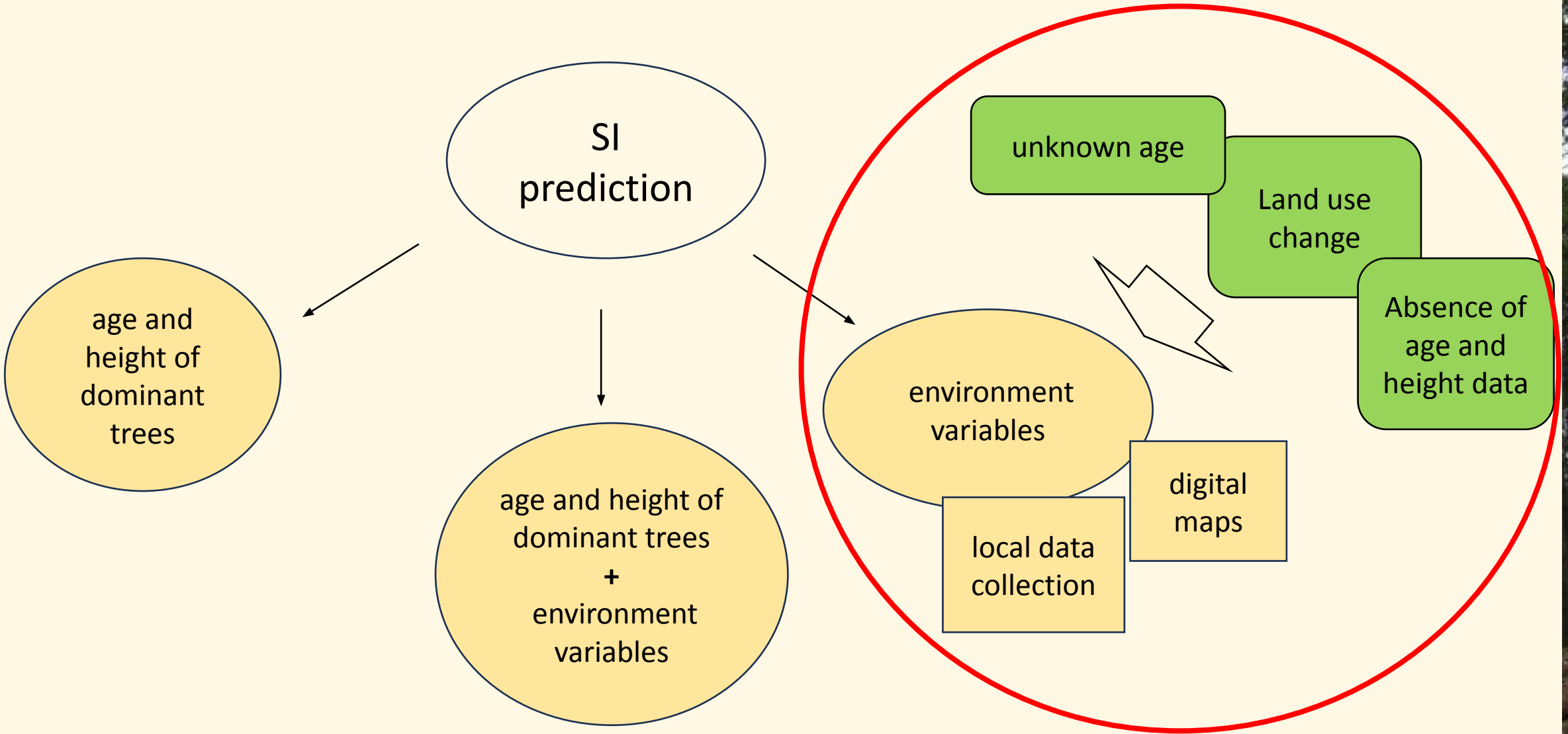
Exploring digital maps as input for the development of the site index models

ARF@pt project steps

✔ **Models for the estimation of site index** (S) for the species that can be selected for a particular site

	Model type	
	Average model for the region with quantiles	Locally calibrated model
	Digital information collected from maps and/or files	Detailed topographic and soil information (soil profile)
Maritime pine	X	
Eucalypt	X	
Cork oak	X	X

Site index prediction

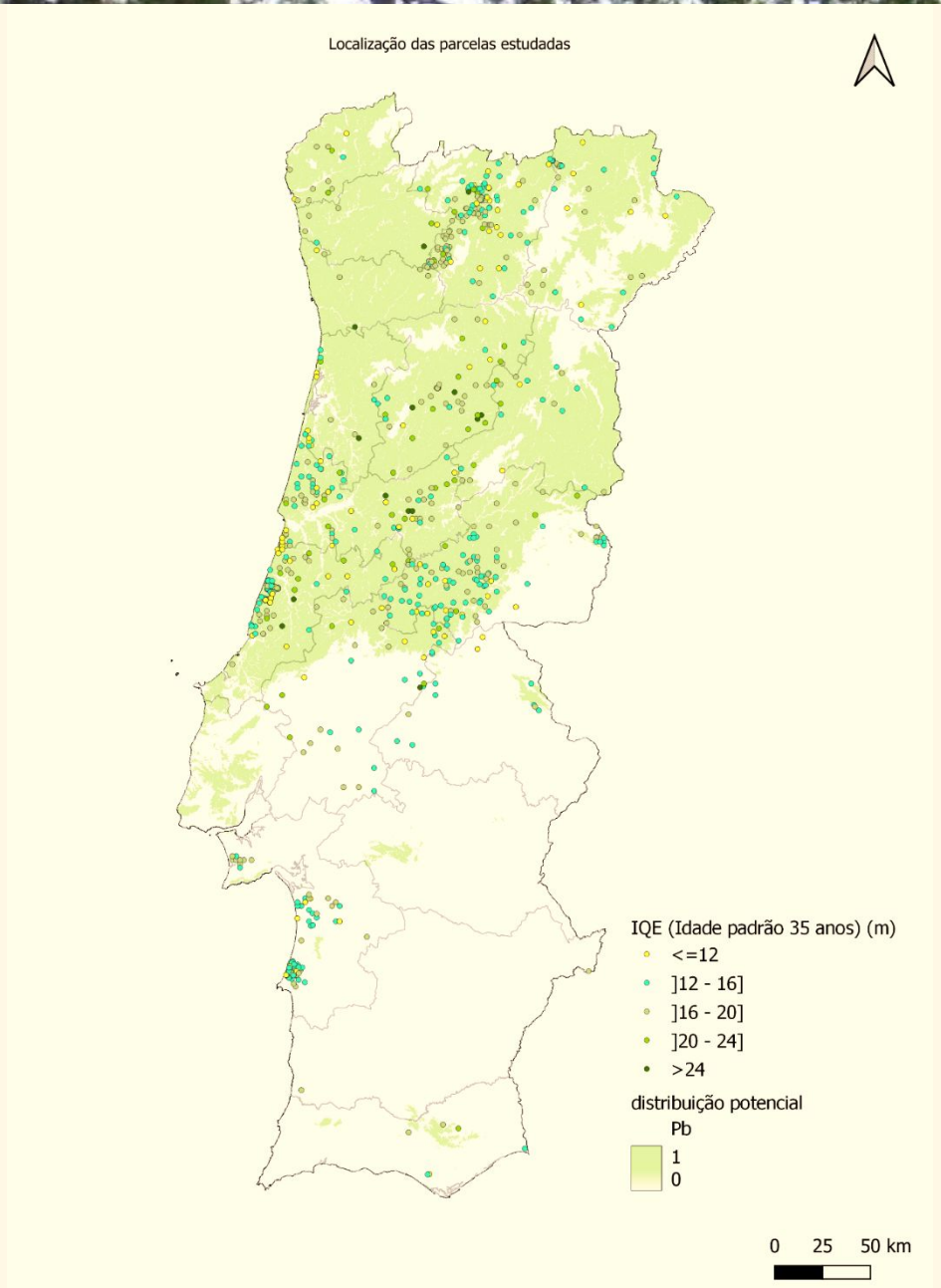


Materials - data used

Pure regular stands

Source	No. Of selected plots	tdom (years) (min-max)	No. Plots with tdom btw 15 e 55 years
4º National Forest Inventory (1995)	261	7.0 - 80	181
5º National Forest Inventory (2005)	386	6.0 – 104.5	308
IPB plots	88	16.0 - 66.0	81
IPCB plots	51	2.6 – 74.0	37
Centro Pinus plots	44	4.0 – 65.0	27
Silvicultural trials (Goes e São Salvador)	29	13.0-35.0	20
National Forests Inventory - Sines	73	12.0 - 68.5	70
Leiria National Forest	45	18.0 – 52.0	45
TOTAL	977	-	**769**

Methods: distribution of plots and site index values



Methods – environmental variables

Climatic data

- Environment Atlas (shapefile 1:1000 000)
- Clipick

Soil data

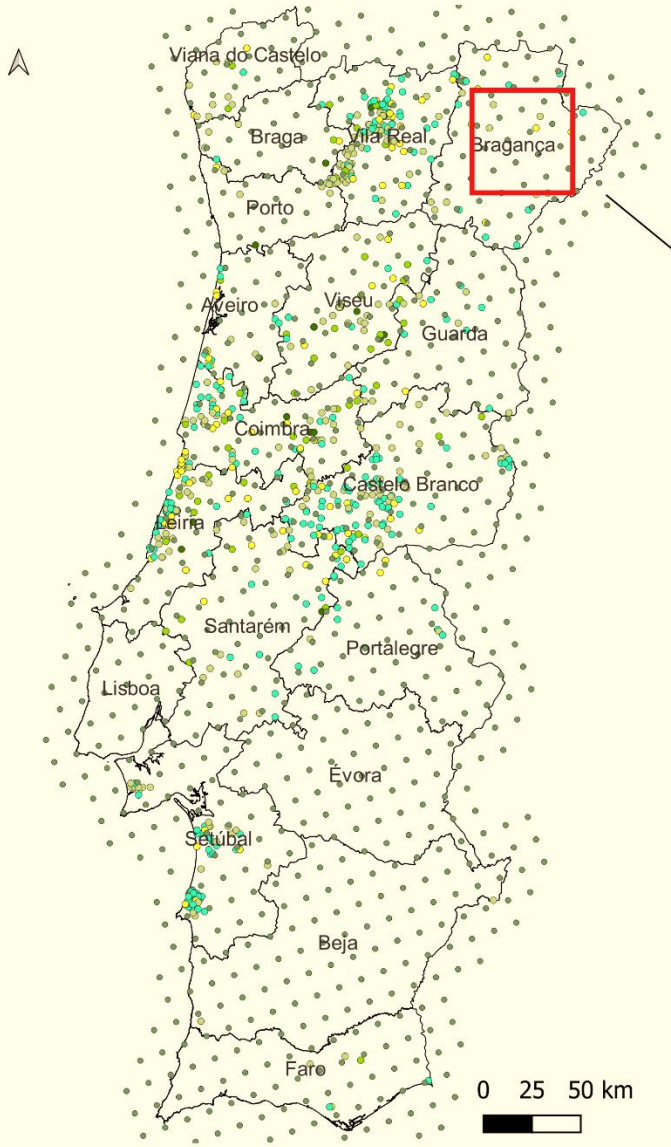
- Environment Atlas (shapefile 1:1000 000)
- EPIC (shapefile e raster 1: 50000
- LUCAS database (raster 1:100 000)
- Digital maps of FR and MaxASW

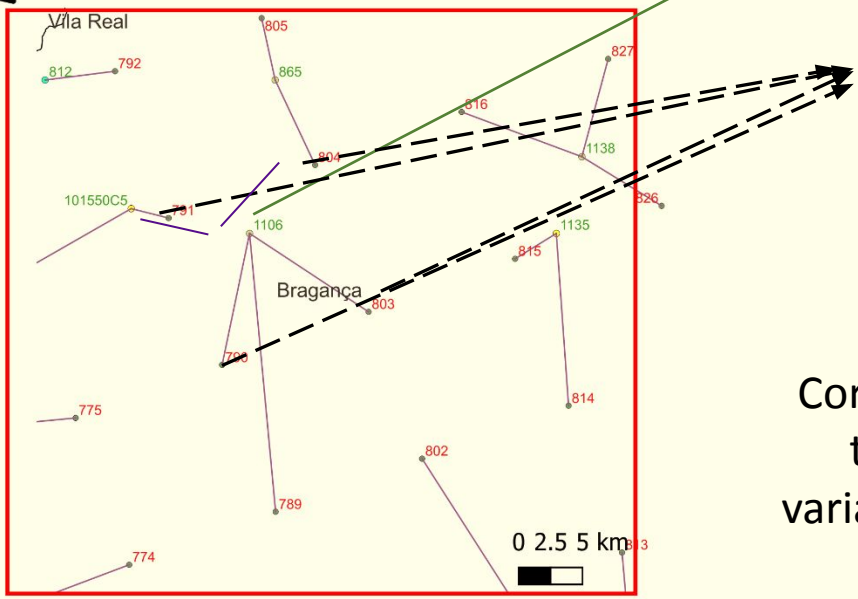
Topographic data

- Digital Terrain Model (raster 1:25 000)

Methods: attribution of variable values to each plot

Climatic variables





Plot **1106**

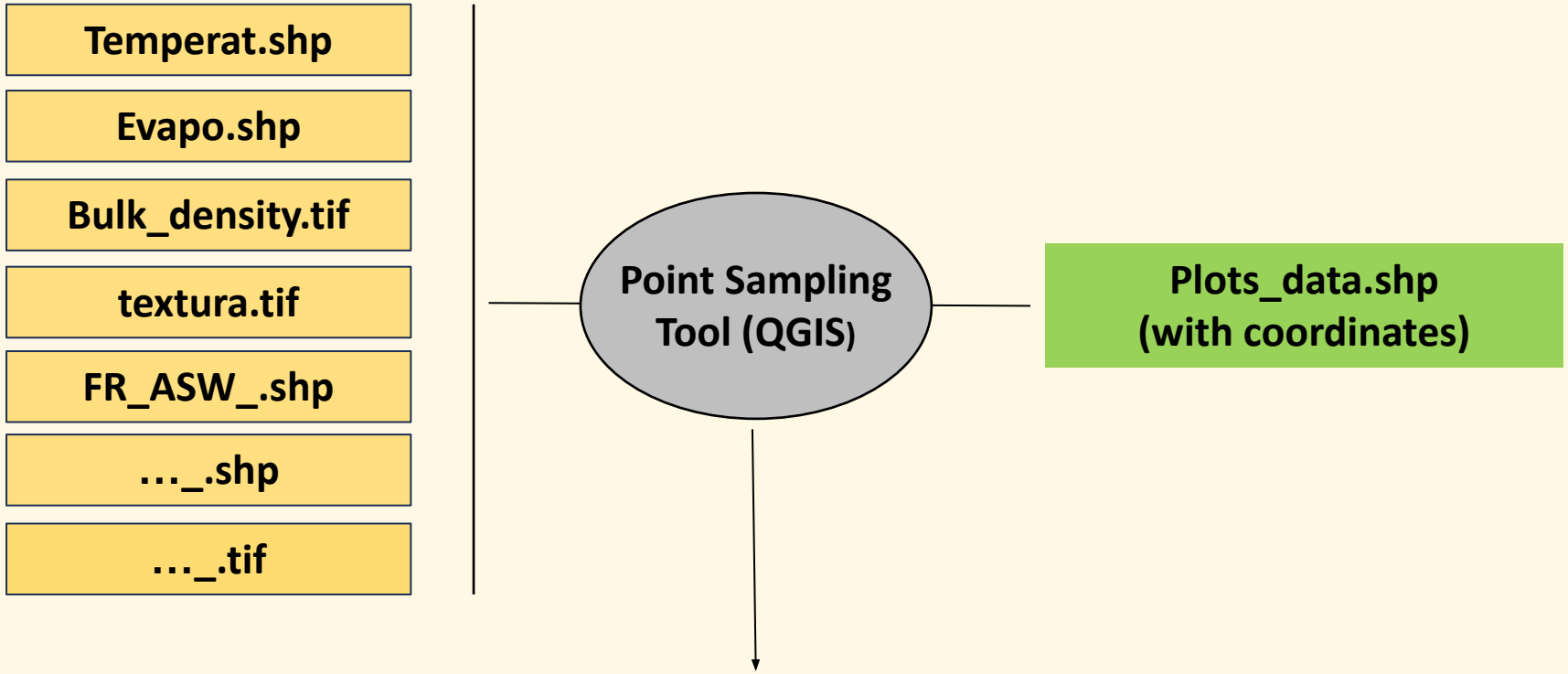
virtual weather stations **Clipick** (virtual weather station 791 is the nearest to plot **1106**)

Correspondence between each plot and the averages of the **Clipick** climatic variables (1971-2000) associated with the nearest virtual station

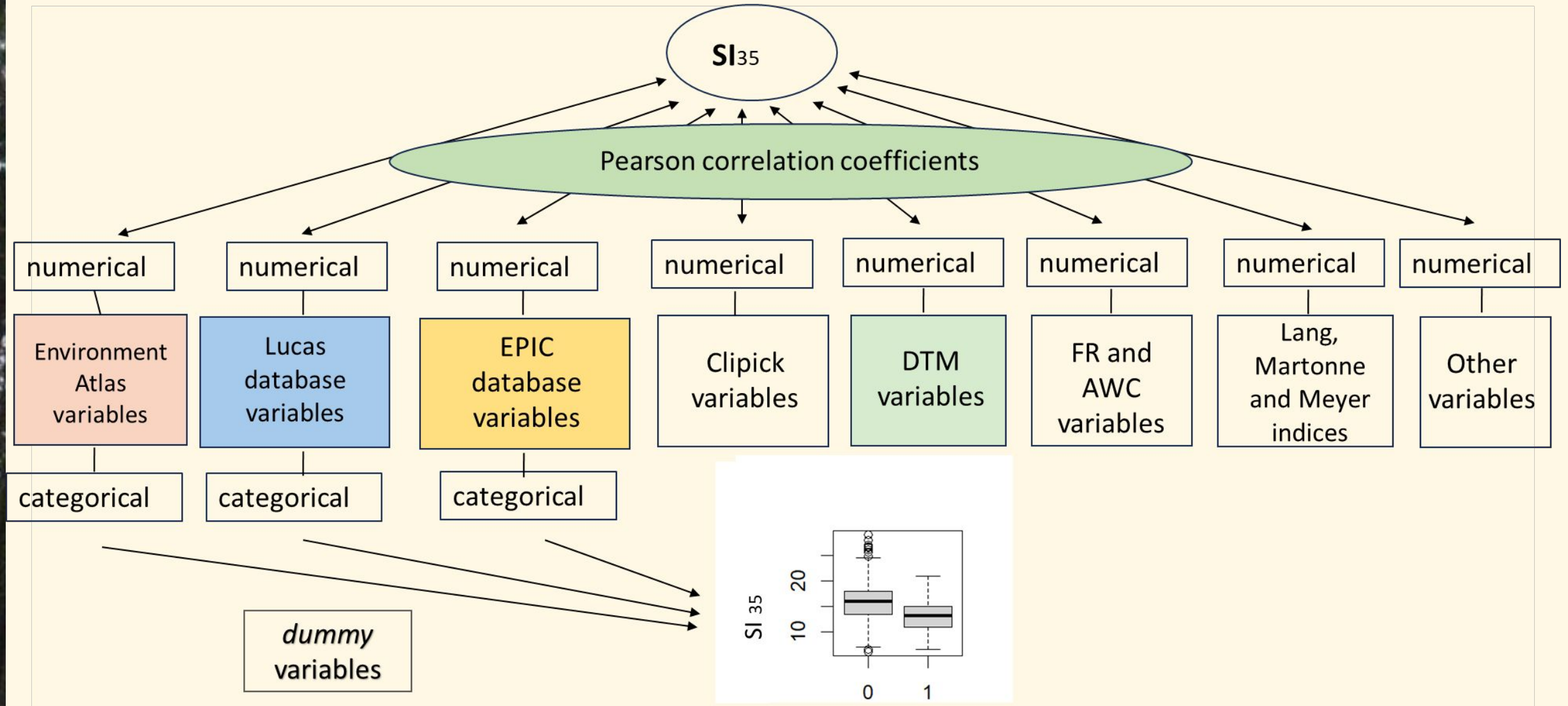
Plots data + Clipick variables.xls

Methods: attribution of variable values to each plot

Climatic, soil and topographic variables



Methods: preliminary analysis of the correlations between Si_{35} and the environmental variables



Methods: variable selection for the linear model:

regsubsets (R) –identification of the variables that give rise to the 3 best models with 6 variables (SSE as criteria)

- very high number of variables
- Significantly different from zero coefficients
- Coefficient sign

Successive use of *regsubsets* and *lm* in a "trial and error" process

testing principal components in models

relation between SI_{35} and the 8 climatic regions (Ribeiro e Tomé, 2000)

Methods: quantile regression

modeling of different quantiles of the response variable (SI_{35})

useful when the relationship between variables varies at different levels of the distribution of the response variable

Minimizes the sum of absolute errors by weighting them according to the quantile

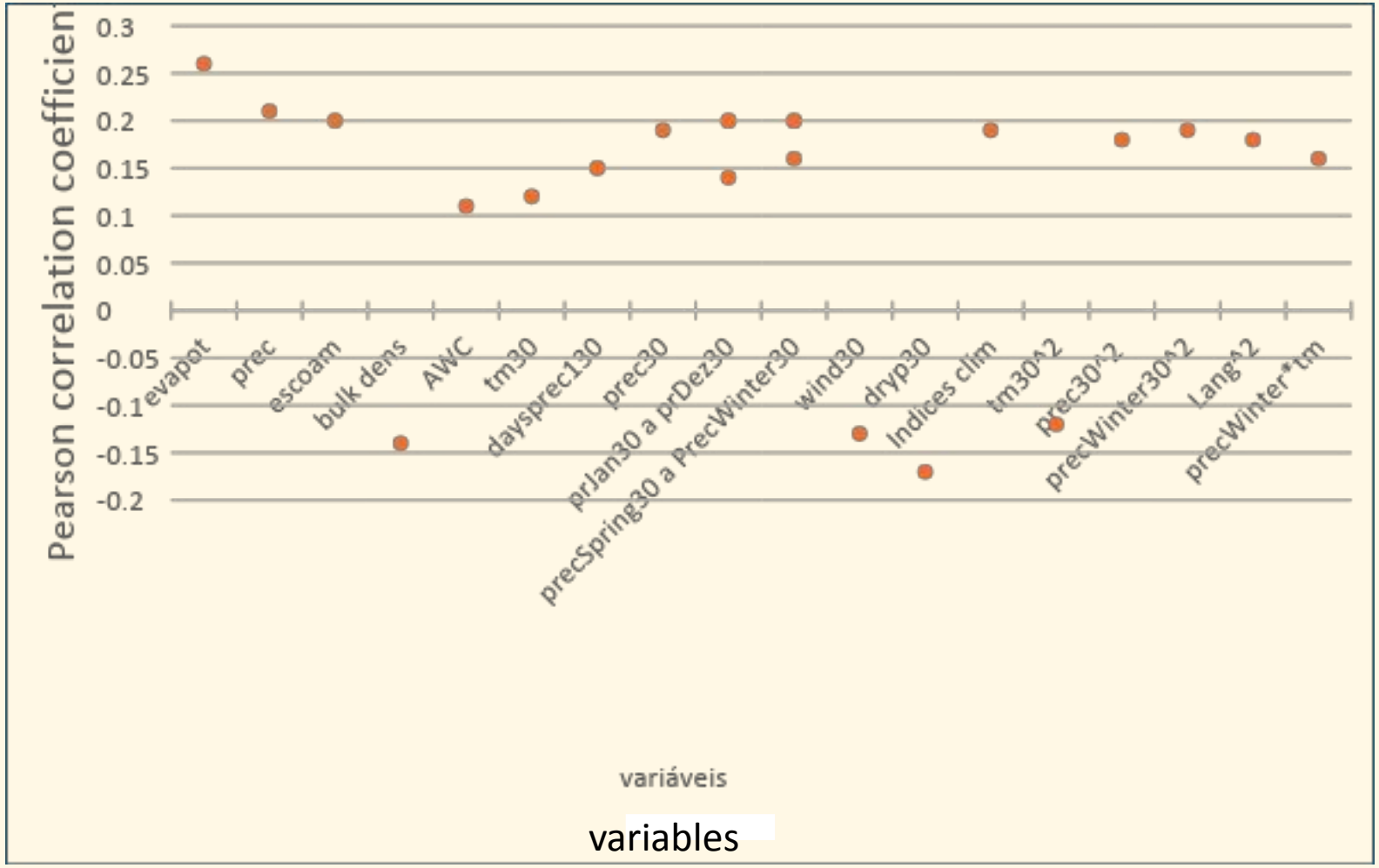
0.05
0.25
0.50
0.75
0.95

Variables used are the ones selected for the linear model

rq function from R

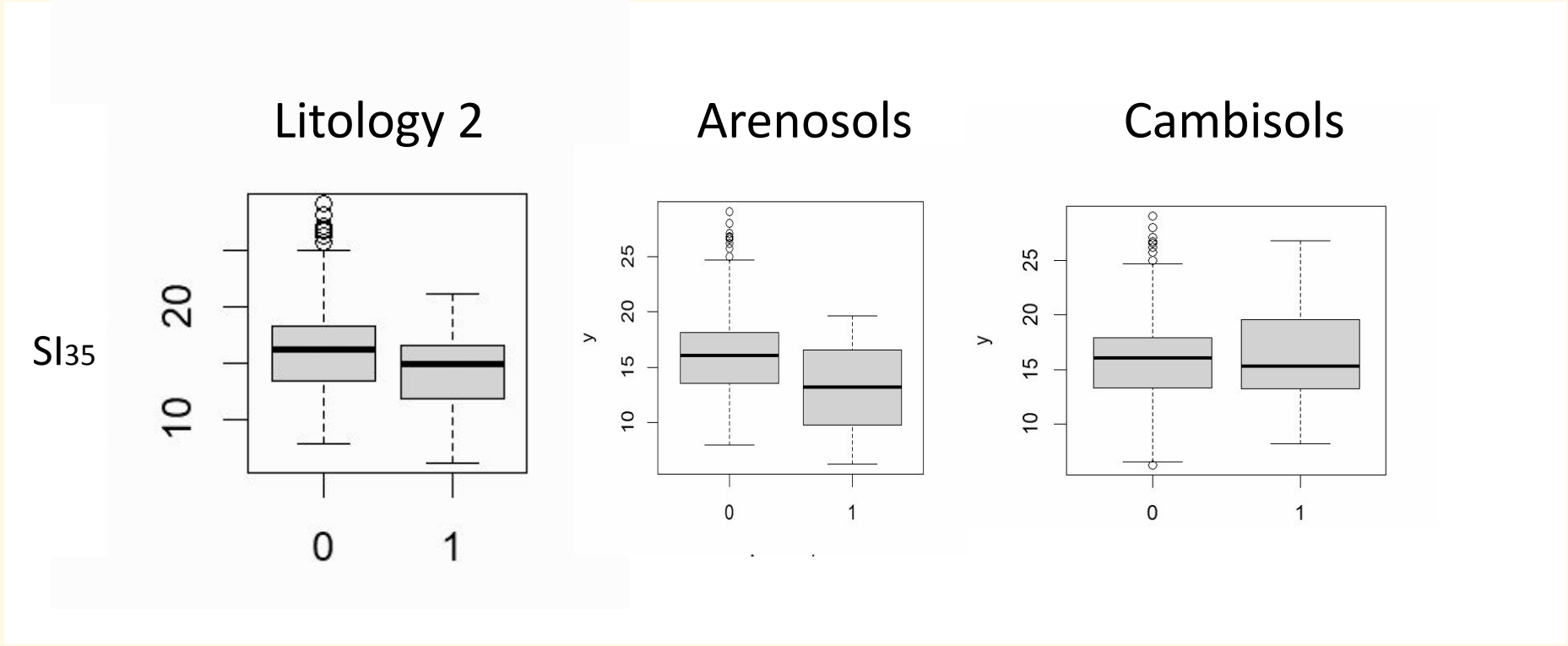
Manual stepwise until all the coeficients are significantly different from zero and whose sign (+/-) makes sense

Results: best correlations



variables

Results: examples with categorical variables



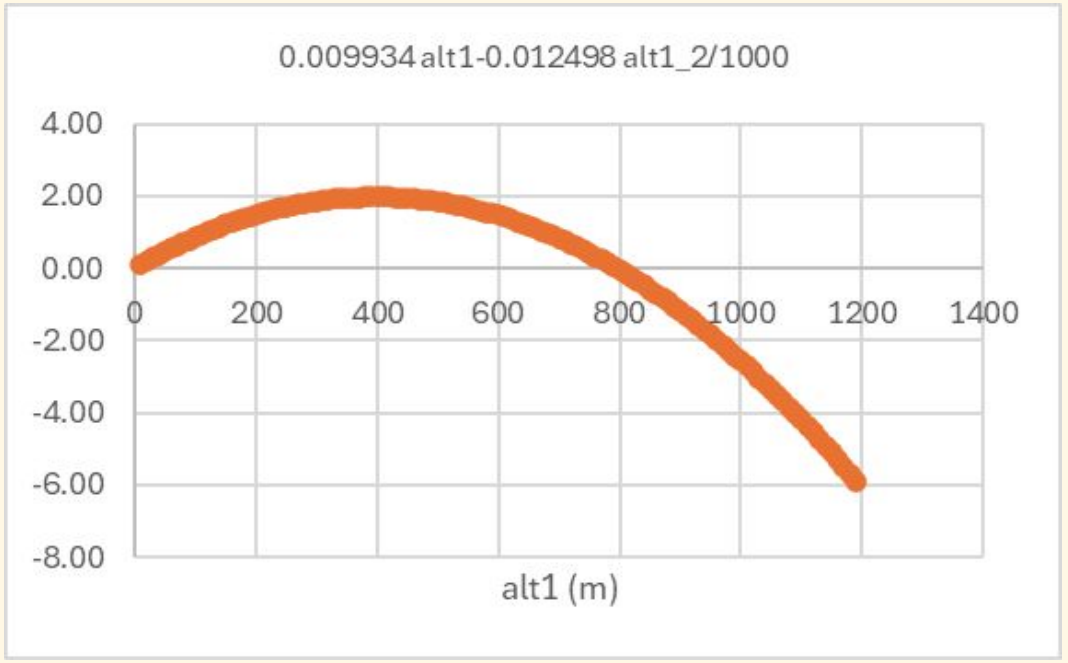
Results - multilinear regression

Final Model:

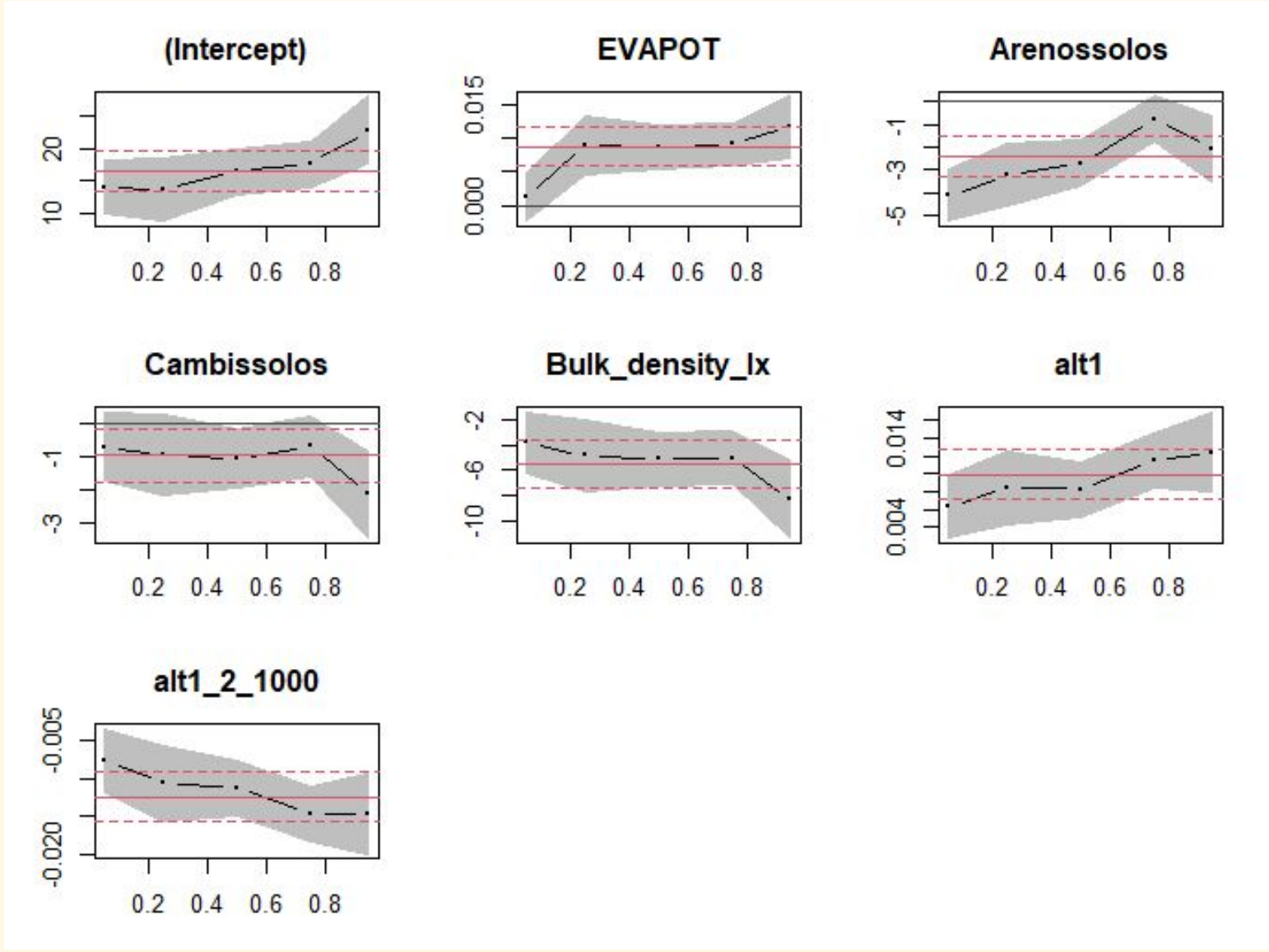
Variable	Intercept	Evapot	Arenossolos	Cambissolos	Bulk_density_lx	Alt1	$Alt1^2/1000$
Coefficient	16.51587 1	0.008727	-2.406520	-0.947988	-5.423130	0.009934	-0.012498
Signif.	***	***	***	-	***	***	***

model	R^2	adj.R^2	aic	vif.max	mean_p	mean_ap	rp_p95	rp_p05	r2p
1	0.16	0.15	3971.83	16.07	-0.0004	2.53	5.15	-5.37	0.15

Results - multilinear regression



Results - quantile regression



Results - quantile regression

Quantil	Intercept	Evapot	sign	Arenos	sign	Cambis	sign	Bulk	sign	alt1	sign	Alt_2/1000	sign
0.05	14.73369	-	-	-3.98798	***	-	-	-3.70786	**	0.00641	***	-0.00769	***
0.25	14.08645	0.00902	***	-3.19156	***	-	-	-5.23142	**	0.00890	***	-0.01206	***
0.50	16.76377	0.00884	***	-2.70745	***	-	-	-5.37416	***	0.00760	***	-0.01025	***
0.75	17.53391	0.00828	***	-	-	-	-	-4.53096	***	0.01046	***	-0.01328	***
0.95	22.26358	0.01157	***	-	-	-	-	-7.75115	***	0.01209	***	-0.01418	***

Results - help for quantile selection

Example of criteria for placing a stand in one of the 5 quantiles:

	soil depth	Thickness of the A horizon	stoniness
Quantile 0.95			
Quantile 0.75			
Quantile 0.50			
Quantile 0.25			
Quantile 0.05			

Conclusions and discussion

very low R^2

in accordance with

Distribution of SI_{35} averages by municipality without clear association with climate variation in the country

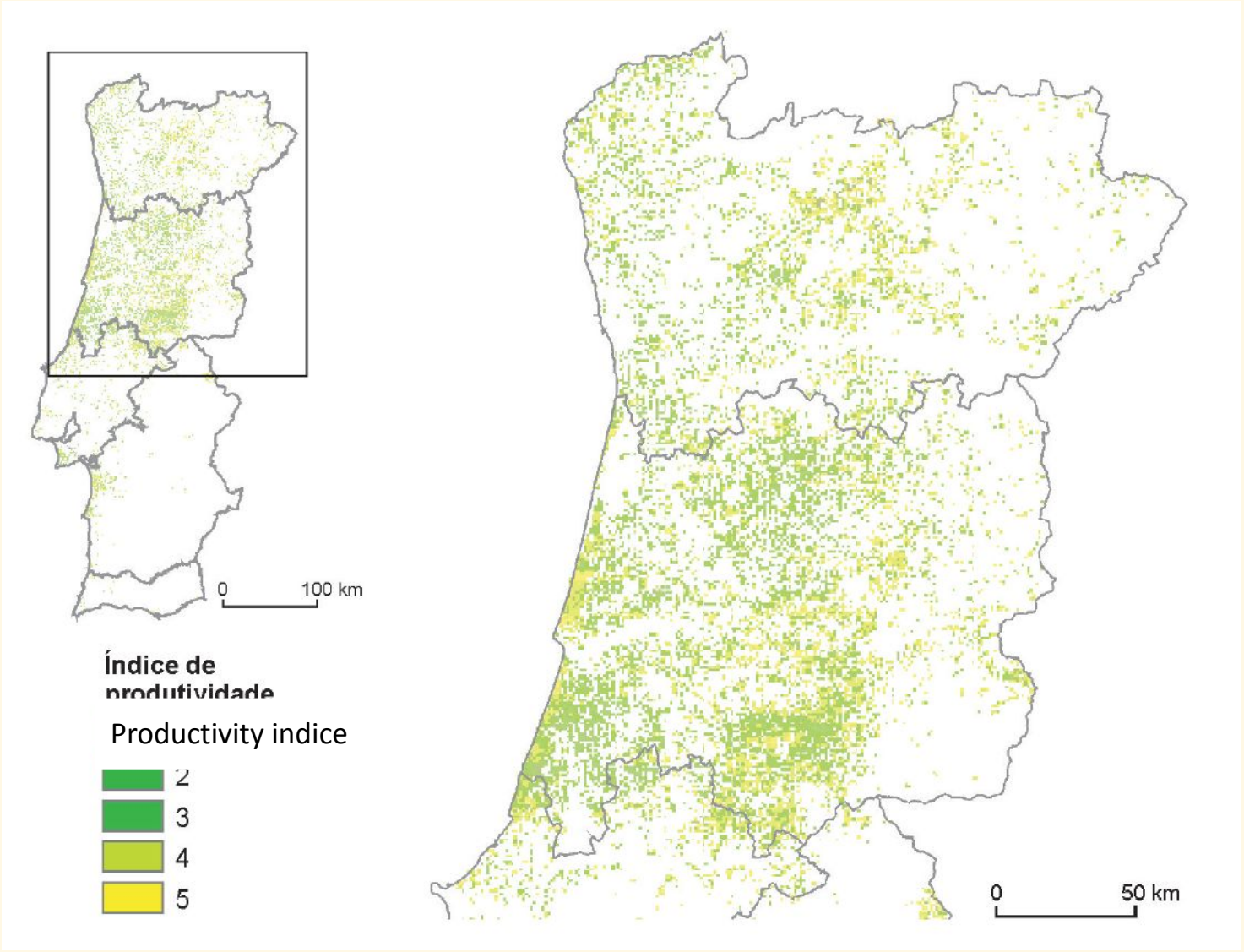
Proximity of plots with very different SI_{35} classes

validated by

Weak or no evident trend between plots SI_{35} values and their location in the 8 climatic regions defined by Ribeiro and Tomé (2000)

Non-selection of variables resulting from principal component analysis

Conclusions and discussion



(Image from Santos e Almeida, 2003)

Conclusions and discussion

The results seem to suggest that **maritime pine** responds much more to **local soil and topography characteristics** than to climate variation and soil characteristics variation obtained from large-scale digital maps

Several authors obtained higher R^2 values by using variables obtained from soil pit analyses as regressors

Future work

Visit the locations of some plots to decide whether to continue to be part of the observation set

Choose some sets of plots where the climate and soil type (given by digital maps) do not differ but which have different SI_{35} values, so that characteristics that explain the difference can be identified locally

Use other methodologies, such as principal component analysis with climate, soil and topographic variables or ML (Machine Learning) regression approach. Use other climate information sources

The ARF project is iterative

- ✔ The **ARF@pt** is using the **best existing knowledge**
- ✔ It allows the identification of **gaps in knowledge**
- ✔ As soon as **new knowledge** will be available, it will be **incorporated**

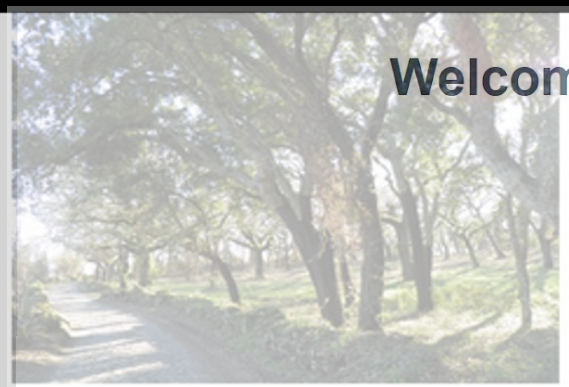
LET'S LOOK AT A BETA VERSION OF ARF@pt

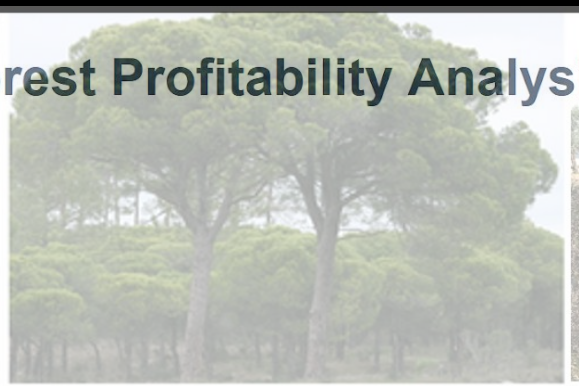
Google Calendar - Week of 7 A | StandsSIM Web App no novo simflo | simflor-web

Not Secure 34.145.60.147:8080/#/

ARF@PT - Beta Version - 2022 [PT] [EN]

Welcome to the Portuguese Forest Profitability Analysis Tool










ARF@Pt

A tool to suport landowners' and policy decisions in Portugal

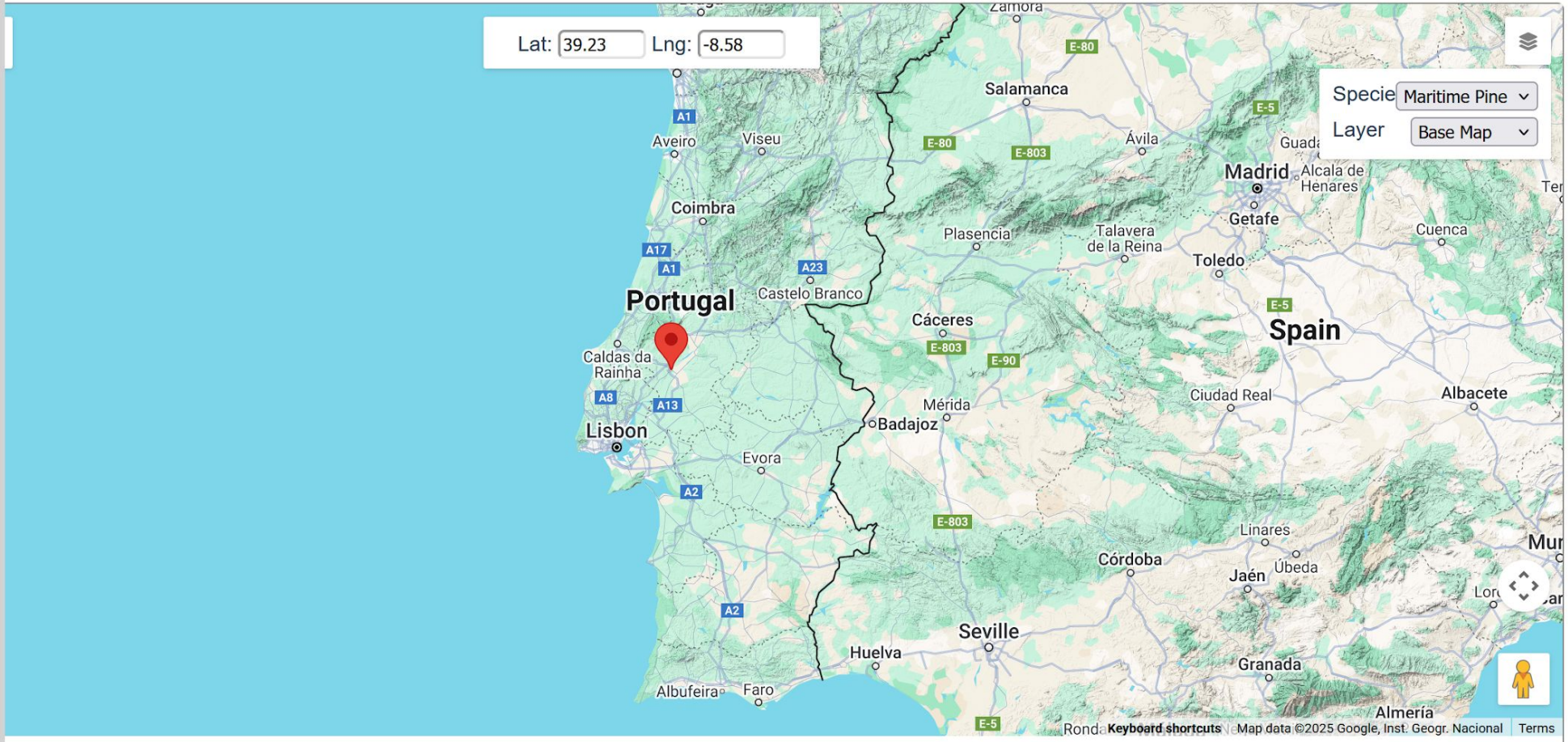
Search

POR 19:12 07/04/2025

ARF@PT - Beta Version - 2022 [PT] [EN]

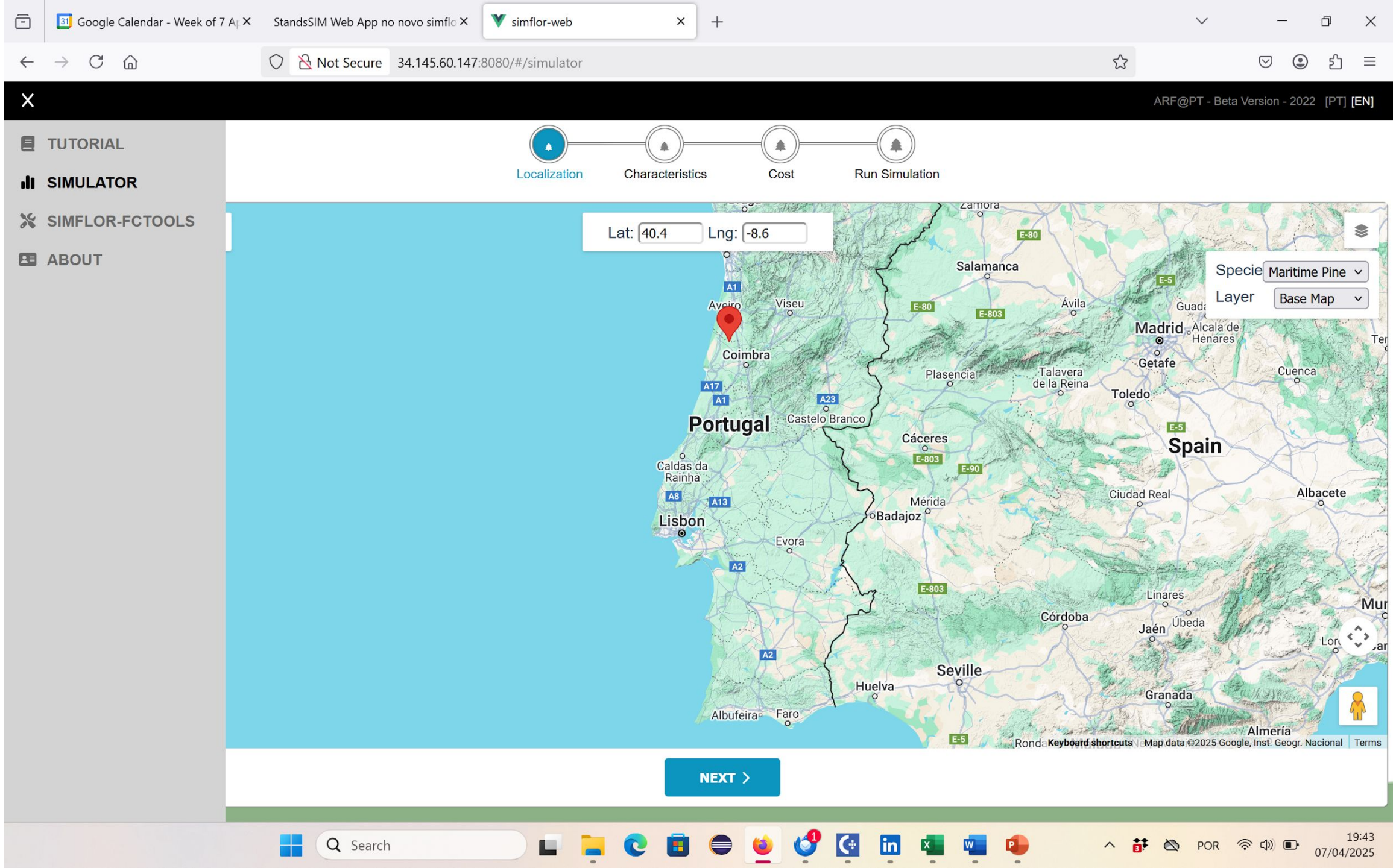
- TUTORIAL
- SIMULATOR
- SIMFLOR-FCTOOLS
- ABOUT

Localization — Characteristics — Cost — Run Simulation



NEXT >

34.145.60.147:8080/#/simulator


Google Calendar - Week of 7 A
StandsSIM Web App no novo simflo
simflor-web
Not Secure
34.145.60.147:8080/#/simulator
ARF@PT - Beta Version - 2022 [PT] [EN]
TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT
Localization
Characteristics
Cost
Run Simulation
Lat: 40.4
Lng: -8.6
Specie
Maritime Pine
Layer
Base Map
Portugal
Spain
Lisbon
Coimbra
Aveiro
Viseu
Salamanca
Ávila
Madrid
Getafe
Toledo
Cuenca
Plasencia
Talavera de la Reina
Castelo Branco
Cáceres
Caldas da Rainha
Mérida
Badajoz
Ciudad Real
Albacete
Evora
Córdoba
Jaén
Úbeda
Linares
Seville
Huelva
Granada
Almería
Albufeira
Faro
Keyboard shortcuts
Map data ©2025 Google, Inst. Geogr. Nacional
Terms
NEXT
Search
POR
19:43
07/04/2025

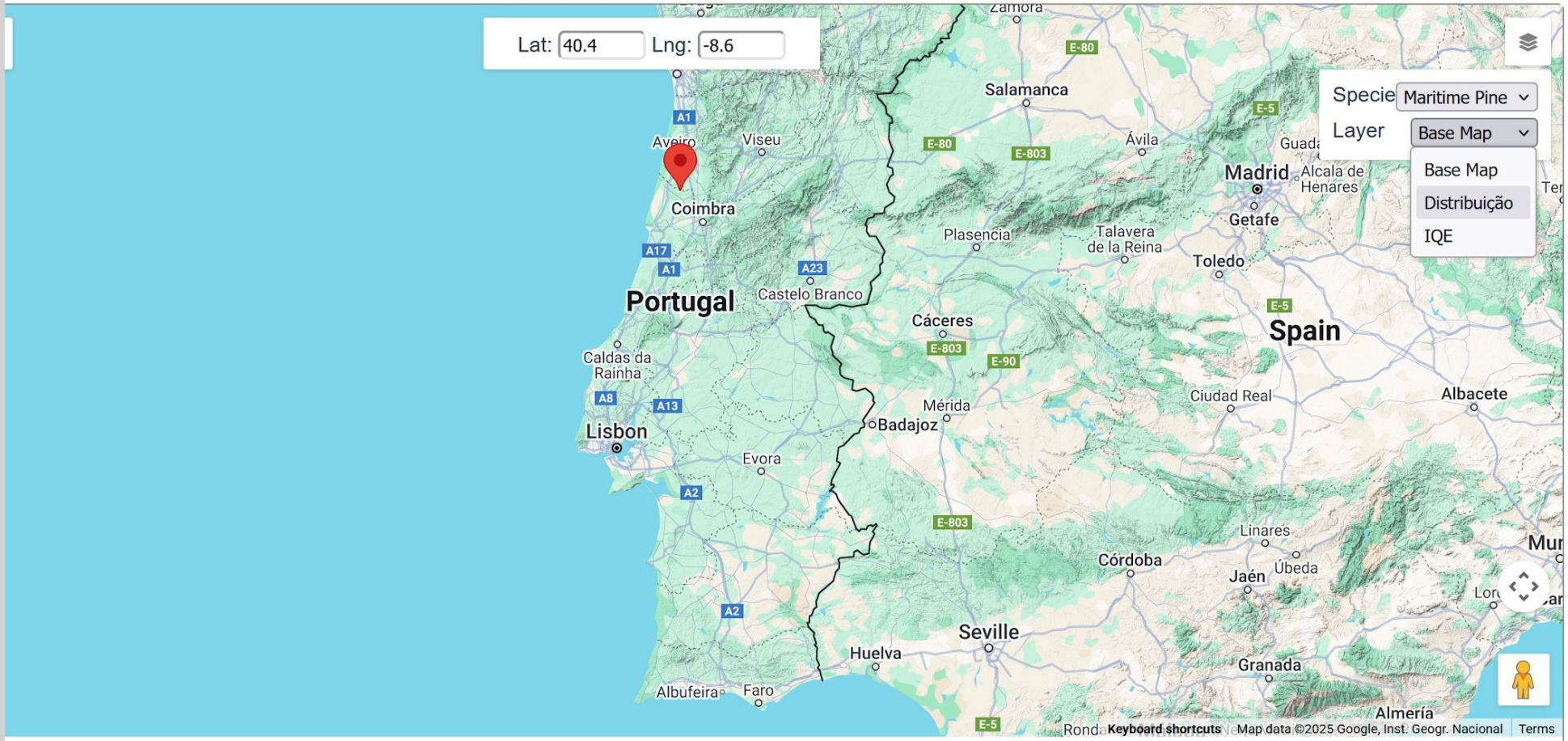
Google Calendar - Week of 7 A | StandsSIM Web App no novo simflo | simflor-web

Not Secure 34.145.60.147:8080/#/simulator

ARF@PT - Beta Version - 2022 [PT] [EN]

- TUTORIAL
- SIMULATOR
- SIMFLOR-FCTOOLS
- ABOUT

Localization > Characteristics > Cost > Run Simulation



NEXT >

Search

POR 19:43 07/04/2025

Google Calendar - Week of 7 A | StandsSIM Web App no novo simflo | simflor-web | WebGlobulus | FCTools | WebGlobulus

Not Secure 34.145.60.147:8080/#/simulator

ARF@PT - Beta Version - 2022 [PT] [EN]

- TUTORIAL
- SIMULATOR
- SIMFLOR-FCTOOLS
- ABOUT

Localization > Characteristics > Cost > Run Simulation

Lat: 40.42 Lng: -8.65

Specie: Maritime Pine

Layer

- Maritime Pine
- Eucalyptus
- Cork Oak
- Stone Pine

Portugal Spain Lisbon Madrid Coimbra Salamanca Viseu Ávila Plasencia Talavera de la Reina Toledo Getafe Alcalá de Henares Castelo Branco Cáceres Mérida Badajoz Ciudad Real Albacete Évora Córdoba Jaén Úbeda Linares Seville Huelva Granada Almería Caldas da Rainha Aveiro Albufeira Faro Ronda

Keyboard shortcuts Map data ©2025 Google, Inst. Geogr. Nacional Terms

NEXT >

Search POR 22:50 07/04/2025

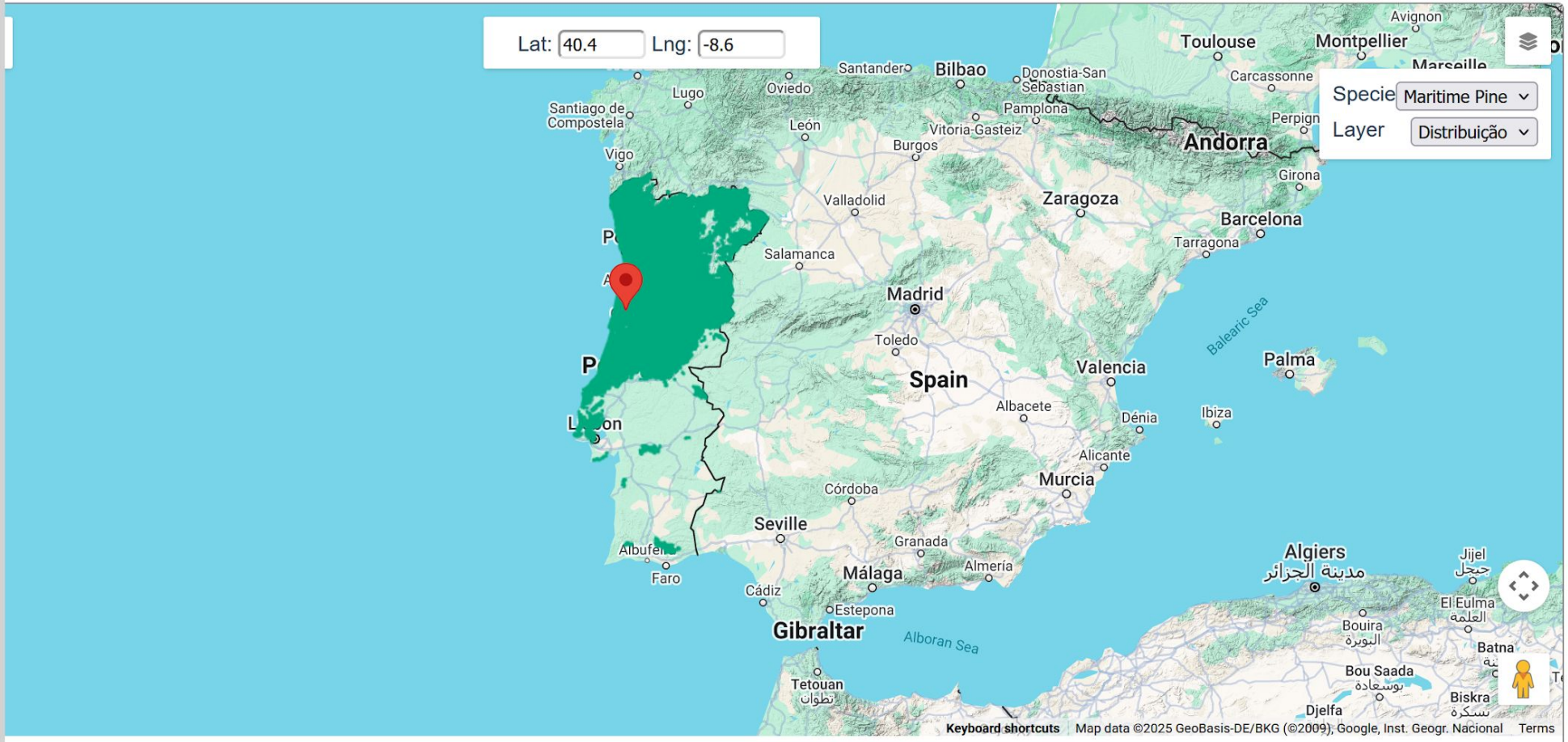
Google Calendar - Week of 7 A | StandsSIM Web App no novo simflo | simflor-web

Not Secure 34.145.60.147:8080/#/simulator

ARF@PT - Beta Version - 2022 [PT] [EN]

- TUTORIAL
- SIMULATOR
- SIMFLOR-FCTOOLS
- ABOUT

Localization > Characteristics > Cost > Run Simulation



NEXT >

Search

POR 19:44 07/04/2025

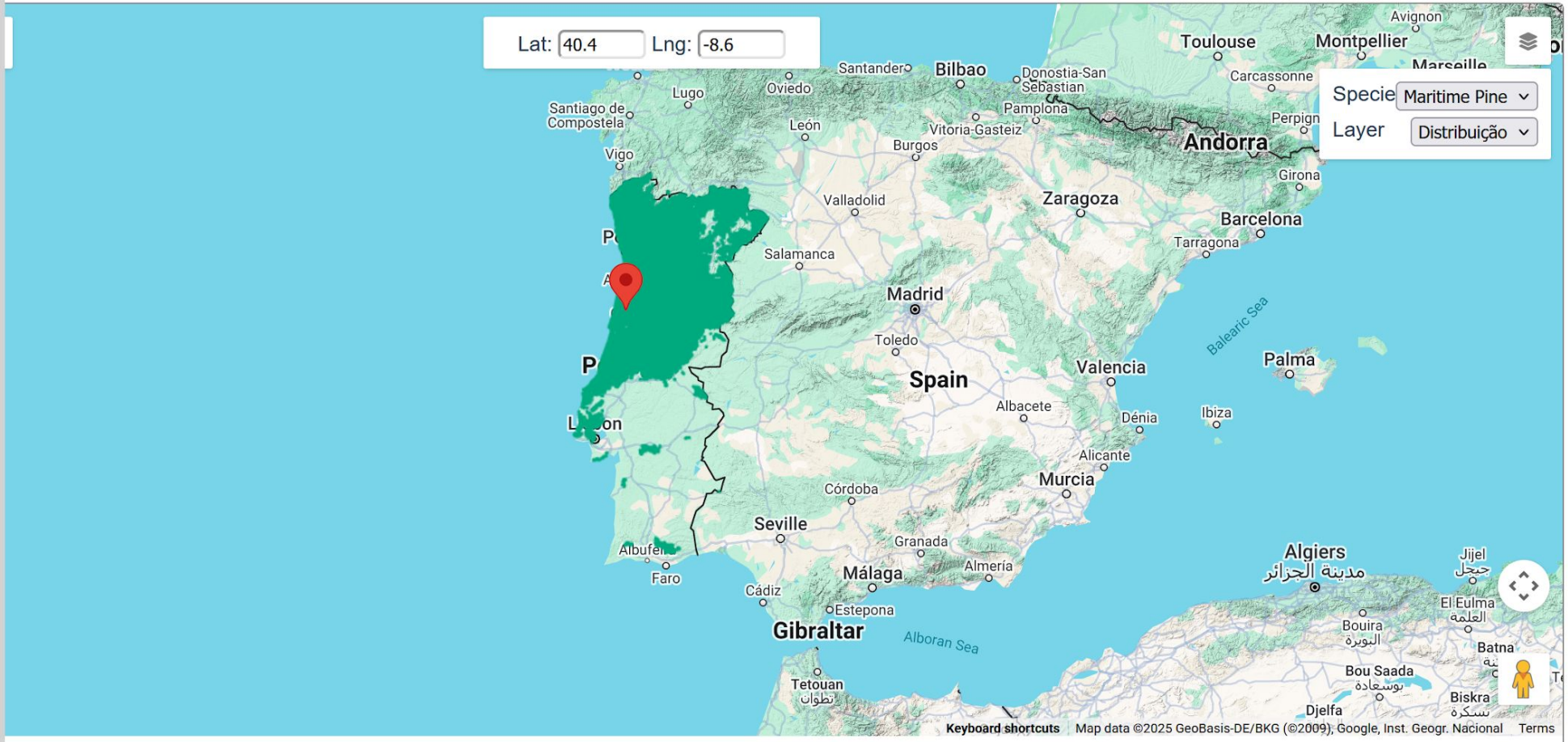
Google Calendar - Week of 7 A | StandsSIM Web App no novo simflo | simflor-web

Not Secure 34.145.60.147:8080/#/simulator

ARF@PT - Beta Version - 2022 [PT] [EN]

- TUTORIAL
- SIMULATOR
- SIMFLOR-FCTOOLS
- ABOUT

Localization > Characteristics > Cost > Run Simulation



NEXT >

Search

POR 19:44 07/04/2025

Google Calendar - Week of 7 A | StandsSIM Web App no novo simflo | simflor-web | WebGlobulus | FCTools | WebGlobulus

Not Secure 34.145.60.147:8080/#/simulator

ARF@PT - Beta Version - 2022 [PT] [EN]

- TUTORIAL
- SIMULATOR
- SIMFLOR-FCTOOLS
- ABOUT

Localization > Characteristics > Cost > Run Simulation

Lat: 40.36 Lng: -8.72

Specie: Maritime Pine

Layer: Distribuição

Site index in the region	
Q95%	25.2
Q75%	22.8
Q50%	20.5
Q25%	18.5
Q5%	13.6
Site index	

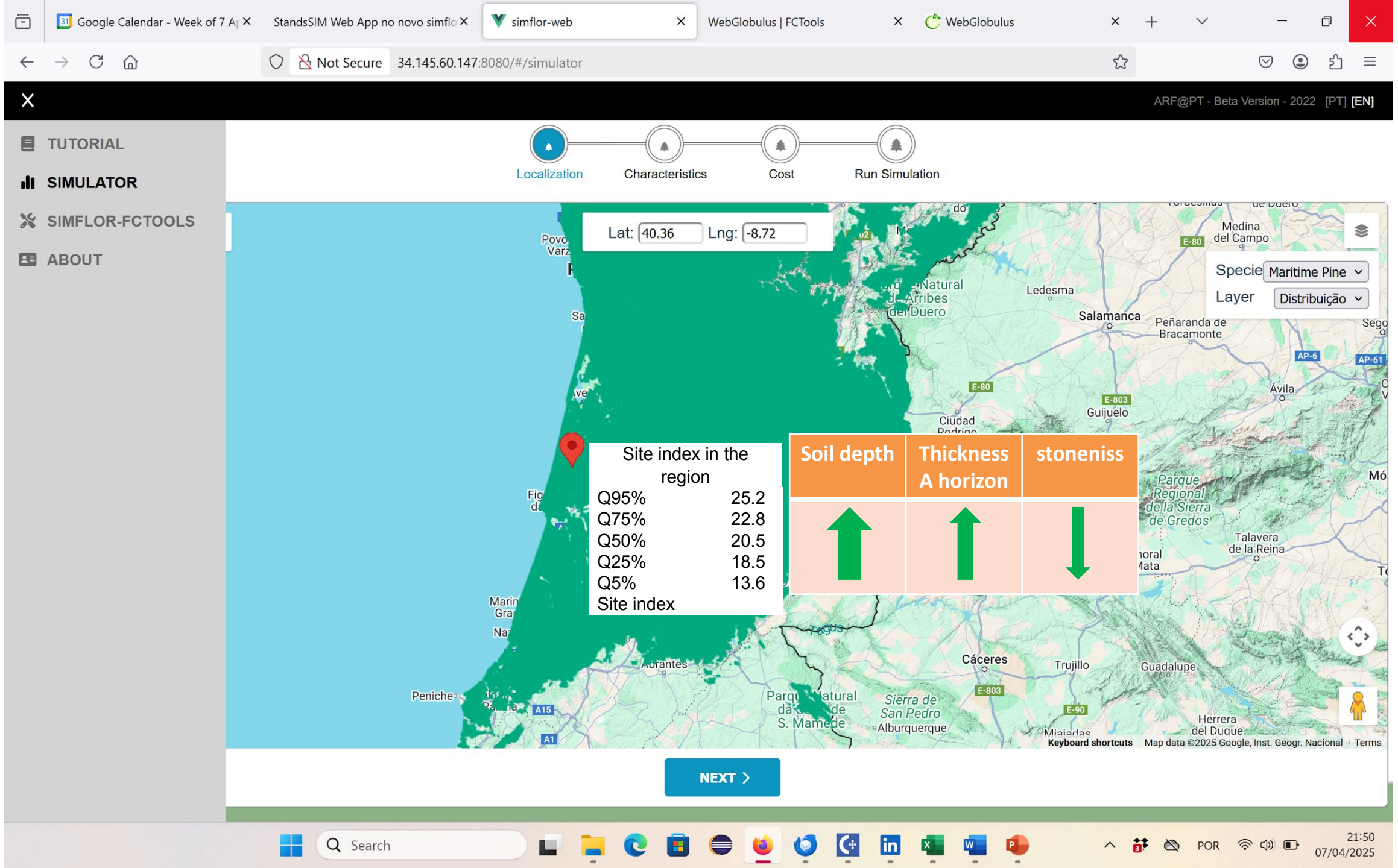
Salamanca, Ledesma, Peñaranda de Bracamonte, Medina del Campo, Ávila, Guijuelo, Ciudad Rodrigo, Béjar, Hervás, Parque Regional de la Sierra de Gredos, Jaraíz de la Vera, Plasencia, Moraleja, Coria, Navalmoral de la Mata, Talavera de la Reina, Cáceres, Trujillo, Guadalupe, Herrera del Duque, Alburquerque, Sierra de San Pedro, Branco

Keyboard shortcuts Map data ©2025 Google, Inst. Geogr. Nacional Terms

NEXT >

Search

POR 21:50 07/04/2025


Google Calendar - Week of 7 A
StandsSIM Web App no novo simflo
simflor-web
WebGlobulus | FCTools
WebGlobulus
Not Secure
34.145.60.147:8080/#/simulator
ARF@PT - Beta Version - 2022 [PT] [EN]
TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT
Localization
Characteristics
Cost
Run Simulation
Lat: 40.36
Lng: -8.72
Specie
Maritime Pine
Layer
Distribuição
Site index in the region
Q95% 25.2
Q75% 22.8
Q50% 20.5
Q25% 18.5
Q5% 13.6
Site index
Soil depth
Thickness A horizon
stoneniss
Salamanca
Ledesma
Peñaranda de Bracamonte
Ávila
Guijuelo
Ciudad Rodrigo
Cáceres
Trujillo
Guadalupe
Talavera de la Reina
Herrera del Duque
Parque Regional de la Sierra de Gredos
Sierra de San Pedro
Alburquerque
Keyboard shortcuts
Map data ©2025 Google, Inst. Geogr. Nacional
Terms
NEXT
Search
POR
21:50
07/04/2025

TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT

Localization > Characteristics > Cost > Run Simulation

Lat: 40.36 Lng: -8.72

Specie: Maritime Pine
Layer: Distribuição

Site index in the region	
Q95%	25.2
Q75%	22.8
Q50%	20.5
Q25%	18.5
Q5%	13.6
Site index	**27**

NEXT >

Google Calendar - Week of 7 A | StandsSIM Web App no novo simflo | simflor-web

Not Secure 34.145.60.147:8080/#/simulator

ARF@PT - Beta Version - 2022 [PT] [EN]

- TUTORIAL
- SIMULATOR
- SIMFLOR-FCTOOLS
- ABOUT

Localization > Characteristics > Cost > Run Simulation

Characteristics

Sellect simulation characteristics

Operational scenario :

Easy

Sylvicultural system - operational schedule

Please Select

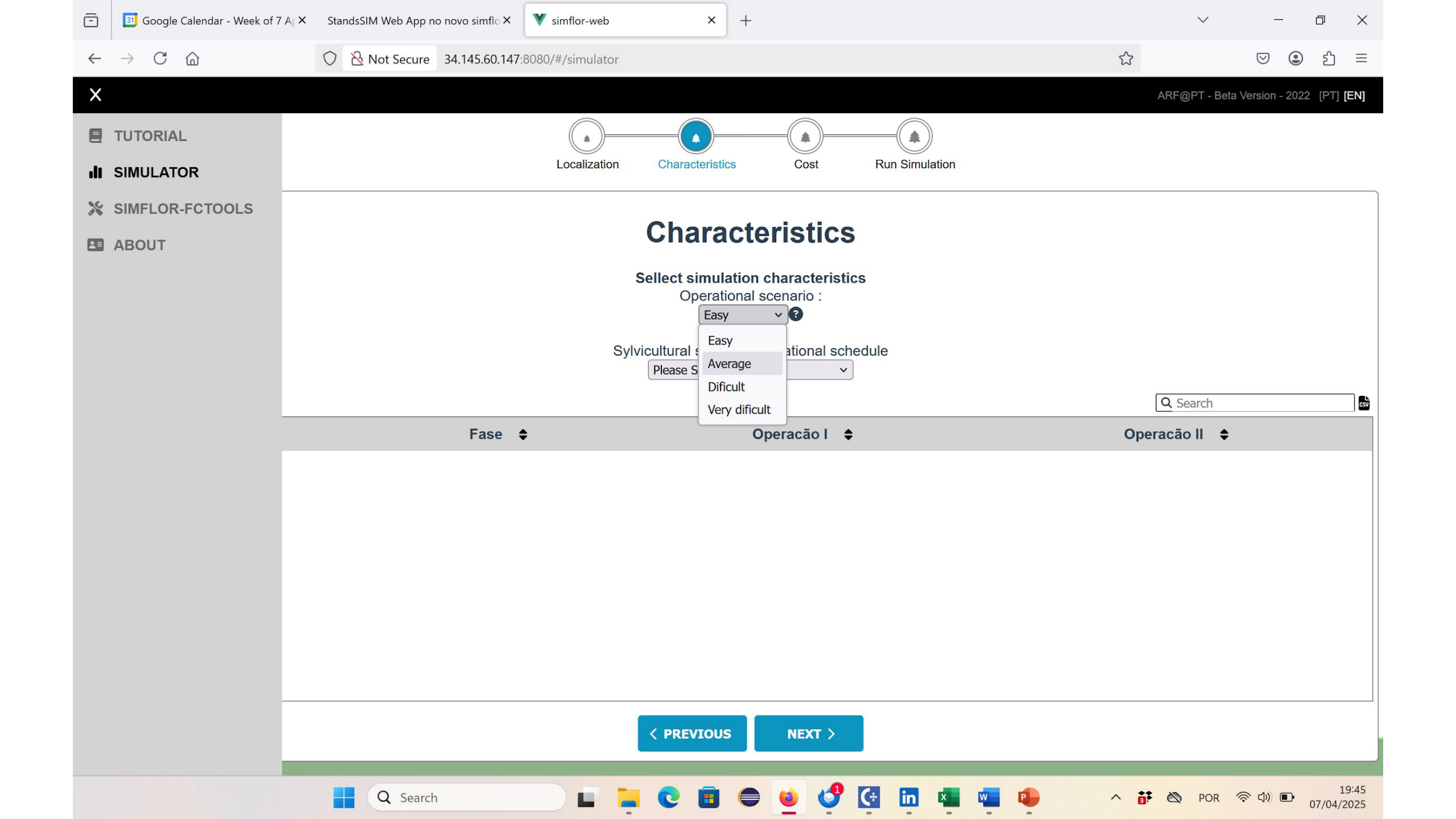
Search

Fase	Operacão I	Operacão II

< PREVIOUS NEXT >

Search

POR 19:45 07/04/2025


Google Calendar - Week of 7 A
StandsSIM Web App no novo simflo
simflor-web
Not Secure
34.145.60.147:8080/#/simulator
ARF@PT - Beta Version - 2022 [PT] [EN]
TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT
Localization
Characteristics
Cost
Run Simulation
Characteristics
Sellect simulation characteristics
Operational scenario :
Easy
Easy
Average
Dificult
Very dificult
Sylvicultural s
ational schedule
Please S
Search
Fase
Operação I
Operação II
PREVIOUS
NEXT
Search
POR
19:45
07/04/2025

TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT

Localization — Characteristics — Cost — Run Simulation

Characteristics

Sellect simulation characteristics

Operational scenario :

Average

Sylvicultural system - operational schedule

Please Select

- Please Select
- Plantation
- Natural regeneration
- High density natural regeneration

Search

Fase	Operacão II

< PREVIOUS NEXT >

TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT

Localization — Characteristics — Cost — Run Simulation

Characteristics

Sellect simulation characteristics

Operational scenario :

Average

Sylvicultural system - operational schedule

Plantation

Search

Fase	Operacão I	Operacão II
PREPARAÇÃO TERRENO	Controlo de vegetação	Limpeza de matos com grade de discos
PREPARAÇÃO TERRENO	Controlo de vegetação	Limpeza de matos com motorroçadora
PREPARAÇÃO TERRENO	Mobilização do solo	Ripagem a 3m com 2 dentes
PREPARAÇÃO TERRENO	Plantação	Abertura manual de covas (30x30x30)
PREPARAÇÃO TERRENO	Marcação e piquetagem	Marcação e piquetagem
INSTALAÇÃO	Plantação	Plantas
INSTALAÇÃO	Adubação	Adubo - Fundo
INSTALAÇÃO	Adubação	Adubação manual na cova
INSTALAÇÃO	Plantação	Plantação manual de resinosas e folhosas em contentor
MANUTENÇÃO	Retanche	Retanche

< PREVIOUS NEXT >

TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT

Localization > Characteristics > Cost > Run Simulation

COSTS

OPERATION	UNIT	COST
Abertura manual de covas (30 x 30 x 30 cm	€/ha	400
Aplicação de adubo total (tractor agrícola/ florestal)	€/ha	90,00 €
Aplicação manual de adubo	€/ha	17,5
Construção da pilha	@	0,5
Controlo da vegetação com corta matos de facas ou correntes (tractor agrícola ou florestal borracheiro)	€/ha	180
Controlo da vegetação espontânea na linha ou de forma localizada (mão de obra especializada, incluindo equipamento)	€/ha	650
Corte seletivo ou salteado	€/ha	26
Desbaste seletivo	0	0
Desbóia	€/ha	46,66667
Descortiçamento	€/ha	116,662

< PREVIOUS NEXT >

TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT

Localization > Characteristics > Cost > Run Simulation

PRICES

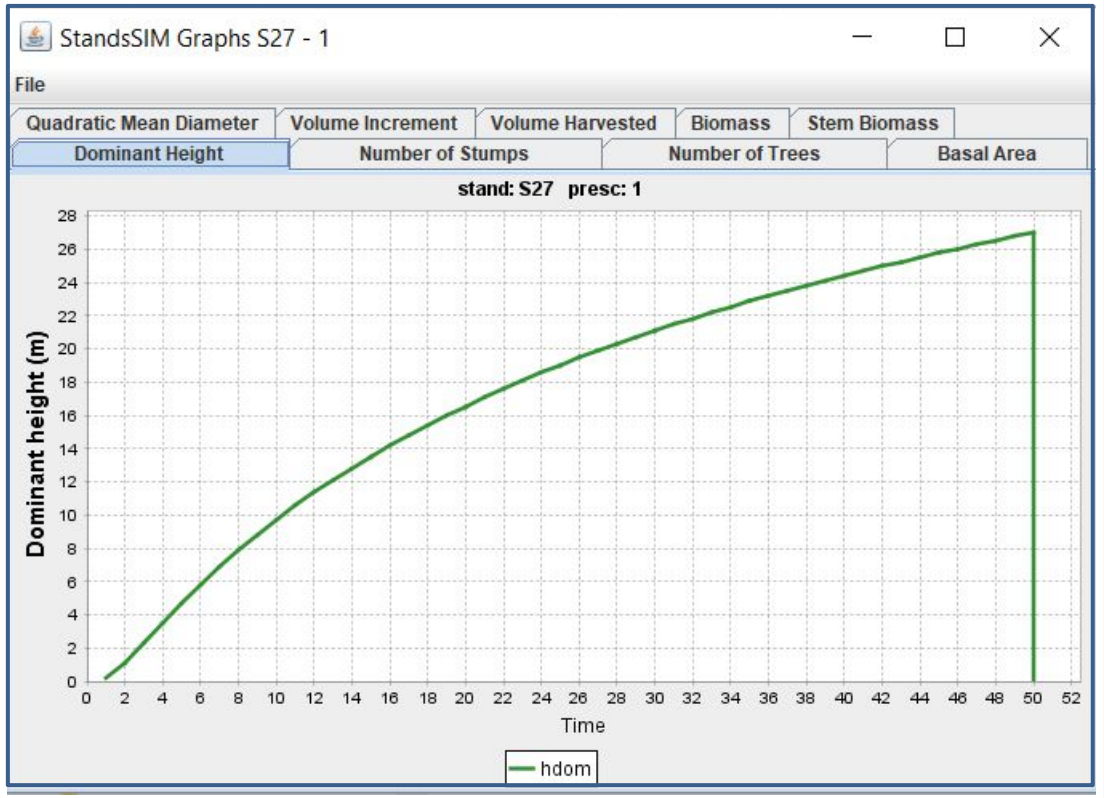
TYPE: CORK			RAW MATERIAL PRICE			
Calibre		Linhas	1/5		6	
mm	mm		min	max	min	max
14	18	6/8	2,30 €	2,50 €		
18	27	8/12	2,50 €	2,50 €		
27	32	12/14	6,00 €	8,00 €	1,75 €	2,00 €
29	34	13/15				
34	45	15/20				
41	54	18/24				
		Refugo				

< PREVIOUS NEXT >

TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT

Localization > Characteristics > Cost > Run simulation

S	t	hdom	N	G	V
27	1	0.2	2500	0	0
27	2	1.1	2450	0	0
27	3	2.3	2401	0	0
27	4	3.5	2353	0	0
27	5	4.7	2306	0	0
27	6	5.8	2300	5.4	14.7
27	7	6.9	2300	7.8	22.9
27	8	7.9	2300	10.5	34.9
27	9	8.8	2300	13.3	49.2
27	10	9.7	2300	16.3	65.8
27	11	10.6	2300	19.4	84.4
27	12	11.4	2300	22.5	104.8
27	13	12.1	2300	25.7	126.7
27	14	12.8	2300	28.9	150.1
27	15	13.5	2300	32	174.7
27	15	13.5	860	12.2	66.6



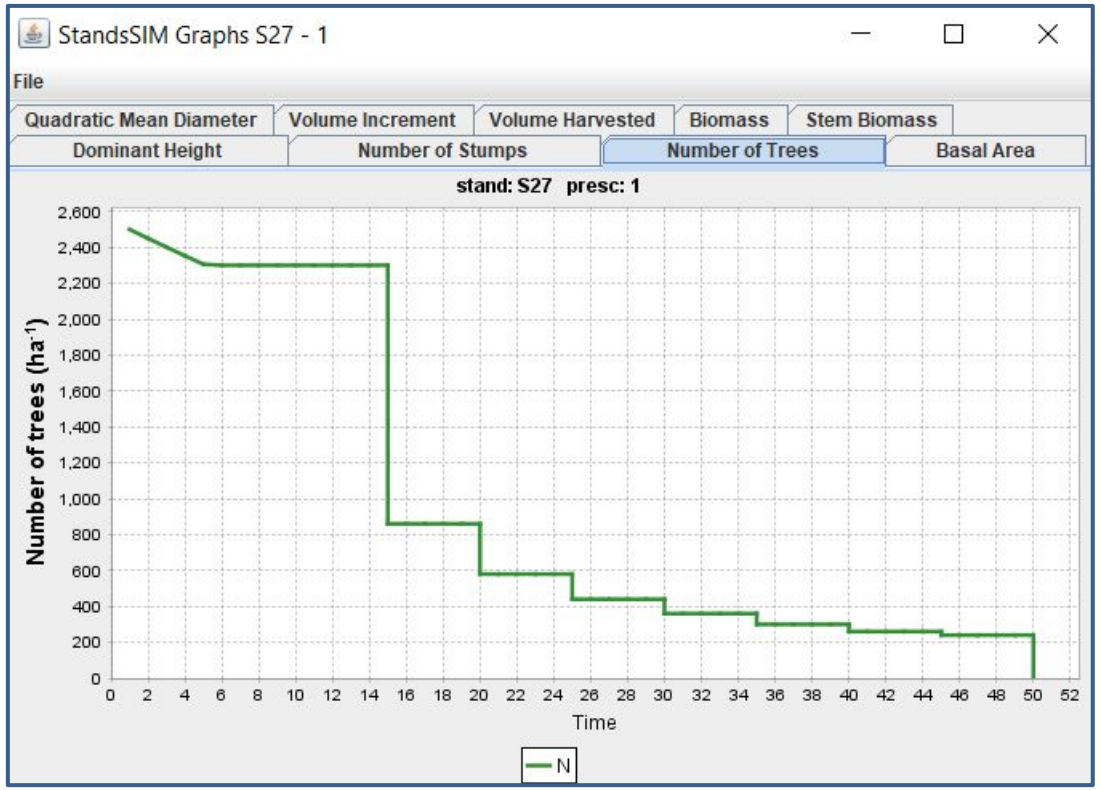
NPV: 1094 euros/ha **EAA:** 51 euros/ha/year

< PREVIOUS NEXT >

TUTORIAL
SIMULATOR
SIMFLOR-FCTOOLS
ABOUT

Localization > Characteristics > Cost > Run simulation

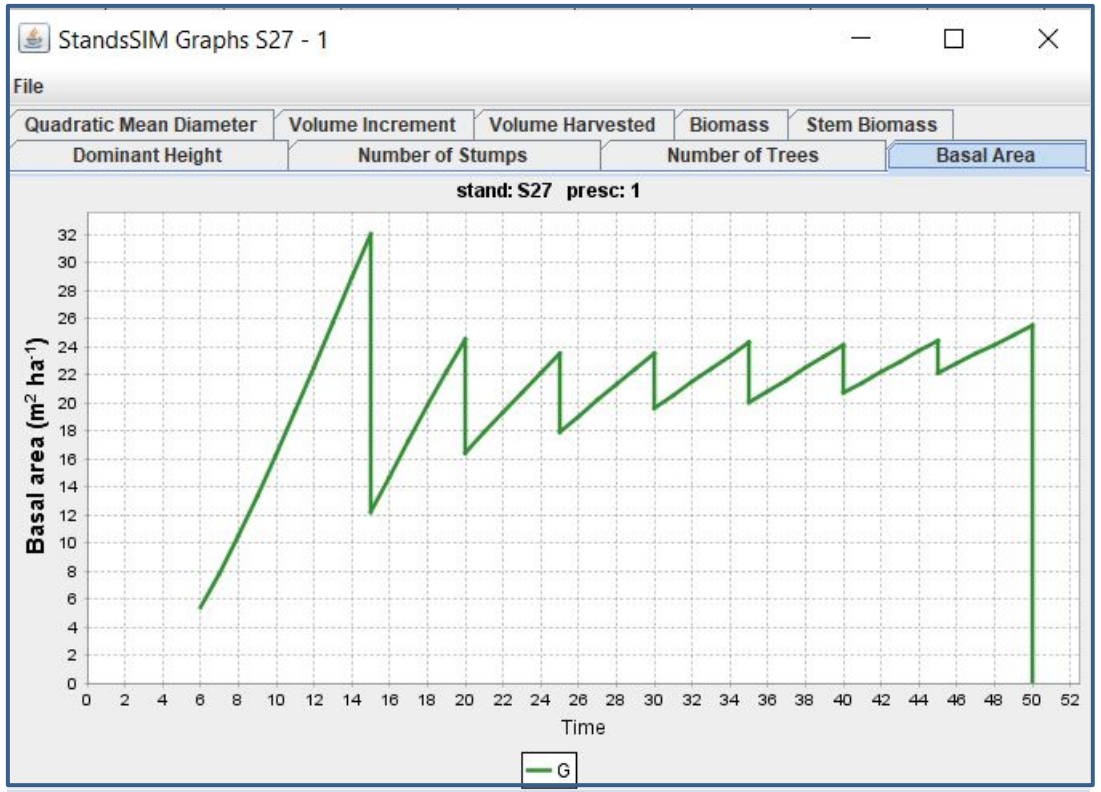
S	t	hdom	N	G	V
27	1	0.2	2500	0	0
27	2	1.1	2450	0	0
27	3	2.3	2401	0	0
27	4	3.5	2353	0	0
27	5	4.7	2306	0	0
27	6	5.8	2300	5.4	14.7
27	7	6.9	2300	7.8	22.9
27	8	7.9	2300	10.5	34.9
27	9	8.8	2300	13.3	49.2
27	10	9.7	2300	16.3	65.8
27	11	10.6	2300	19.4	84.4
27	12	11.4	2300	22.5	104.8
27	13	12.1	2300	25.7	126.7
27	14	12.8	2300	28.9	150.1
27	15	13.5	2300	32	174.7
27	15	13.5	860	12.2	66.6



NPV: 1094 euros/ha **EAA:** 51 euros/ha/year

PREVIOUS NEXT

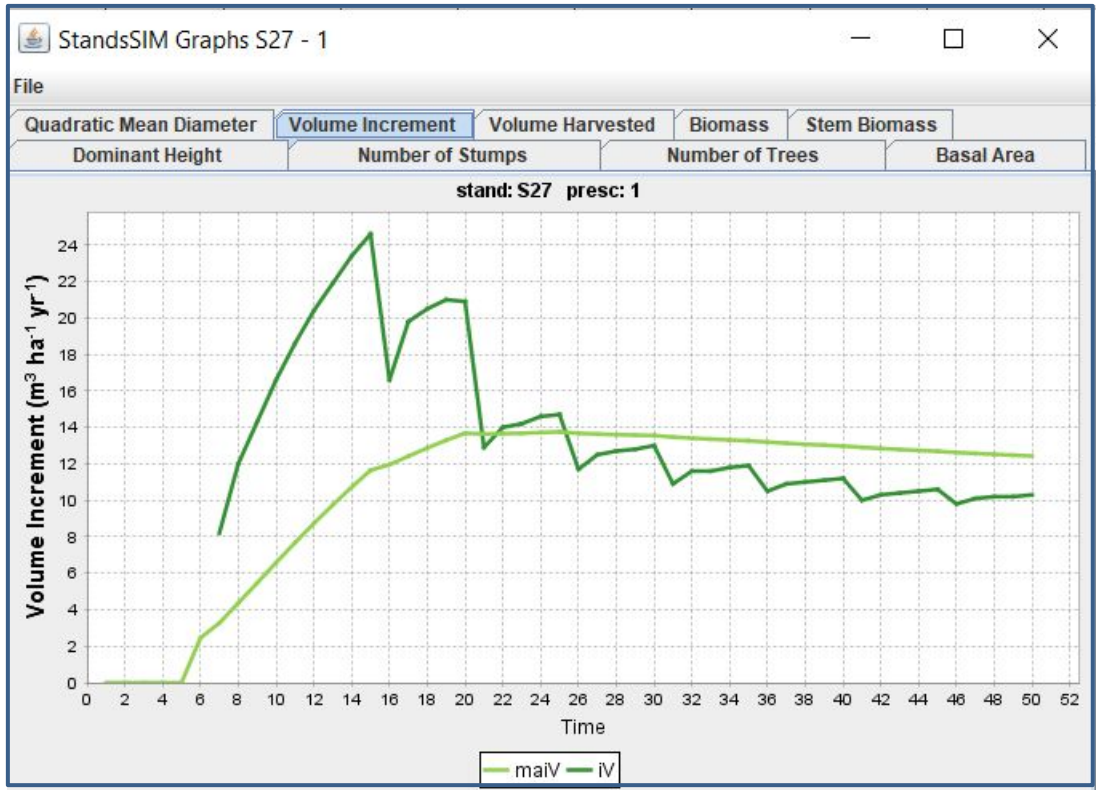
S	t	hdom	N	G	V
27	1	0.2	2500	0	0
27	2	1.1	2450	0	0
27	3	2.3	2401	0	0
27	4	3.5	2353	0	0
27	5	4.7	2306	0	0
27	6	5.8	2300	5.4	14.7
27	7	6.9	2300	7.8	22.9
27	8	7.9	2300	10.5	34.9
27	9	8.8	2300	13.3	49.2
27	10	9.7	2300	16.3	65.8
27	11	10.6	2300	19.4	84.4
27	12	11.4	2300	22.5	104.8
27	13	12.1	2300	25.7	126.7
27	14	12.8	2300	28.9	150.1
27	15	13.5	2300	32	174.7
27	15	13.5	860	12.2	66.6



NPV: 1094 euros/ha **EAA:** 51 euros/ha/year

< PREVIOUS NEXT >

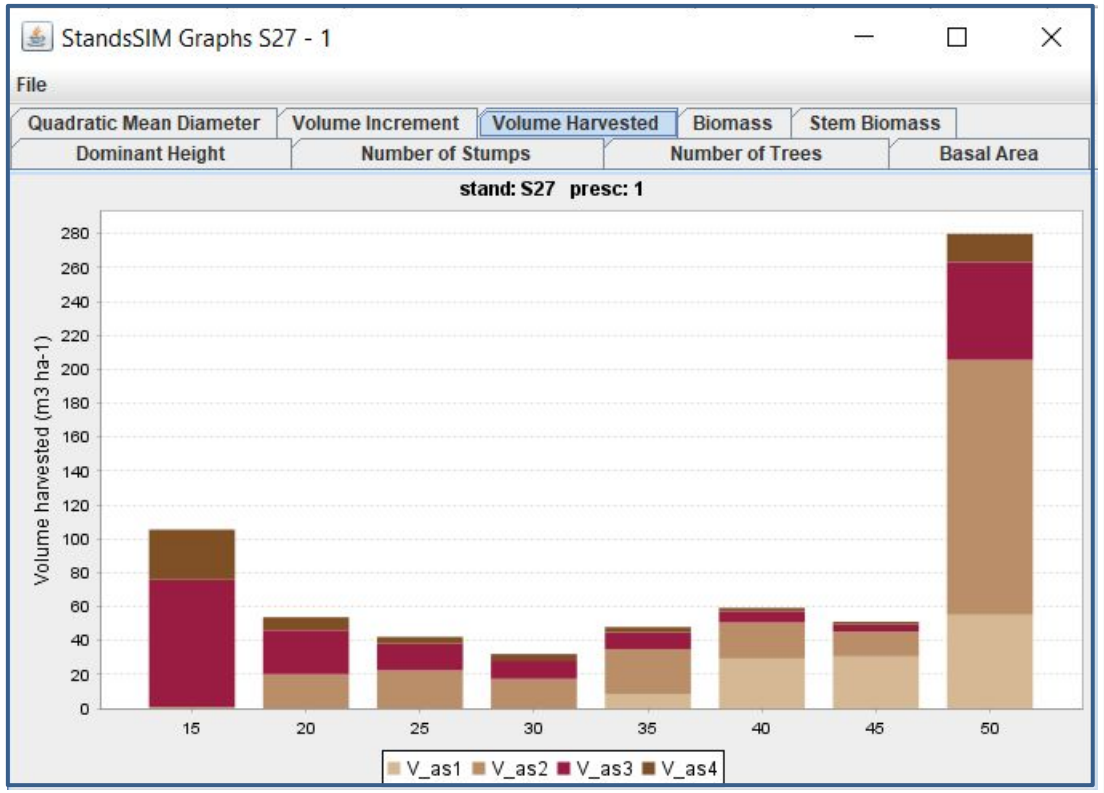
S	t	hdom	N	G	V
27	1	0.2	2500	0	0
27	2	1.1	2450	0	0
27	3	2.3	2401	0	0
27	4	3.5	2353	0	0
27	5	4.7	2306	0	0
27	6	5.8	2300	5.4	14.7
27	7	6.9	2300	7.8	22.9
27	8	7.9	2300	10.5	34.9
27	9	8.8	2300	13.3	49.2
27	10	9.7	2300	16.3	65.8
27	11	10.6	2300	19.4	84.4
27	12	11.4	2300	22.5	104.8
27	13	12.1	2300	25.7	126.7
27	14	12.8	2300	28.9	150.1
27	15	13.5	2300	32	174.7
27	15	13.5	860	12.2	66.6



NPV: 1094 euros/ha **EAA:** 51 euros/ha/year

< PREVIOUS NEXT >

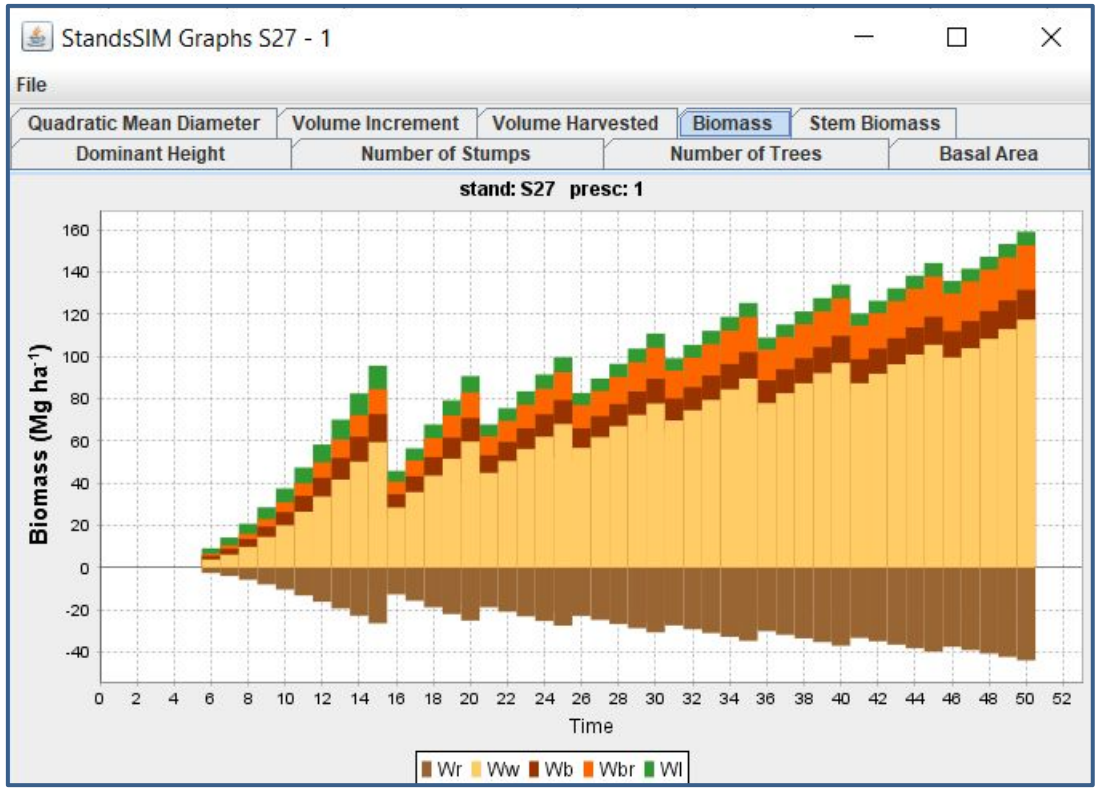
S	t	hdom	N	G	V
27	1	0.2	2500	0	0
27	2	1.1	2450	0	0
27	3	2.3	2401	0	0
27	4	3.5	2353	0	0
27	5	4.7	2306	0	0
27	6	5.8	2300	5.4	14.7
27	7	6.9	2300	7.8	22.9
27	8	7.9	2300	10.5	34.9
27	9	8.8	2300	13.3	49.2
27	10	9.7	2300	16.3	65.8
27	11	10.6	2300	19.4	84.4
27	12	11.4	2300	22.5	104.8
27	13	12.1	2300	25.7	126.7
27	14	12.8	2300	28.9	150.1
27	15	13.5	2300	32	174.7
27	15	13.5	860	12.2	66.6



NPV: 1094 euros/ha **EAA:** 51 euros/ha/year

< PREVIOUS NEXT >

S	t	hdom	N	G	V
27	1	0.2	2500	0	0
27	2	1.1	2450	0	0
27	3	2.3	2401	0	0
27	4	3.5	2353	0	0
27	5	4.7	2306	0	0
27	6	5.8	2300	5.4	14.7
27	7	6.9	2300	7.8	22.9
27	8	7.9	2300	10.5	34.9
27	9	8.8	2300	13.3	49.2
27	10	9.7	2300	16.3	65.8
27	11	10.6	2300	19.4	84.4
27	12	11.4	2300	22.5	104.8
27	13	12.1	2300	25.7	126.7
27	14	12.8	2300	28.9	150.1
27	15	13.5	2300	32	174.7
27	15	13.5	860	12.2	66.6



NPV: 1094 euros/ha **EAA:** 51 euros/ha/year

PREVIOUS NEXT


Questions?