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A Marteloscope in a cork oak stand: integrating biodiversity and non-timber products in Mediterranean forestry

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Introduction. A marteloscope in a cork oak stand: challenges

- A special Marteloscope, setup in a cork oak stand, is presented
- The main product that provides the economic value of the trees is not the wood but the cork.
- The main challenge in this case is that the harvesting of the product (cork) and the regulation of stand density (thinning) are dissociated: **CUTTING TREES DOES NOT PRODUCE THE ECONOMIC VALUE**
- The cork production and developtment of trees both are affected by cork harvesting and by silviculture (thinnings)
- But the influence of these factors does not appear until the next cork harvesting, so **A SIMULATION INTO THE FUTURE IS NEEDED**
- What is not new: most TreMs are related to poor quality of the product (cork), so trade-offs between economic and ecological value of trees remain relevant

Some pictures of the stand and the cork harvesting (just in case some of you have never seen it!)

Ten years ago cork harvesting took place in *Pino Gordo Estate* (now is time for a new go)

Students collecting data of harvesting

Cork planks
just harvested

debarking

debarking

debarking

debarking

Loading the cork planks for their removal and transport

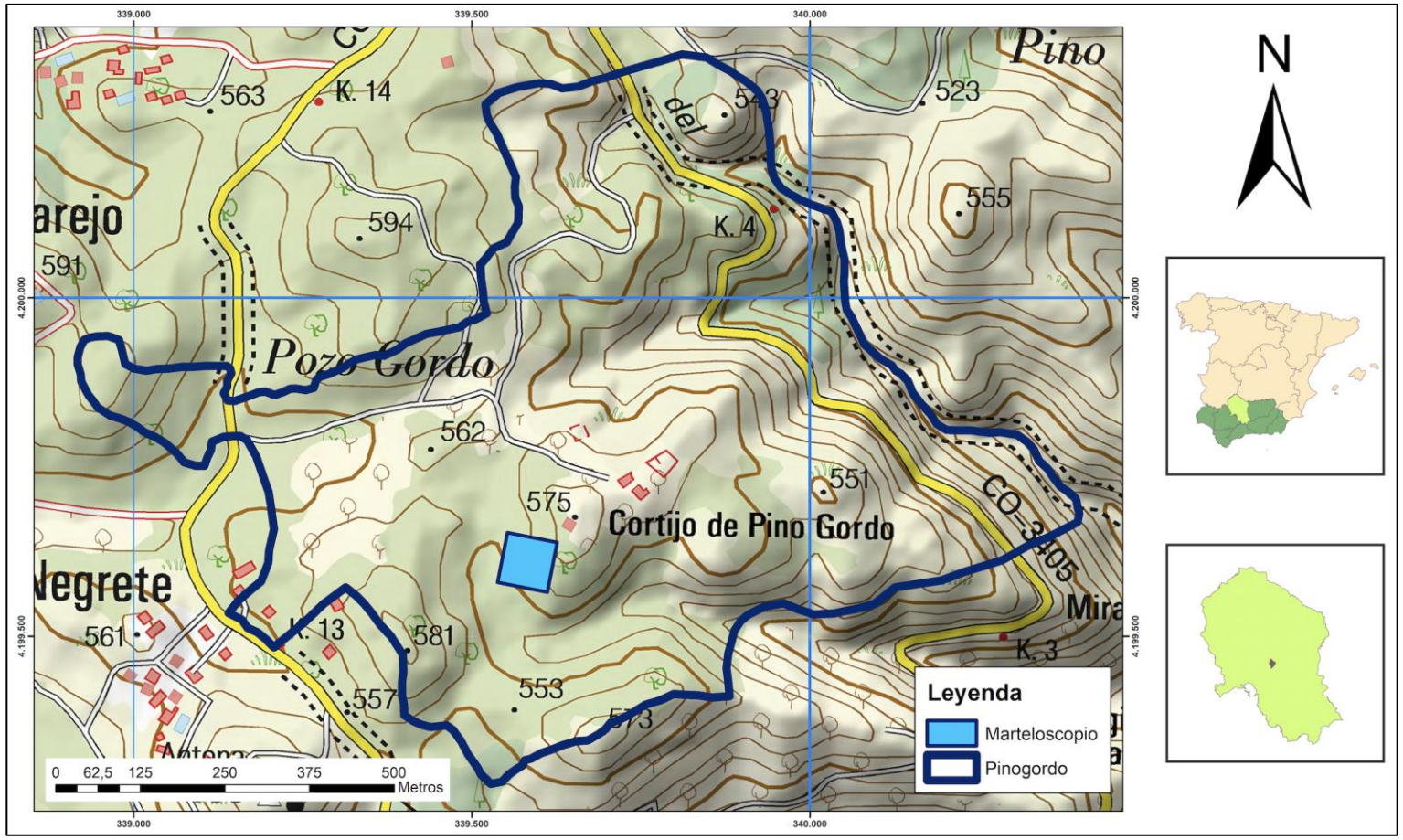
Loading the cork planks for their removal and transport

Removal cork planks out of the wood

Materials and methods: the field and the app

1. Plot Location

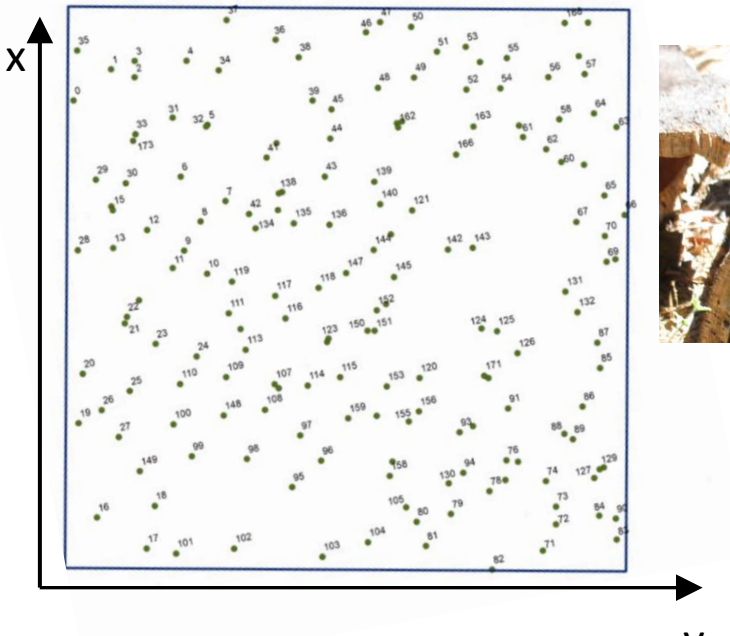
- Place: *Pino Gordo Estate* (Córdoba Mountain Range, Spain)
- Altitude: 550 a.s.l.
- Climate: Mediterranean genuine
- P: 620 mm. Long summer drought period
- Litology: slates, schists and quartzites
- Vegetation: Cork oak woodland
- Area: 0,6 ha

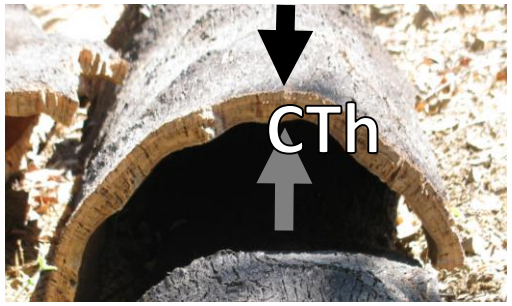


2. Data recorded per tree:

2.1: In the field:

- Identity and location: NUM, X,Y,Z, Field-Map
- Dendrometry: OCBH, UCBH,H, HCB, CPA, CTh
- Debarking: Hd
- Ecological value: TreMs





https://play.google.com/store/apps/details?id=efi.integrate.microhabitats&hl=es&gl=US

2. Data recorded per tree:

2.1: In the field:

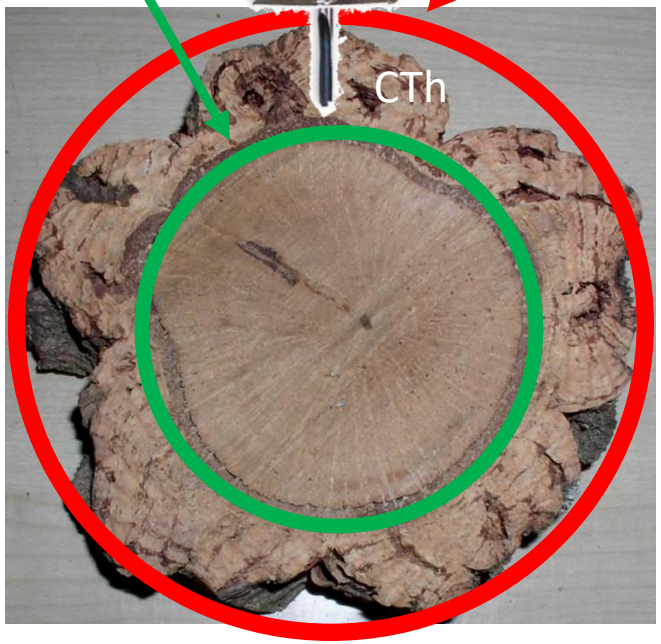
Underbark
Circunference
at **B**reast
Height

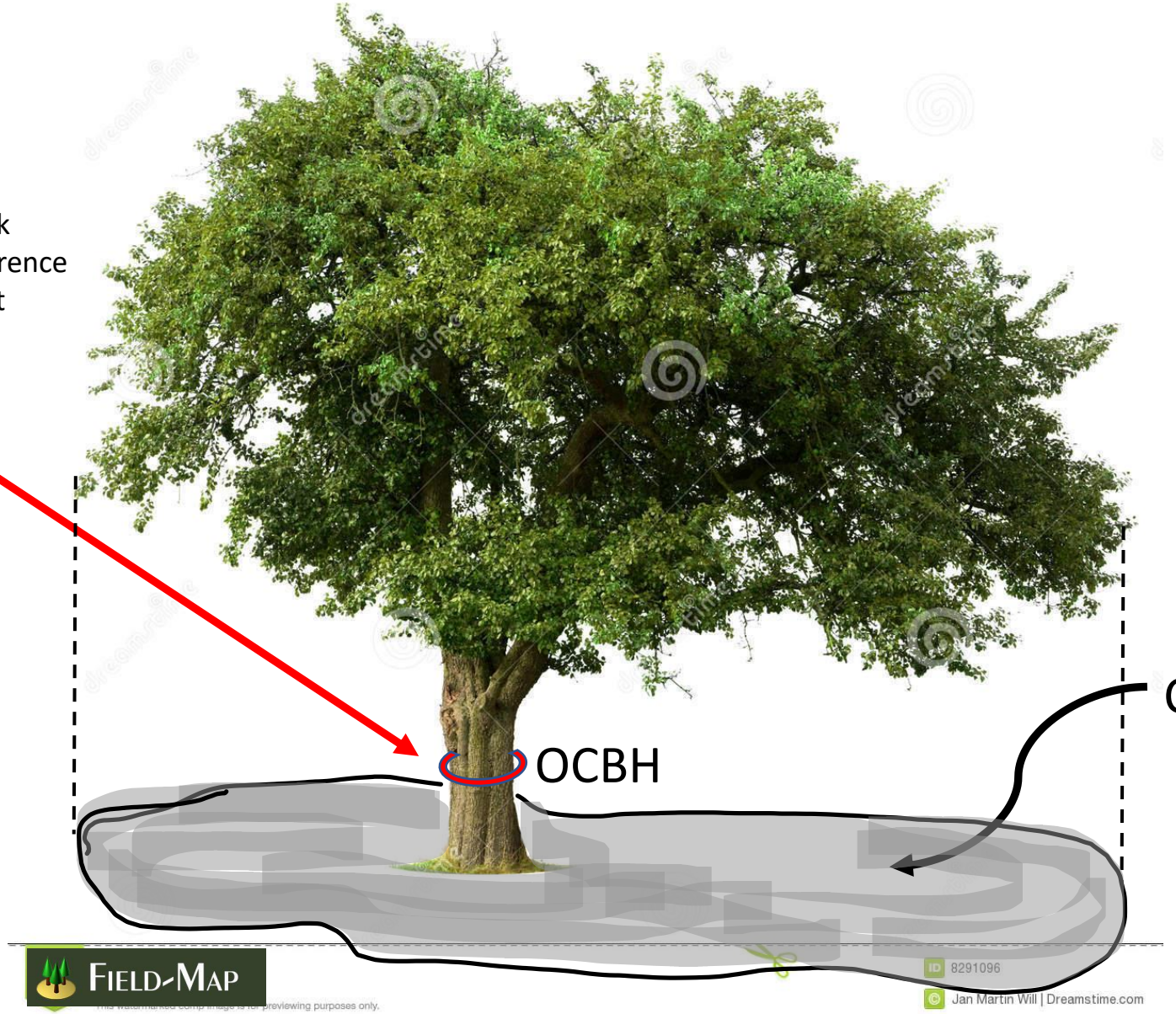
Bark gauge

UCBH

OCBH

Overbark
Circunference
at **B**reast
Height





2. Recorded data per tree:

2.2. Derived variables:

- Dendrometry: Under cork stem dimensions: **UCBH, DBH, Ug**; *f(OCBH,CTh)*
- Debarking: **Sd**= *UCBH*Hd;*

  Id=*Sd/Ug (debarking pressure on the tree.* *(Negative effect on tree growth)*

- Spatial Competition Index: Hegyi $\boldsymbol{HD2}_i = \sum_{j=1}^{n} \frac{DBH_j}{DBH_i} * \frac{1}{dist_{ij}}$ *(Negative effect on tree growth)*

  (*d_{ij}: distance from target tree, i, to neighbour j;* number of competitors according with the rule D2: *$dist_{ij}$<0.33*DBH_j*) (*Daniels, 1976*)

- Ecological value: **Ecoval** *f(number and type of TreMs)* (points)

3. Simulation into the future: after next debarking (9 years later)

CORKFIT (Surovy et al., 2011) model fitted . Only stem section area growth (iUCBH) is considered (variation in cork thickness is not considered, as cork production is mainly related to debarking area, **Sd**, and debarking period (9-10 years at the Pino Gordo farm) and variation in debarking period is not considered.

$$Incg = IncgPot * Modifier\ (Id, HD2)$$

g= Ug; Incg: basal área increment; IncgPot: Potential basal área increment;

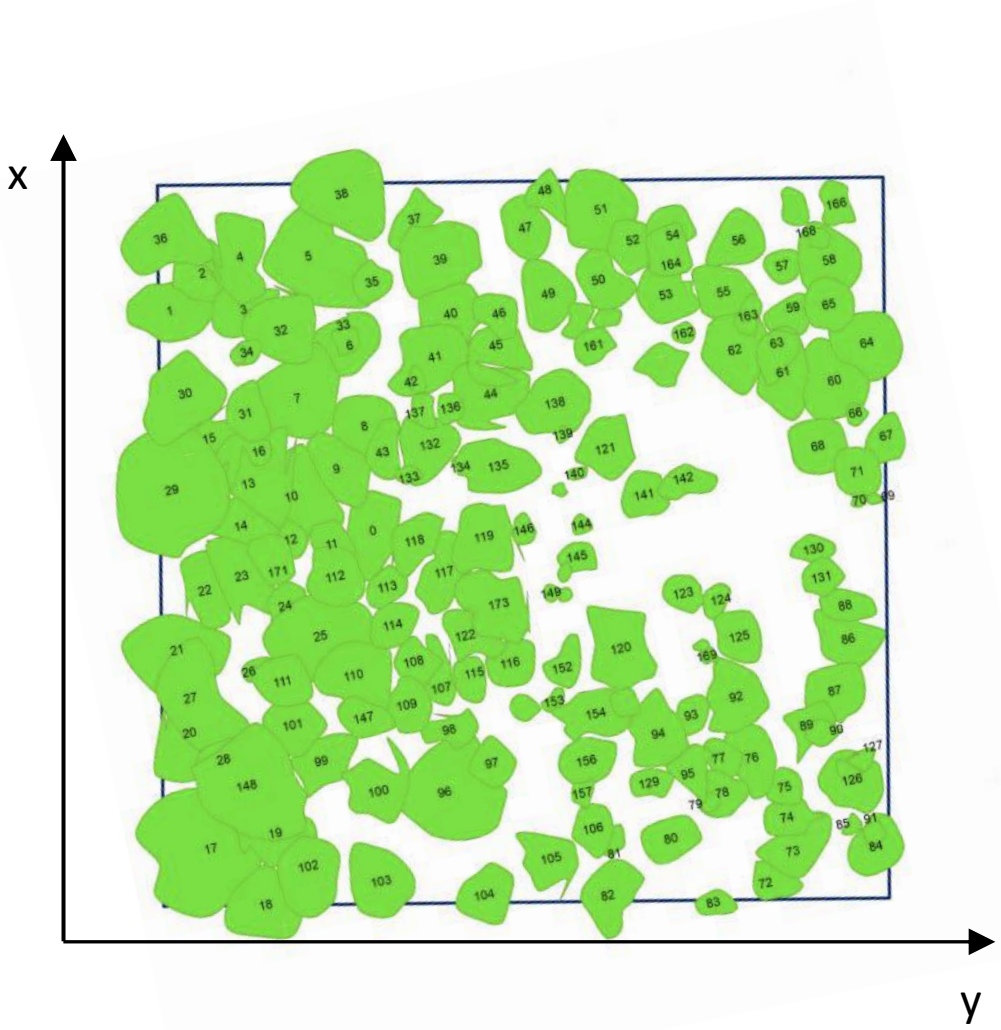
Modifier is the reduction factor as function of spatial competition index (**HD2**) and the intensity of debark (**Id**)

Potential growth (Yoshida I):

$$IncgPot = \frac{a \cdot b \cdot d \cdot Ug^{d}}{Ug(b+Ug^{d})^{2}};$$

$$Modifier = e^{-a \cdot HD2^{b \cdot Id}}$$

Results: the plot and the simulation



1.The Marteloscope:

- N: 174 trees (309.3 trees/ha)
- G:6.41 m^2 (11.4 m^2/ha)
- Species: *Quercus suber* (92%N), *Q.ilex*, *Q.faginea, P.pinea*
- 118 stripped cork oaks, 42 non-stripped cork oaks (14 trees of other species)
- Mean Hd= 1.9 m
- Mean Id= 33.3
- Mean Sd= 1.48 m^2/tree

2. Simulation tool (Excel)

- Operation sheet
- Data & Analysis sheets
- Current results (numeric and spatial) sheets
- Results at next debarking (9 years later)(numeric and spatial) sheets

2.1. Operation sheet

MARTELOSCOPE "PINO GORDO"

Árbol Nº	Debarking		Tree Selection		
	Hd	△Hd	Cut	Plus tree	Max △Hd
1	3.00	-0.3			2.2
2	3.10	-0.3			0.6
3	1.36				2.65
4	3.05	-0.3			0.74
5	3.30		1		0.328
6	1.60				0.537
7	2.64				0.629
8	1.59				0.1
9	1.53	-0.2	1		1.34
10	1.67				0.41
11	1.10		1		2.25
12	0.91		1		1.42
13	2.05				0.54
14	2.26		1		2.168
15	0.00				2.66
16	0.00		1		2.25
17	2.89				0.48
18	1.91	0.2			2.5
19	2.03		1		1.15
20	2.53		1		0.57
21	2.10				0.87
22	2.74				2.41
23	2.64				0.38
24	0.00				2.45
25	2.43	-0.2			1.04
26					
27	3.05				0.462
28	1.46				1.231
29	2.78	-0.1			1.499
30	2.86	-0.15			1.07
31	2.78		1		0.92
32	1.50				1.444
33	0.00				2.532
34					
35	0.00				3.375
36	2.26				2.23
37	1.47				1.561
38	3.01	-0.2			1.526
39	2.10				1.398
40	1.47				1.91

Trainer name	4

a) THINNING SIMULATION: Mark with "1" in the proper column the trees selected to cut in the thinning or those to promote as Plus Trees

b) DEBARKING SIMULATION: Indicate the proposed variation in Height of Debark (△Hd) from the current one (Hd) in green cells (m). Variation can be positive or negative. Leave the cell blank for no variation. (Hd limited by HCB; debarking branches is not allowed)

0.5625	Plot area
5	Diameter Class Width(cm)
0	Lower limit for the first DBH class (cm)
174	Total number of trees in the plot
0	Excluded trees
65	Minimum OCBH for the first debarking (cm)

Data date: February 2018

2. Simulation tool (Excel)

2.2. Numeric results: mean and total values

Initial Stand							
N (trees/ha)	G (m2/ha)	mean g (cm2)	mean DBH (cm)	mean Hd (m)	mean Id	Sd total (m2)	meanEcoVal
309.33	11.39	368.31	21.66	1.88	33.11	171.33	6.01

Thinning							
N (trees/ha)	G (m2/ha)	mean g (cm2)	mean DBH (cm)	mean Hd (m)	mean Id	Sd total (m2)	meanEcoVal
44.44	2.08	468.30	24.42	1.84	32.35	35.13	10.43

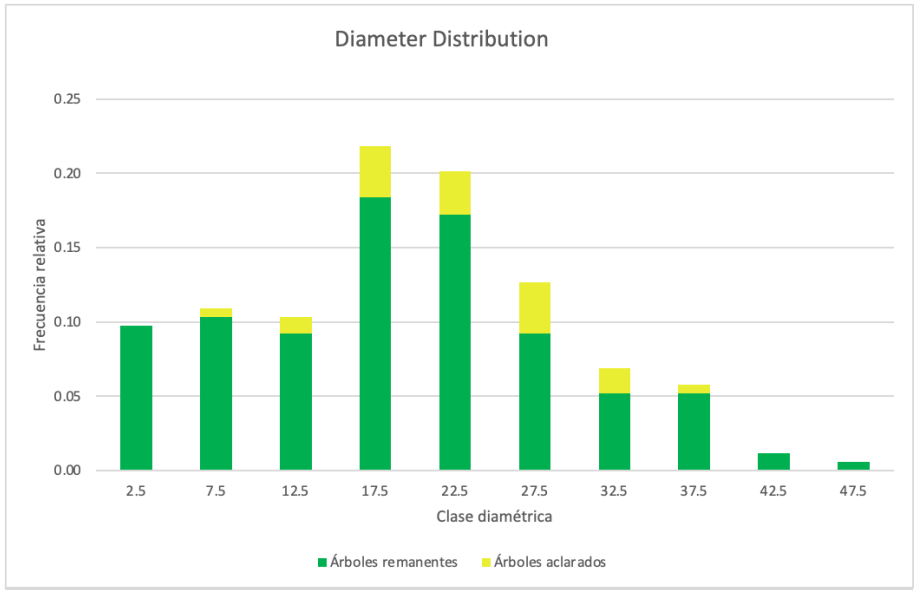
Final stand							
N (trees/ha)	G (m2/ha)	mean g (cm2)	mean DBH (cm)	mean Hd (m)	mean Id	Sd total (m2)	meanEcoVal
264.89	9.31	351.54	21.16	1.89	33.30	136.21	5.27

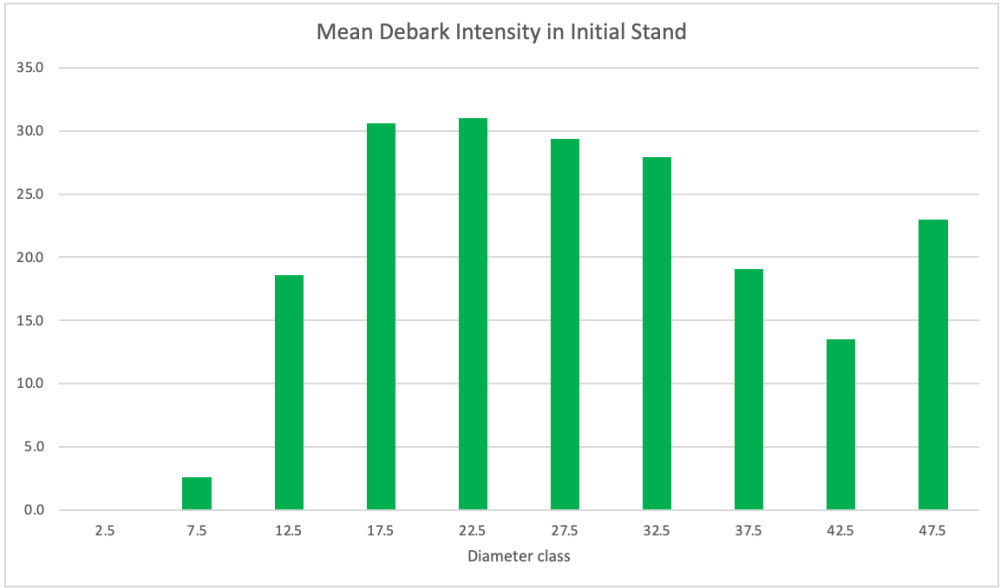
Virgin cork	Reprod. cork	Virgin cork	Reprod. cork	Income
Sd_Born (m2)	**Sd_Rep** (m2)	**Prod_Born** (kg)	**Prod_Rep** (kg)	**Ingresos** (€)
1.03	170.31	12.54	2079.46	3,919.41

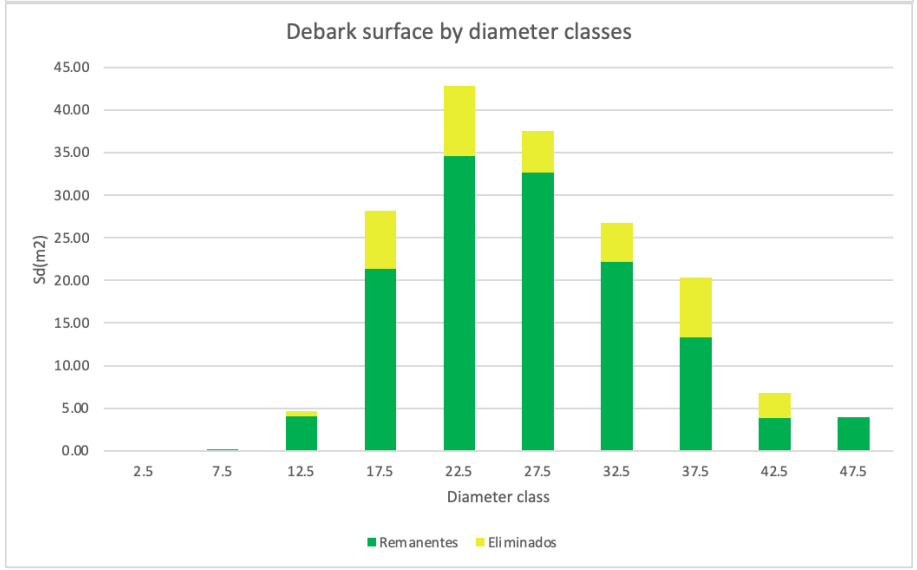
Variation of Ecoval
-12.33%

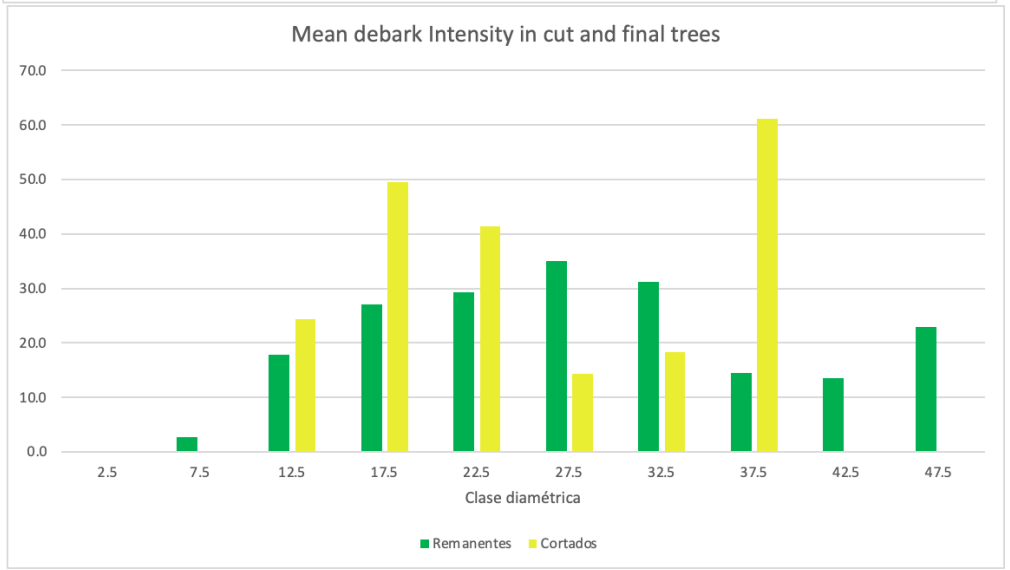
2. Simulation tool (Excel).

2.2. Numeric results: Distributions



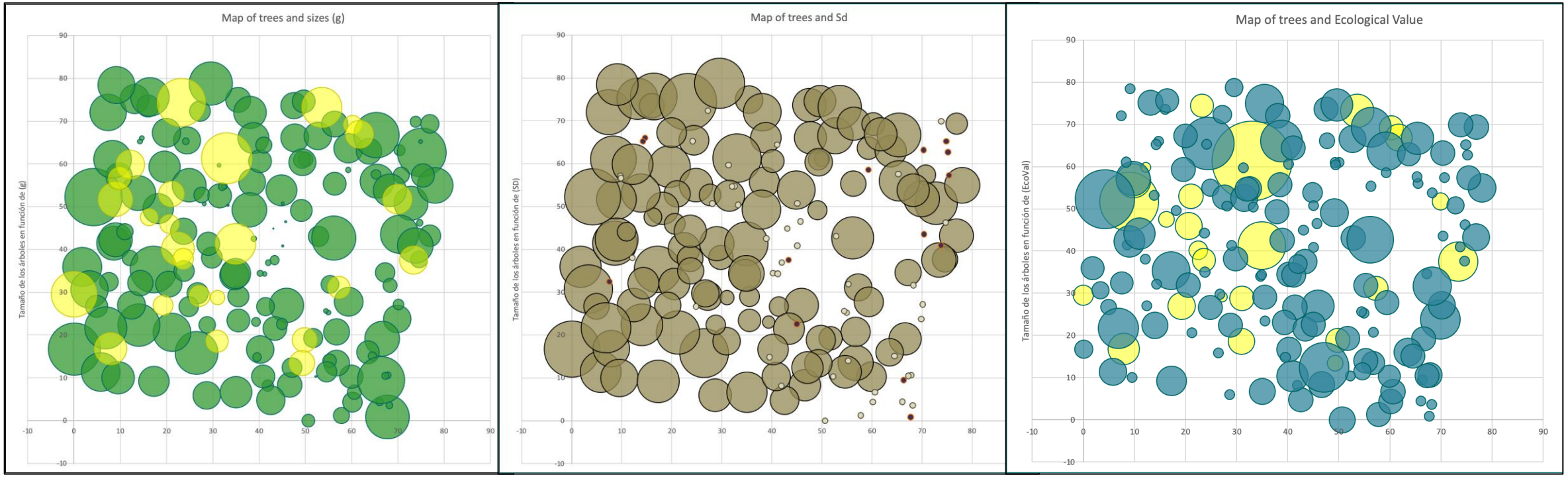






2. Simulation tool (Excel)

2.3. Spatial results: maps



Size of circles proportional to each variable
Yellow circles: cut trees in the simulation

3. Simulation into the future: 9-year growth model:

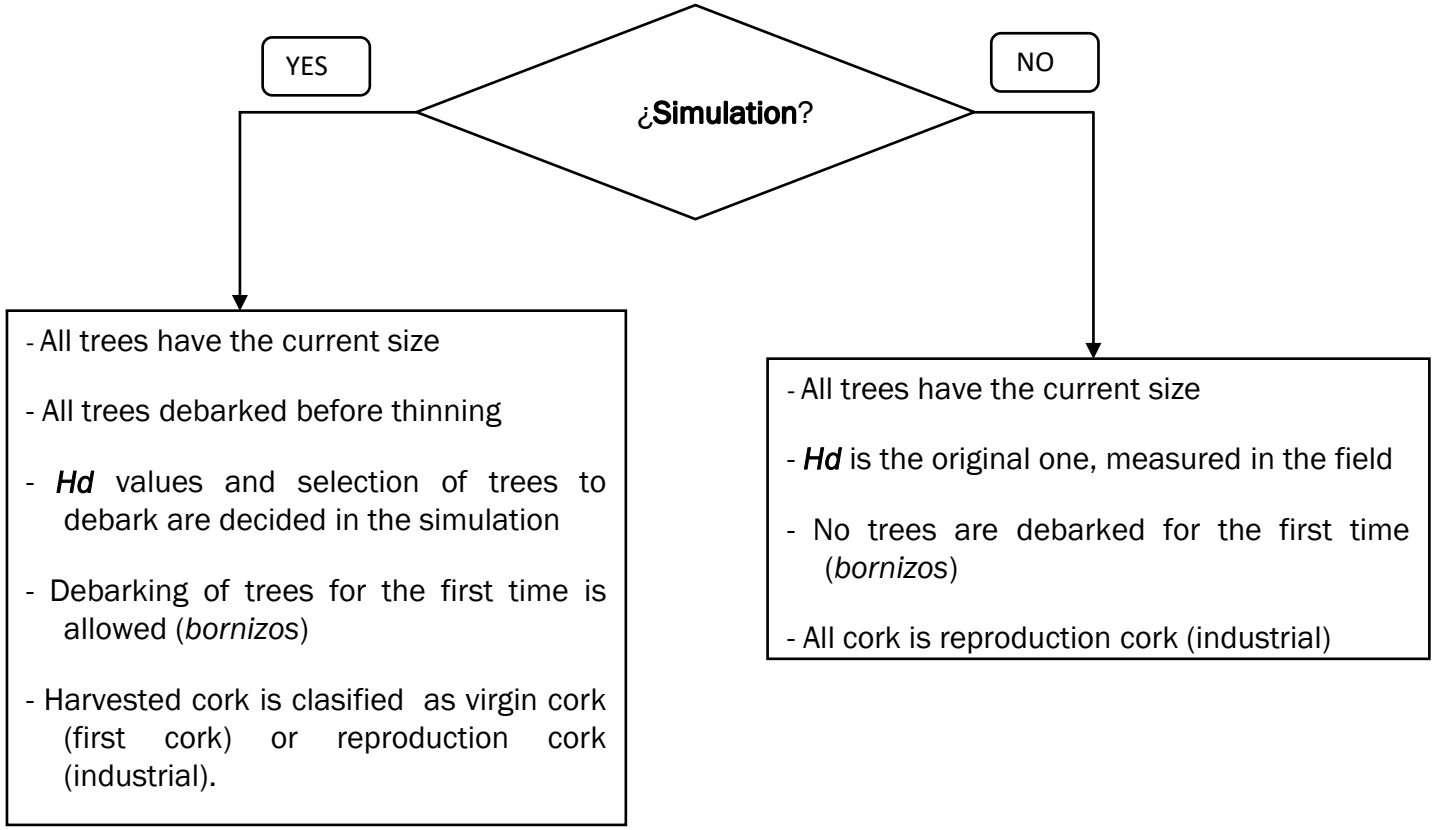
Corkfit fitted model:

$$Incgpot = \frac{152.855 \cdot (Ug\ )^{1.714}}{Ug(0.343 + (Ug)^{1.714})^2}$$

$$Modifier = \ e^{-0.559 \cdot HD2^{0.003 \cdot Id}}$$

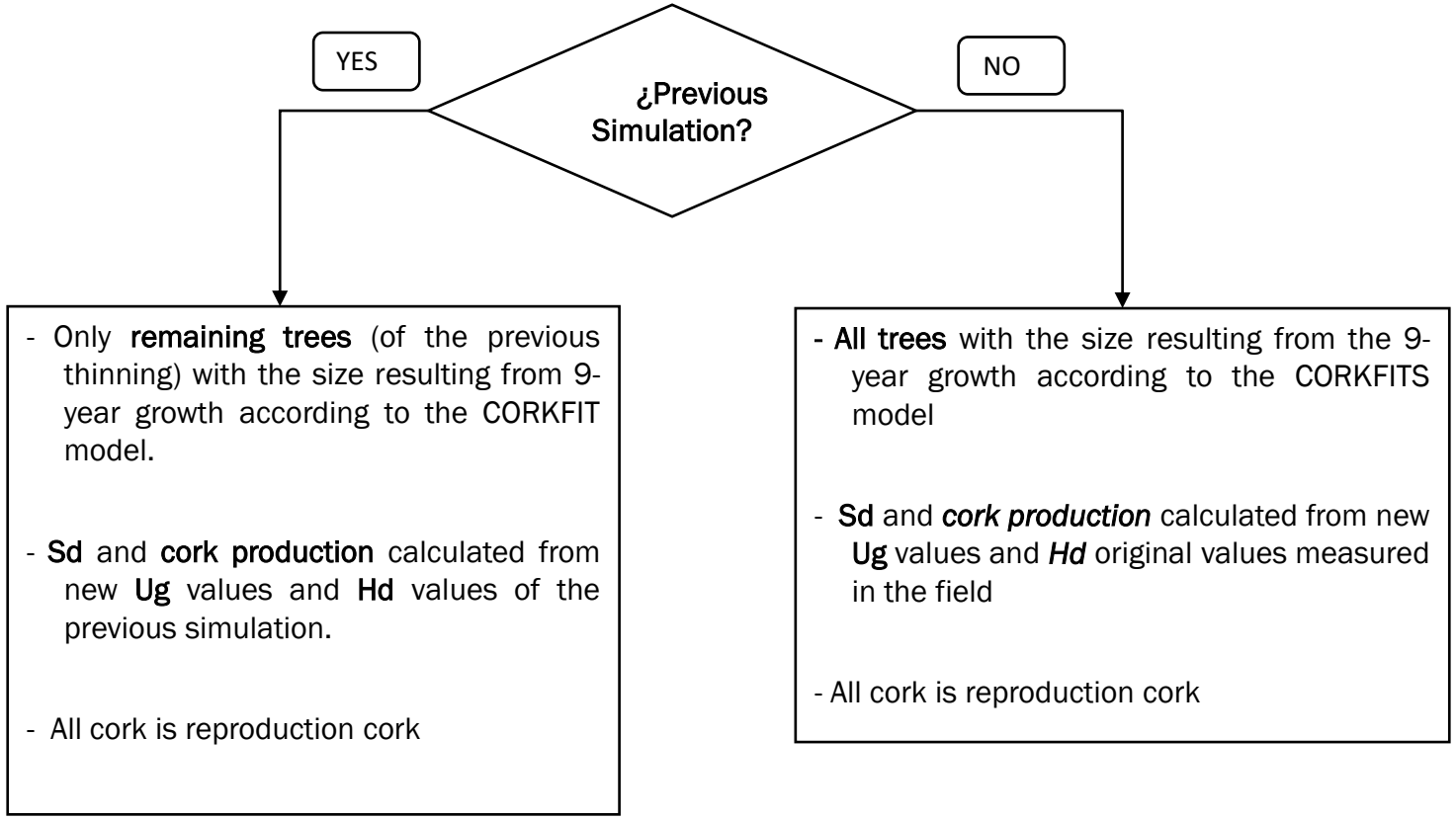
FLOW CHART I:

A) **RESULTS AFTER CURRENT DEBARKING (SIMULATION OF THINNING AND/OR DEBARKING)**



FLOW CHART II:

B) **RESULTS AFTER NEXT DEBARKING (9 YEARS LATER) (ONLY DEBARKING)**



Some simulations for validation

0_Ref:	No thinning. Standard debarking (same as measured in the field)
A_Clara_Ecoval:	Thinning promoting Ecological value. Standard debarking
B_Clara:	Thinning promoting future tree growth and cork quality. Standard debarking
C_Dextr:	Extreme debarking (maximum allowed). No thinning
D_Dextr_Clara:	Extreme debarking. Standard thinning

Some simulations for validation

Stand variables (Dasometry)								
	After current simulation				After next debarking (9 years later)			
	Density (pies/ha)	Stand Basal Area (m2/ha)	Tree Basal Area (cm2)	Mean DBH (cm)	Density (pies/ha)	Stand Basal Area (m2/ha)	Tree basal Area (cm2)	Mean DBH (cm)
0_REF	309,33	11,39	368,31	21,66	309,33	18,9 (+65,94%)	664,45 (+80,40%)	29,09 (+34,30%)
A	247,11	8,07	326,51	20,39	247,11	14,11 (+74,85%)	615,43 (+88,49%)	27,99 (+37,27%)
B	234,67	7,32	311,82	19,93	234,67	12,77 (+74,45%)	593,73 (+90,41%)	27,49 (+37,93%)
C	309,33	11,39	368,31	21,66	309,33	18,56 (+62,95%)	652,56 (+77,18%)	29,09 (+34,30%)
D	234,67	7,32	311,82	19,93	234,67	12,6 (+72,13%)	585,54 (+87,78%)	27,3 (+36,98%)

Cork Production Variables										
	After current simulation					After next debarking (9 years later)				
	Mean Debark Height **Hd** (m)	Mean Intensity of Debark **Id**	Total Surface of Debark **Sd** (m2)	Total Cork Production (kg)	Economic value (€)	Mean Debark Height **Hd** (m)	Mean Intensity of Debark **Id**	Total Surface of Debark **Sd** (m2)	Total Cork Production (kg)	Economic value (€)
0_REF	1,89	33,33	172,94	2.111,64	3.969,88	1,89	24,31 (-27,06%)	231,55 (+33,89%)	2.827,2 (+33,89%)	5.315,14 (+33,89%)
A	1,81	32,93	122,36	1.494,02	2.808,75	1,89 (+4,42%)	23,83 (-27,63%)	165,38 (+35,16%)	2.019,31 (+35,16%)	3.796,3 (+35,16%)
B	1,84	33,61	113,76	1.389,01	2.611,34	1,89 (+2,72%)	24,26 (-27,82%)	153,7 (+35,11%)	1.876,62 (+35,11%)	3.528,05 (+35,11%)
C	2,89	52,6	274,14	3.347,25	6.292,83	2,89	38,72 (-26,39%)	363,9 (+32,74%)	4.444,23 (+32,74%)	8.353,27 (+32,74%)
D	2,83	52,95	182,42	2.227,35	4.187,41	2,89 (+2,12%)	38,47 (-27,35%)	245,69 (+34,68%)	2.999,89 (+34,38%)	5.369,8 (+34,38%)

Ecological variables		
	After current simulation	After next debarking (9 years later)
	Ecological value	Ecological value
0_REF	6,01	6,21 (+3,33%)
A	6,98	7,22 (+3,44%)
B	5,44	5,56 (+2,21%)
C	6,01	6,21 (+3,33%)
D	5,47	5,59 (+2,19%)

Some conclusions:

- The tool designed has made it possible to correctly simulate various thinning and debarking criteria with the predicted results.
- The growth model used (Corkfit) correctly simulates the effect of competition and intensity of debarking on basal area growth and, consequently, on future Sd.
- It should be clarified that this is not a simulation model of real production or growth but a training model for field management. The growths have been amplified to highlight the results of the decisions made in the simulation.
- There is still room for improvement including in the simulation the ***quality of the cork*** (and not only quantity) and the ***diversity of TreMs*** (and not only the ecological value of trees)

Nomenclature cited:

- Location and identification:
  - NUM: Tree number identification
  - Coordinates X,Y,Z,
- Dendrometry:
  - OCBH: Overcork Circunference at Breast Height (cm)
  - UCBH: Undercork Circunference at Breast Height (cm)
  - Ug: Undercork Basal Area (m^2)
  - CTh: Cork Thickness (at Breast Height) (mm)
  - H: Total Tree Height (m)
  - HCB: Height to Crown Base (m)
  - CPA: Crown Projection Area (m^2)
- Ecological value:
  - TreMs: Tree Microhabitats (type, number)
  - Ecoval: Ecological value of the tree (points)
- Debarking:
  - Hd: Debark Height (m)
  - Sd: Debark Surface (Sd=Hd*UCBH) (m^2)
  - Id: Intensity of Debark = Sd/Ug
- Competition:
  - Hegyi Index HD2: (number of competitors according with the rule D2: $dist_{ij}<0.33*d_j$) (*Daniels, 1976*)

Acknowledgments:

- To the company PADEPAMA S.L. for ceding the Pino Gordo estate for the installation and subsequent educational use of the marteloscope in the cork oak forest.
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Thank you!

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