Influence of the thinning on the stand structure and yield maritime pine stands

An exercise with ModisPinaster

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Overview

Influence of the thinning on the stand structure and yield maritime pine stands

1 Stand growth and thinning

2 Overview of thinning types

3 Maritime pine in Portugal

4 Traditional silvicultural guidelines

5 Designing alternative itinerairies with ModisPinaster

6 Influence of the thinning type on the stand structure and yield

7 Next steps

Capsis4

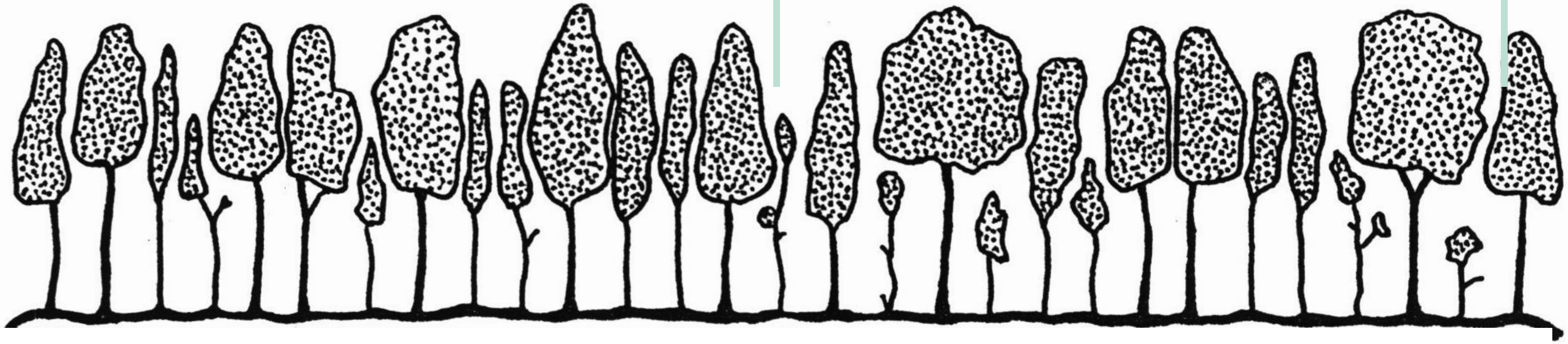
Capsis

Computer-aided projection of strategies in silviculture

Thinning and Growth: A Full Turnaround
(B. Zeide, 2001)

A major impetus for the origin and development of forestry has been the search for stand density that provides trees with “room to grow and none to waste.”

Is it possible to increase natural growth of forest stands by judicious removal of some trees?



ACG

Evolution of silvicultural thinning: from rejection to transcendence (B. Zeide, 2006)

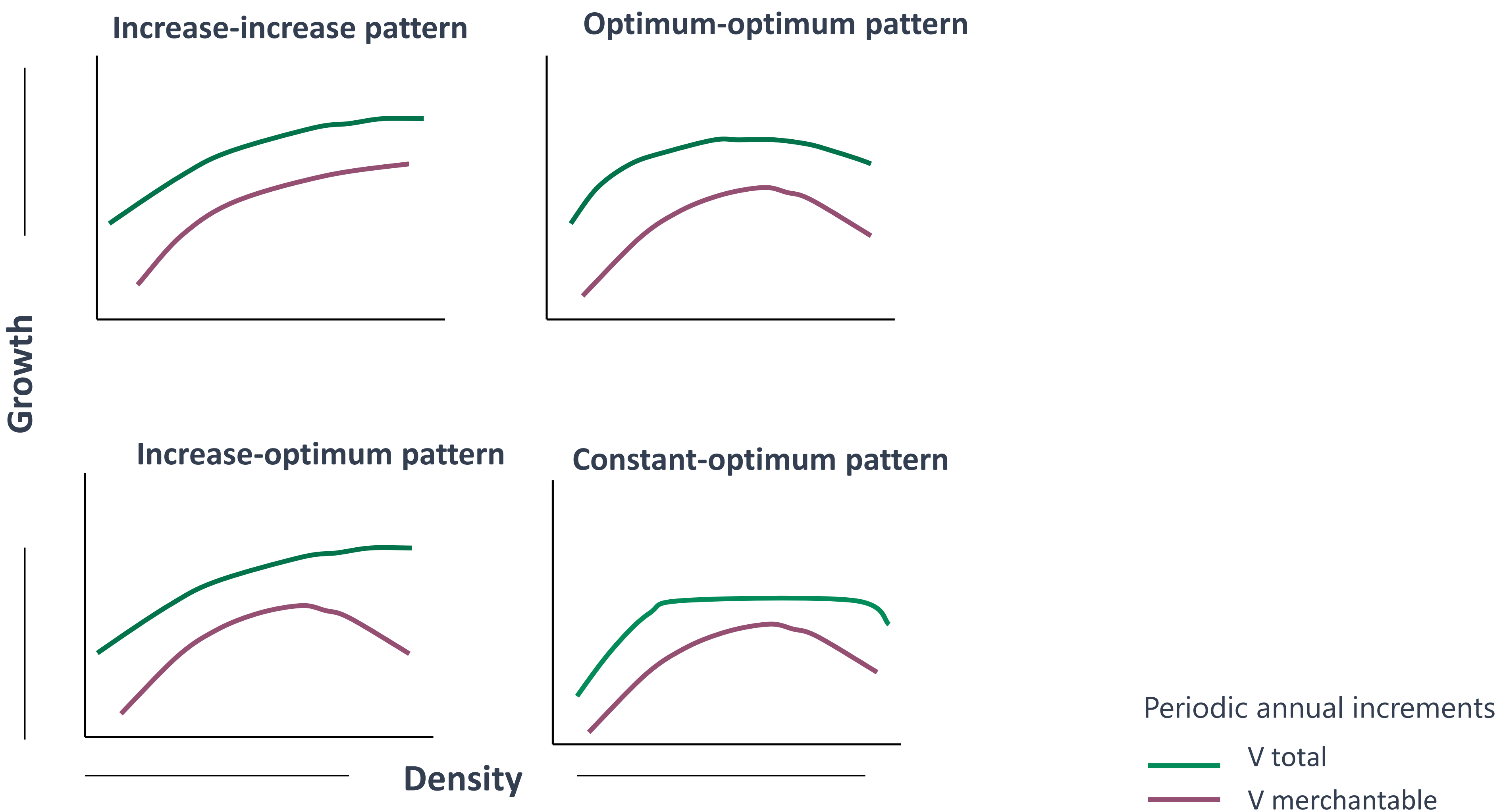
Conceptual development

	Prior 1795 – 1795-1911	1911-1932	1932 - present / 1937 - present	2005 -
Concept	Thinning decreases growth and volume	Thinning increases growth and volume	Thinning redistributes growth	Initial spacing as density control (minimax)
Planted number	> 20 000 (≈ Nature)			250 – 450
Thinning intensity	No thinning (Prior 1795); Light (1795-1911)	Medium-heavy	Medium-heavy (1932 - present); Decreasing (1937 - present)	No thinning

Technical implementations →

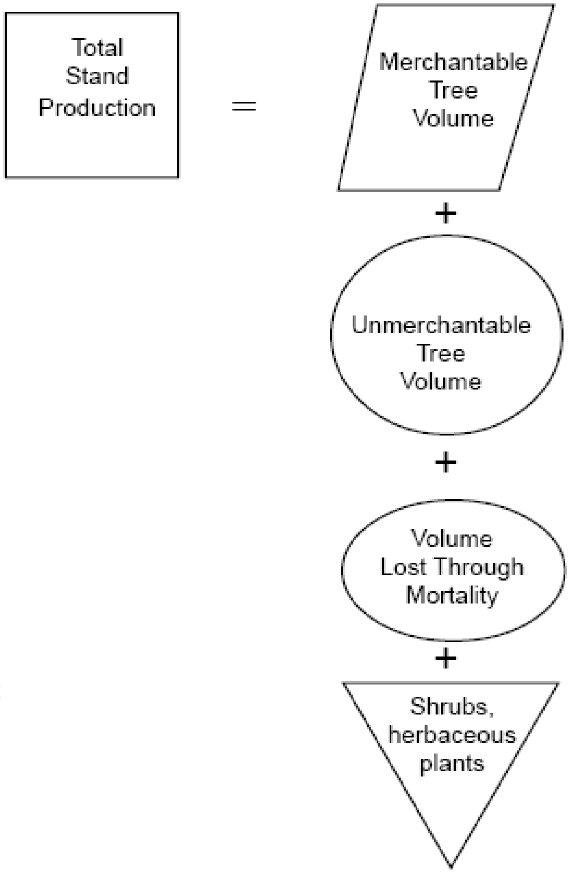
https://www.srs.fs.usda.gov/pubs/gtr/gtr_srs092/gtr_srs092-075-zeide.pdf

Relationship between thinning and production



Curtis et al. 1997

Relationship between thinning and production

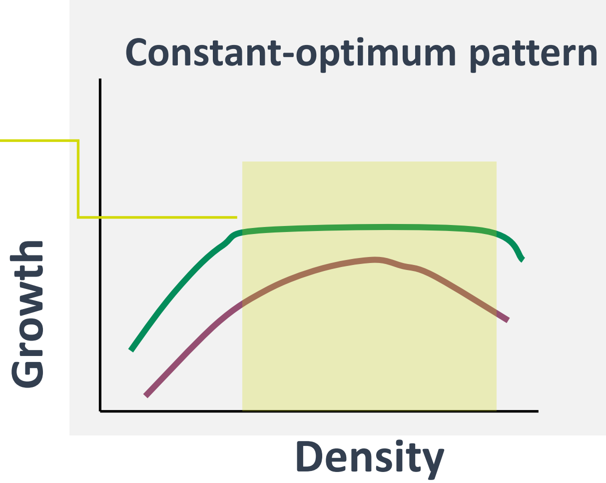


Langsaeter-Moller's plateau

Increment of cubic volume is virtually independent of variations in stocking

Actual consensus

Thinning can redistribute the incremente from smaller to larger stems but not increase its amount.
Beyond a wide range of density, stand production declines.



Thinning

- The loss of total volume might be more than compensate by the value of the increased merchantable volume of thinned stands.
- Contributes to enhanced aesthetics.
- Contributes to understory, hence favoring biodiversity.

Periodic annual increments

V total

V merchantable

Willcocks, A.J., W. Bell, 1994. How initial forest plantation density affects future forest growth. OMNR, Northeast Science & Technology. TN-08 16p.

"The **total production** of cubic volume by a stand on a given site is, for all practical purposes, **constant and optimum for a wide range of density or stocking**. It can be decreased, but not increased, by altering the amount of growing stock to levels outside this range."

Thinning intensity

pN, pG, pV
Fw, SDI

Thinning type

From below

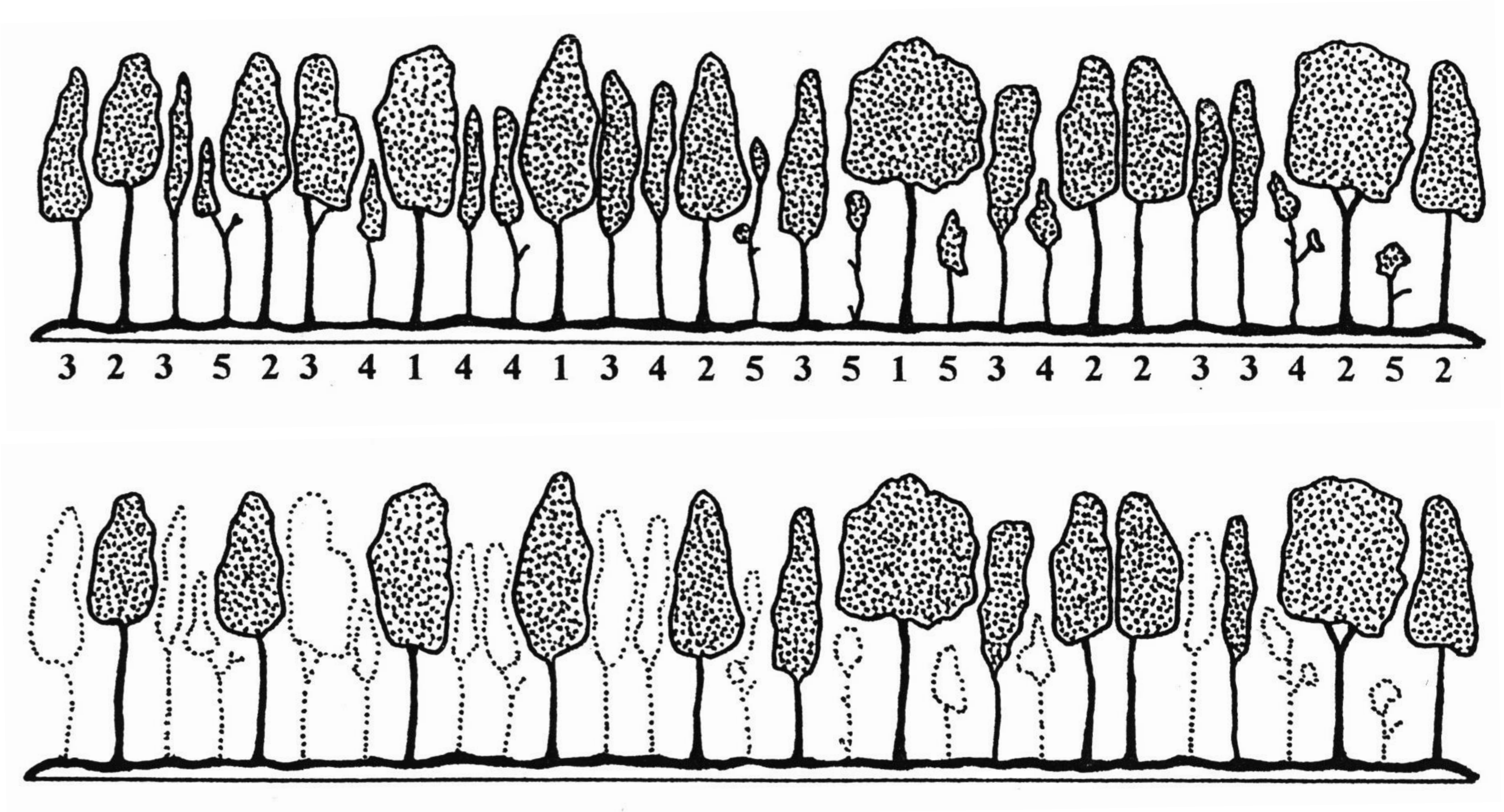
From above

Mixed (selective)

Mechanical

Thinning type can be defined by the relationship between the classes and the position in the crown of the trees removed in relation to the trees in the main stand. However, other factors, such as stem and crown conformation, are also important.
The type of thinning reflects a change in the spatial arrangement of trees within stands.

Thinning from below

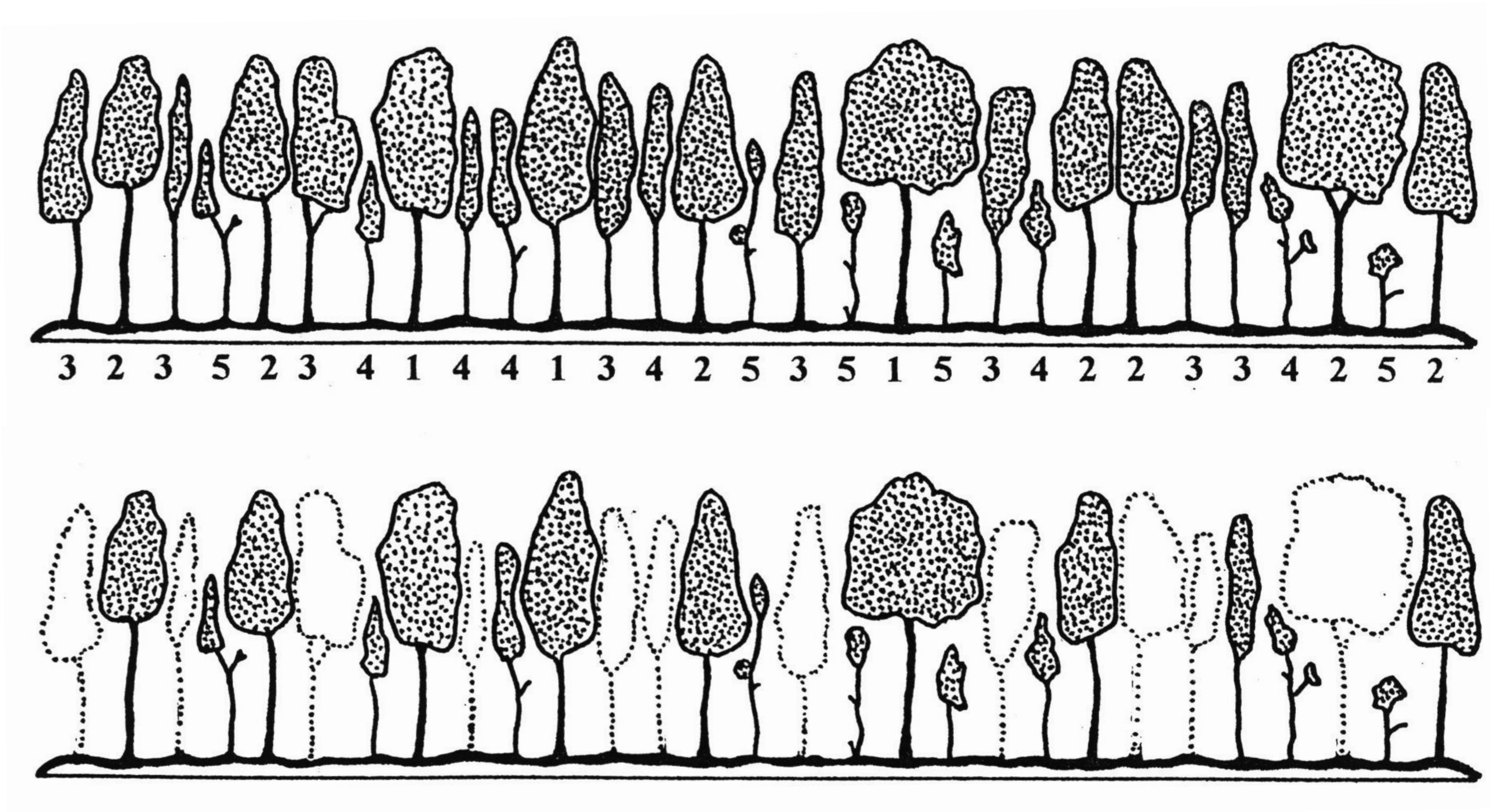


It presents better results in intolerant species, in which the individuals of the lower levels (dominated and subordinate), removing the trees from the upper levels, cannot compete and respond to defoliation.

The main objective of is to **favor the development of the best trees on the upper levels**, those with larger dimensions and better crowns.

The dominated and hopeless individuals are removed first, and individuals from the codominant and dominant storeys where necessary (e.g. defective trees).

Thinning from above



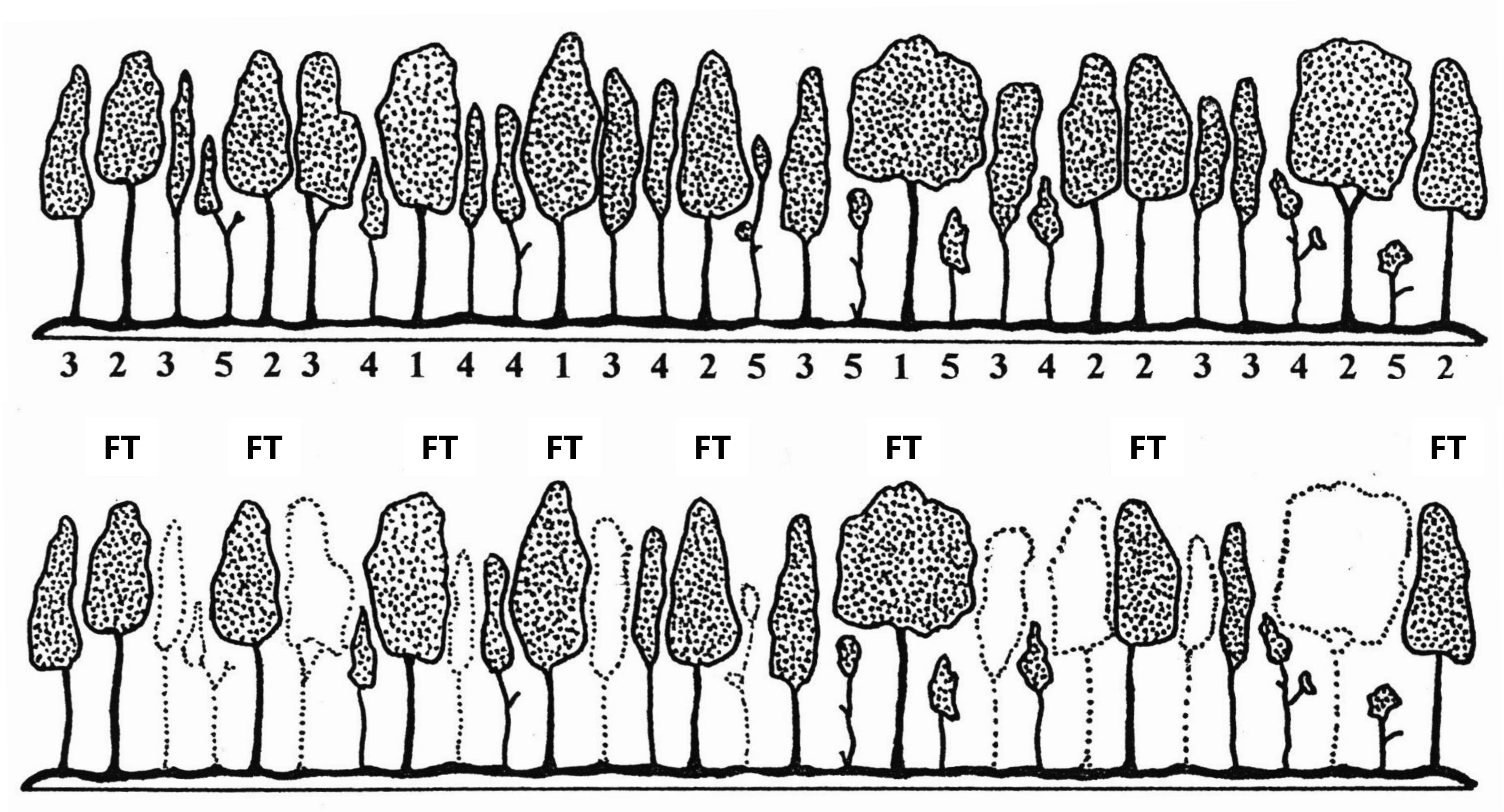
The main objective of is to **preserve until the end of the revolution the best trees of the dominant storey**.

Predominantly trees from the upper storeys (dominant and codominant) that are in direct competition with the most promising trees are removed, giving the latter conditions for growth.

It is best suited for tolerant and semi-tolerant species to shade in pure stands, especially when there are enough trees of good characteristics in the lower levels. Not recommended to intolerant species, especially at advanced ages.

Individuals from the lower levels (dominant and subdominant) are preserved to promote the natural pruning of the selected trees.

Mixed or selective thinning



All trees of each class have to be examined to eliminate individuals that disturb the development of future trees, whatever their initial positions may be.

This type of thinning assumes the **selection of trees of the future** (those with better stems and crowns and more promising growth)

The trees of the future are selected, and the most direct competitors are removed.
All others that could benefit the future trees are left in the stand.

Marking of future trees is not static but is re-selected and reclassified before each thinning.

Pinus pinaster distribution and area occupation

Maritime pine (*Pinus pinaster* Ait.) is an important native conifer from the Western Mediterranean basin that occupies an environmentally diverse area. In southwestern Europe (Portugal, Spain, France, and Italy), this species covers over 3 million hectares.

In mainland Portugal, the maritime pine is the most represented native conifers species. It occupies approximately 714 thousand ha (**22% of the forest area**).

Threats: Forest fires, pinewood nematode

Maritime pine forest regenerated after fire. Tâmega's Valley (Seirós's Pilot forest, ForManRisk - https://formanrisk.eu/)

Typical silvicultural model

t_0

natural regeneration
or
plantation/seeding

1250 trees ha^{-1}
4 × 2 or 3 × 2.65

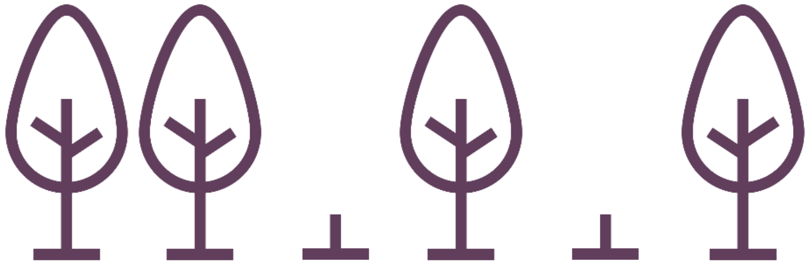
1670 trees ha^{-1}
(better sites)
3 × 2 or 4 × 1.5

2500 trees ha^{-1}
(e.g. Tâmega's Valley)

The thinning interval is short to medium (5-10 years), corresponding to a top height growth of 2 to 3 m.

1st thinning	**2nd thinning**	**3rd thinning**
15 < t < 20	**25 < t < 30**	**30 < t < 40**

top height : 8 – 10m

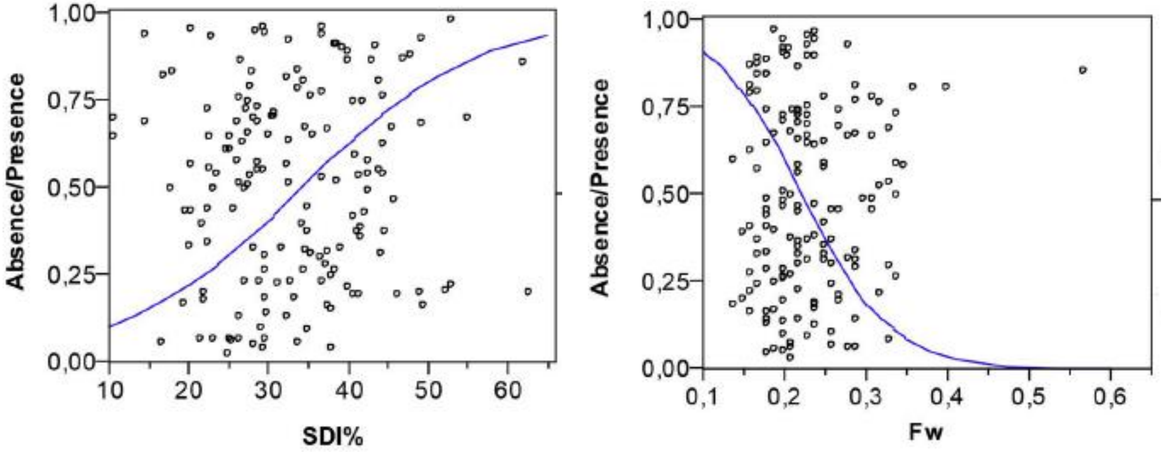


$t_{harvest}$ = 45 yrs
(average)

Harvest age depends on **site quality** and **management objectives**

Examples of silvicultural guidelines proposals

(1) A silvicultural stand density model to control understory in maritime pine stands
(Fonseca and Duarte, 2017)



Logistic fit of understory vegetation by Stand Density Index (SDI) and spacing factor of Wilson (Fw) for log odds of Absence/Presence

Absence: stands with 0-10% understory vegetation cover;
Presence: stands with understory vegetation cover > 10%.

Adaptive management

t (years)	*Fw* = 0.23 N_r (trees ha^{-1})	dg_r (cm)	V_r (m^3 ha^{-1})	*Fw* = 0.21 N_r (trees ha^{-1})	dg_r (cm)	V_r (m^3 ha^{-1})
22 (1st thin.)	844	9.6	36.8	574 (- 32%)	9.5 (- 1.0%)	24.2 (- 34.2%)
29 (2nd thin.)	484	14.2	57.0	580 (+ 20%)	13.3 (- 6.3%)	60.0 (+ 5.3%)
36 (3rd thin.)	229	19.0	57.1	274 (+ 20%)	17.8 (- 6.3%)	59.2 (+ 3.7%)
43 (4th thin.)	129	23.5	56.2	155 (+ 20%)	21.9 (- 6.8%)	58.5 (+ 4.1%)
50 (final cut)	514	31.5	374.7	617 (+ 20%)	29.9 (- 5.1%)	409.1 (+ 9.2%)
50 (Total)	-	-	581.8	-	-	611.0 (+ 5.0%)

Summary of the output results obtained with ModisPinaster

$$N = 18877 \exp(-0.656\, dg^{0.5})$$

Expected stand density level that ensures a null or lower cover of the understory (Fw = 0.21)

(2) Management of Maritime Pine: Energetic Potential with Alternative Silvicultural Guidelines.

Fonseca e Lousada (2021)

Scenarios

S1 **1100** trees ha^{-1}
S2 **2200** trees ha^{-1} **45** years
S3 **40 000** trees ha^{-1}
S4 **40 000** trees ha^{-1} **20** years

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4
0	Site preparation	Site preparation		
0	Stand establishment: artificial regeneration (plantation) 1100 plants/ha	Artificial regeneration (seeding or plantation) 2200 plants/ha	Natural regeneration. It is assumed a value of 40,000 plants/ha	Natural regeneration. It is assumed a value of 40,000 plants/ha
7–8			Release operation (8 yr). Reduction of stand density to 30,000 trees/ha through systematic (mechanical) thinning by 3 m width strips, leaving 1 m wide strips with trees	Release operation (8 yr). Reduction of stand density to 30,000 trees/ha through systematic (mechanical) thinning by 3 m width strips, leaving 1 m wide strips with trees
3–10	Control of spontaneous vegetation (3, 8 yr)	Control of spontaneous vegetation (3, 8 yr)	Control of spontaneous vegetation (8 yr)	Control of spontaneous vegetation (8 yr)
8–12			Thinning from below (12 yr). Removal of a. 60% trees/ha within the 1 m-wide strips with trees	Thinning from below (12 yr). Removal of a. 50% trees/ha within the 1 m-wide strips with trees
15–40	Three thinning from below (15, 25, 35 yr). Removal of a. 30% trees/ha per action	Three thinning from below (22, 29, 36 yr). *Fw* a. 0.21 after thinning	Four thinning from below (16, 20, 28, 36 yr). Removal of a. 35-40% trees/ha per action	Thinning from below (16 yr). Removal of a. 40% trees/ha
15–45	Final harvest at 45 yr	Final harvest at 45 yr	Final harvest at 45 yr	Final harvest at 20 yr

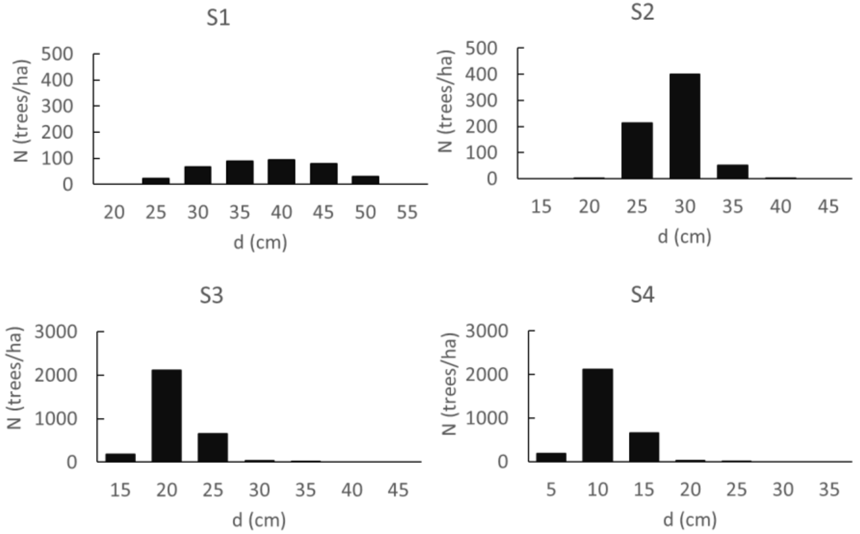
Characterization of the silvicultural models

(2) Management of Maritime Pine: Energetic Potential with Alternative Silvicultural Guidelines.

Fonseca e Lousada (2021)

t (yr)	Interv.	N_b (trees/ha)	N_r (trees/ha)	V_r (m^3/ha)	dg_r (cm)	B_r (t/ha)	C_r (t/ha)	E_r (GJ/ha)
8	Tree release	40,000	30,000	–	–	(890)	(308)	(13,527)
12	Shrubs release	–	–	–	–	(3)	(1)	(65)
12	First thinning	10,000	6000	45	3.8	115 (62)	40 (29)	1744 (936)
16	Second thinning	4000	1600	27	6.5	35 (38)	13 (18)	594 (647)
20	Third thinning	2400	840	35	9.3	28 (35)	11 (17)	502 (607)
28	Fourth thinning	1560	470	59	13.9	36 (46)	15 (22)	657 (787)
36	Fifth thinning	1090	380	107	18.9	60 (51)	24 (24)	1079 (841)
45	Harvest	710	710	469	28.8	252 (139)	102 (35)	4549 (1201)
Total (total forest residues)				**741**		**527** (1219)	**205** (454)	**9125** (18612)

Summary of the output results obtained with ModisPinaster (S3)



Diameter distributions per 5 cm classes at harvest age (45 years for Scenarios 1–3, and 20 years for Scenario 4).

Scen.	t (yr)	N_r (tree/ha)	dg_r (cm)	V_r (m3/ha)	B_r (t/ha)	C_r (t/ha)	E_r (GJ/ha)
1	45	380	38.5 (+25%)	583 (-27%)	550 (-217%)	220 (-199%)	9247 (-200%)
2	45	670	28.9 (≈0%)	591 (-25%)	614 (-184%)	250 (-164%)	9623 (-188%)
3	45	710	28.8	741	1745	659	27737
4	20	3000	11.1 (-159%)	218 (-239%)	1318 (-32%)	490 (-35%)	20705 (-34%)

Total yield at harvest age obtained with the four scenarios.

Effect of thinning type on stand structure and stand yield

Effect of thinning type on stand structure and stand yield

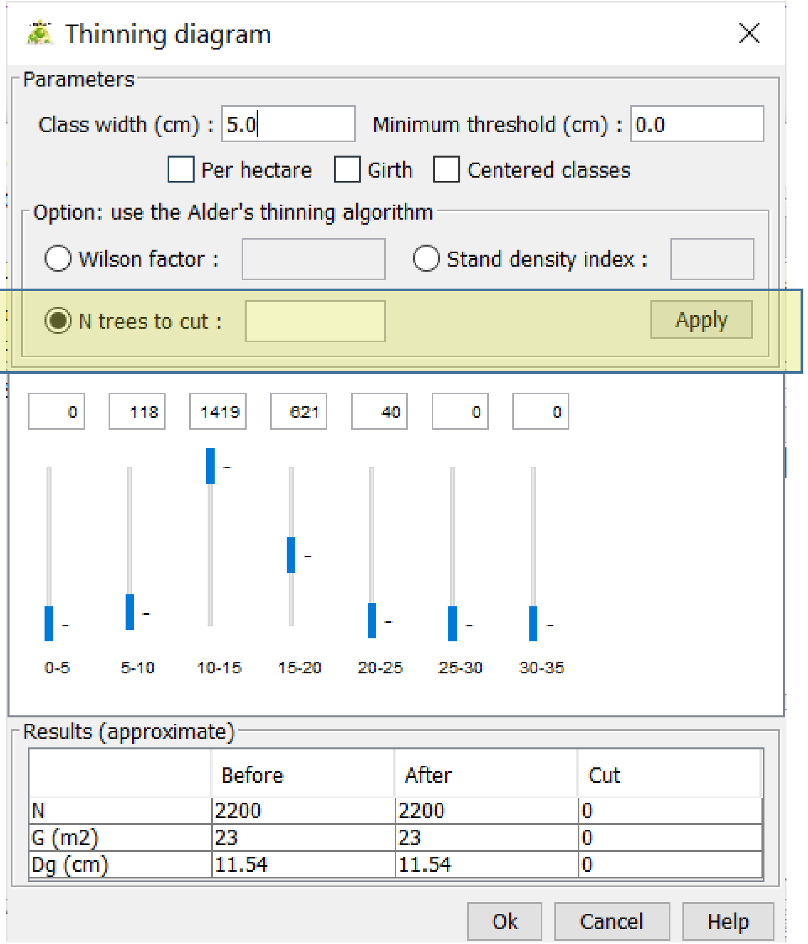
- **M1250-Sup**
  - **1st thinning from below** (40%) **2nd thinning from above** (30%)
    - **3rd thinning from above** (30%) and **final cut at 42 yr** **(M-1250-S-BAA-42)**
    - **Final cut at 30 yr** **(M-1250-S-BA-30)**
  - **1st** (40%) **and 2nd** (30%) **thinning from below**
    - **3rd thinning from below** (30%) **and final cut at 42 yr** **(M-1250-S-BBB-42)**
    - **Final cut at 30 yr** **(M-1250-S-BB-30)**

Characterization of the silvicultural models selected for the essay

AIM: to analyze differences in stand structure and production for different silvicultural models regarding **thinning types**, with variation in **initial density** (1250 vs 1000 trees), **site quality** (superior vs average) and **final harvest age** (30 years vs 42 years).

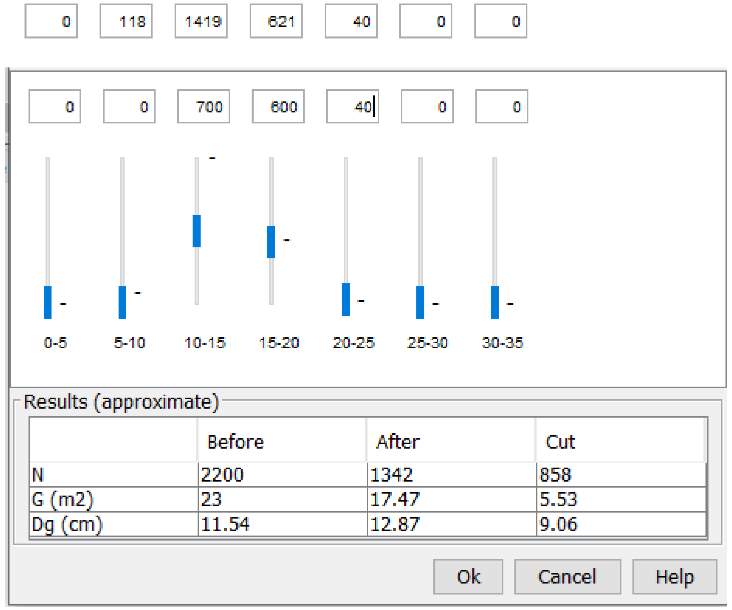
- Similar trials considering an initial density of N = 1000 trees ha^{-1}.
- Similar experiments with the two variations in the initial number of trees (1250 and 1000 trees ha^{-1}) but for medium-quality site.

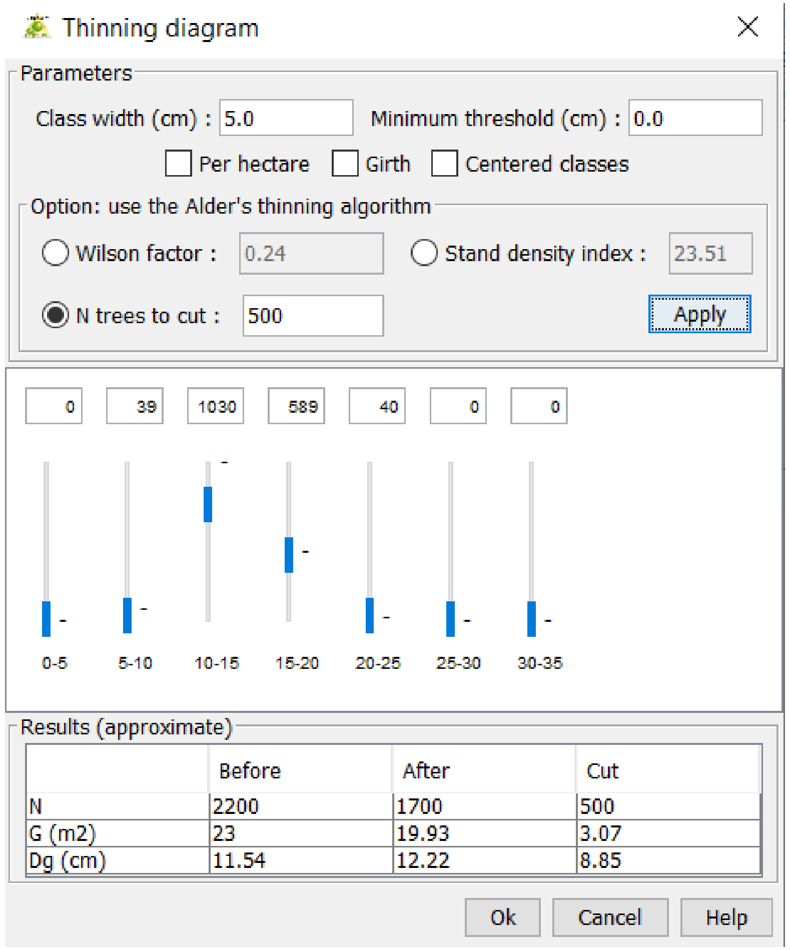
Simulation options



Before thinning

1. Spacing factor of Wilson (Fw)
2. Stand Density Index (SDI)
3. N trees to cut (thin. from below)
4. N trees to cut per diameter class (thin. from above)





After thinning

Intermediate results

	SUP-1250-BA30|BAA42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1^{st}) B	500	8.8	11.8	6.8
22	(2^{nd}) A	225	16.8	29.0	15.2
30		525	24.3	183.5	90.6
30 (Total)	*Final cut*			***224.3***	***112.6***
30	(3^{rd}) A	158	21.8	43.0	20.5
42	Final cut	367	34.3	321.6	157.3
42 (Total)				**405.4**	**199.8**

Effect of stand density

✓ **Consistent with expected pattern**

Same pattern for thinning from below

A higher density corresponds to a higher total stand volume and biomass and a lower mean diameter of the trees

1250 trees.ha^{-1}

	SUP-1250-BA30|BAA42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1st) B	500	8.8	11.8	6.8
22	(2nd) A	225	16.8	29.0	15.2
30		525	24.3	183.5	90.6
30 (Total)	*Final cut*			***224.3***	***112.6***
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42 (Total)				405.4	199.8

	MED-1250-BA30|BAA42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1st) B	500	7.7	8.5	4.9
22	(2nd) A	225	16.8	28.6	15.2
30		525	23.0	159.9	78.5
30 (Total)	*Final cut*			***197.0***	***98.6***
30	(3rd) A	158	21.8	42.6	20.5
42	Final cut	367	32.9	287.5	138.9
42 (Total)				367.2	179.5

1000 trees.ha^{-1}

	SUP-1000-BA30|BAA42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1st) B	400	9.4	10.9	6.3
22	(2nd) A	150	18.8	19.3	10.1
30		450	25.9	180.8	90.9
30 (Total)	*Final cut*			***211***	***107.3***
30	(3rd) A	90	25.0	33.3	16.4
42	Final cut	360	35.1	330.3	159.9
42 (Total)				393.8	192.7

Site quality: superior. Thinning from above.

	MED-1000-BA30|BAA42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1st) B	350	8.3	7.2	4.2
22	(2nd) A	195	16.8	25.2	13.1
30		455	24.3	157.5	79.2
30 (Total)	*Final cut*			***189.9***	***96.5***
30	(3rd) A	91	26.8	38.9	19.9
42	Final cut	364	33.7	294.6	147.8
42 (Total)				365.9	185

Site quality: average. Thinning from above.

Effect of site quality

✓ **Consistent with expected pattern**

Same pattern for thinning from above

Stands growing in better sites have higher values of total stand volume and biomass and lower mean diameter

	SUP-1250-BB30|BBB42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1^{st}) B	500	8.8	11.8	6.8
22	(2^{nd}) B	225	15	22.1	11.3
30		525	24.3	183.5	90.6
30 (Total)	*Final cut*			***217.4***	***108.7***
30	(3^{rd}) B	158	22.5	46.1	22.2
42	Final cut	367	34.1	318.4	154.2
42 (Total)				398.4	194.5

	SUP-1000-BB30|BBB42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1^{st}) B	400	9.4	10.9	6.3
22	(2^{nd}) B	149	16.1	17.3	8.9
30		451	25.9	181.0	91.0
30 (Total)	*Final cut*			***209.2***	***106.2***
30	(3^{rd}) B	90	24.0	30.5	15.0
42	Final cut	361	35.1	330.7	160.0
42 (Total)				389.4	190.2

Site quality: superior. Thinning from below.

	MED-1250-BB30|BBB42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1^{st}) B	500	7.7	8.5	4.9
22	(2^{nd}) B	226	13.8	18.3	9.3
30		524	23.0	157.7	78.3
30 (Total)	*Final cut*			***184.5***	***92.5***
30	(3^{rd}) B	158	21.2	39.2	19.0
42	Final cut	366	33.0	285.9	139.6
42 (Total)				351.9	172.8

	MED-1000-BB30|BBB42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1^{st}) B	350	8.3	7.2	4.2
22	(2^{nd}) B	195	14.5	17.8	9
30		455	24.3	157.5	79.2
30 (Total)	*Final cut*			***182.5***	***92.4***
30	(3^{rd}) B	91	21	22.5	10.8
42	Final cut	364	33.7	292.0	146.9
42 (Total)				339.5	170.9

Site quality: average. Thinning from below.

Effect of thinning type

Same pattern for superior site quality

Thinning from above yields higher stand volume and biomass. No clear pattern for average tree diameter

	MED-1250-BB30|BBB42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1st) B	500	7.7	8.5	4.9
22	(2nd) B	226	13.8	18.3	9.3
30		524	23.0	157.7	78.3
30 (Total)	*Final cut*			***184.5***	***92.5***
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30	(3rd) B	91	21	22.5	10.8
42	Final cut	364	33.7	292.0	146.9
42 (Total)				339.5	170.9

Site quality: medium. Thinning from below.

	MED-1250-BA30|BAA42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
15	(1st) B	500	7.7	8.5	4.9
22	(2nd) A	225	16.8	28.6	15.2
30		525	23.0	159.9	78.5
30 (Total)	*Final cut*			***197.0***	***98.6***
30	(3rd) A	158	21.8	42.6	20.5
42	Final cut	367	32.9	287.5	138.9
42 (Total)				367.2	179.5

	MED-1000-BA30|BAA42				
t (years)	Thin	Nr (trees/ha)	dgr (cm)	Vr (m^3/ha)	Ba (Mg/ha)
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42 (Total)				365.9	185

Site quality: medium. Thinning from above.

Effect of thinning type and harvest age

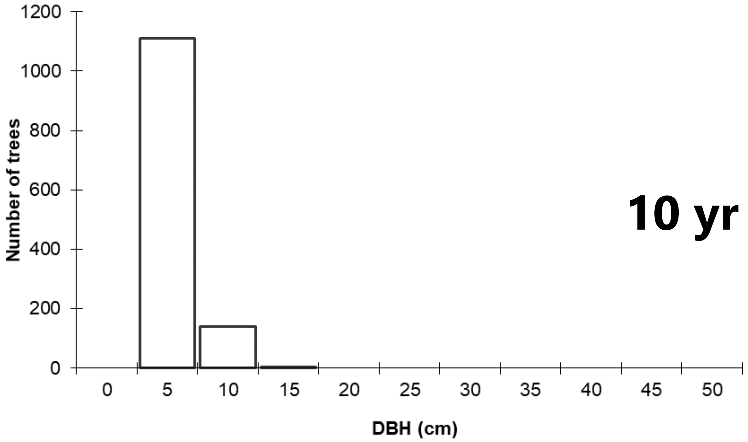
Thinning from above yields higher stand volume and biomass than thinning from below.

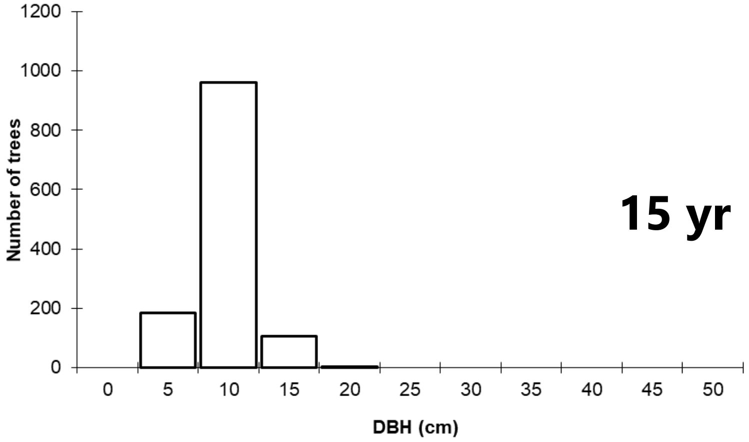
Silvicultural model	Vr (m^3/ha) Harvest age		Dif.	Ba (Mg/ha) Harvest age		
	30	42		30	42	
SUP-1250-Thin. from below	217.4	398.4	*181.0*	108.7	194.5	*85.8*
SUP-1250-Thin. from above	224.3	405.4	*181.1*	112.6	199.8	*87.2*
Dif.	**-6.9**	**-7**		**-3.9**	**-5.3**	
SUP-1000-Thin. from below	209.2	389.4	*180.2*	106.2	190.2	*84*
SUP-1000-Thin. from above	211.0	393.8	*182.8*	107.3	192.7	*85.4*
Dif.	**-1.8**	**-4.4**		**-1.1**	**-2.5**	
MED-1250-Thin. from below	184.5	351.9	*167.4*	92.5	172.8	*80.3*
MED-1250-Thin. from above	197.0	367.2	*170.2*	98.6	179.5	*80.9*
Dif.	**-12.5**	**-15.3**		**-6.1**	**-6.7**	
MED-1000-Thin. from below	182.5	339.5	*157.0*	92.4	170.9	*78.5*
MED-1000-Thin. from above	189.9	365.9	*176.0*	96.5	185	*88.5*
Dif.	**-7.4**	**-26.4**		**-4.1**	**-14.1**	

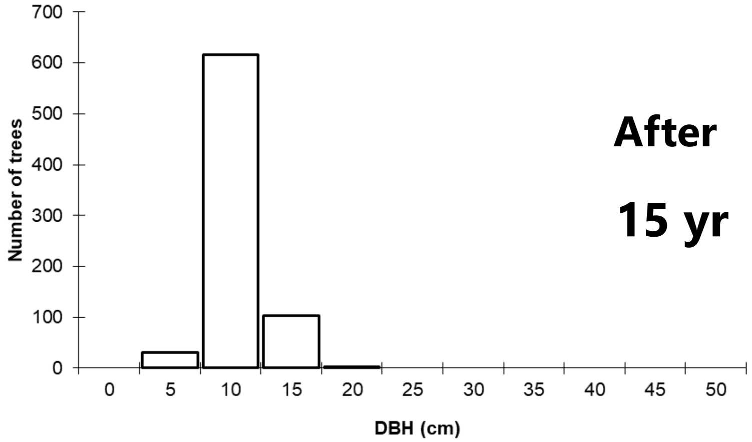
From 30 to 42 years, the stand produces ≅ 77 to 94% as up to 30 years.

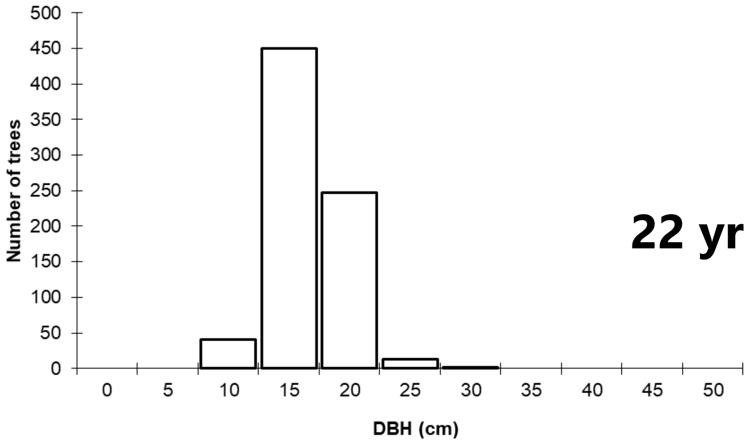
Effect on stand structure

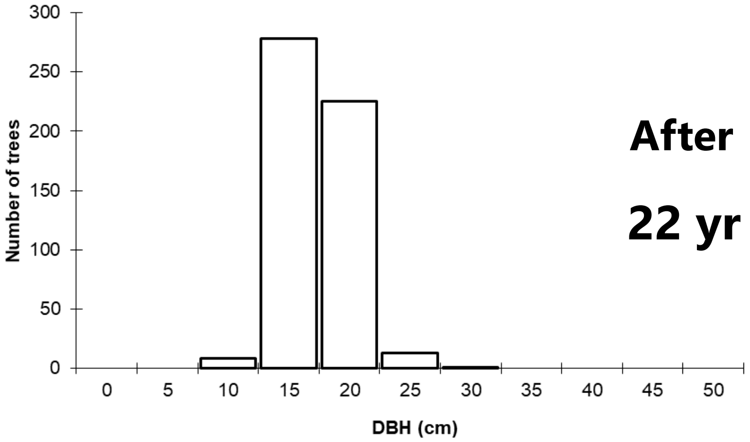
Site quality: Superior. Initial stand density: 1250 trees.ha^{-1}. Two thinnings from below at ages 15 and 22 yr.

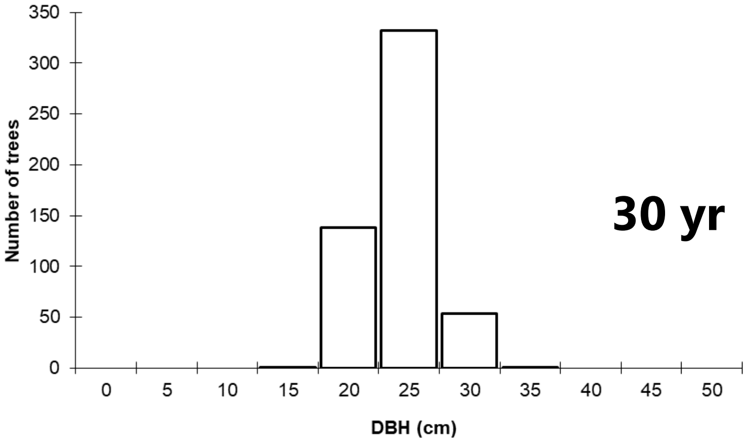






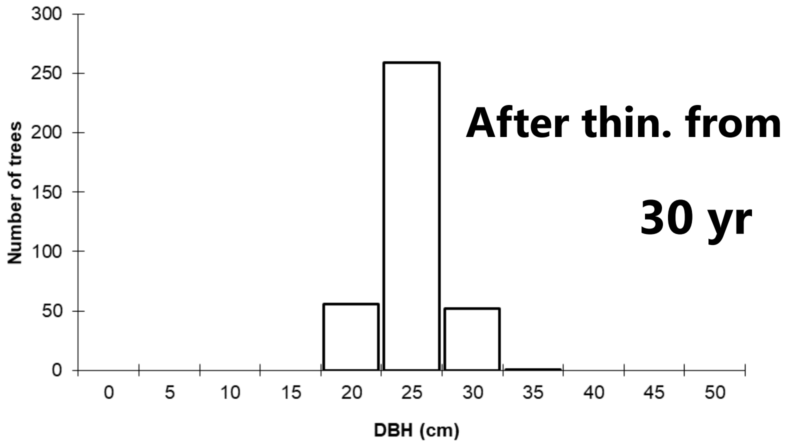






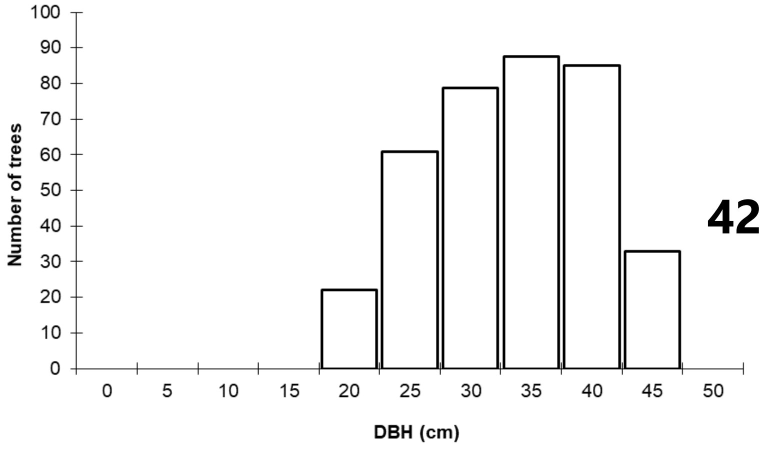
Effect on stand structure

Site quality: Superior. Initial stand density: 1250 trees.ha^{-1}. Thinning from below vs thinning from above at 30 yr.



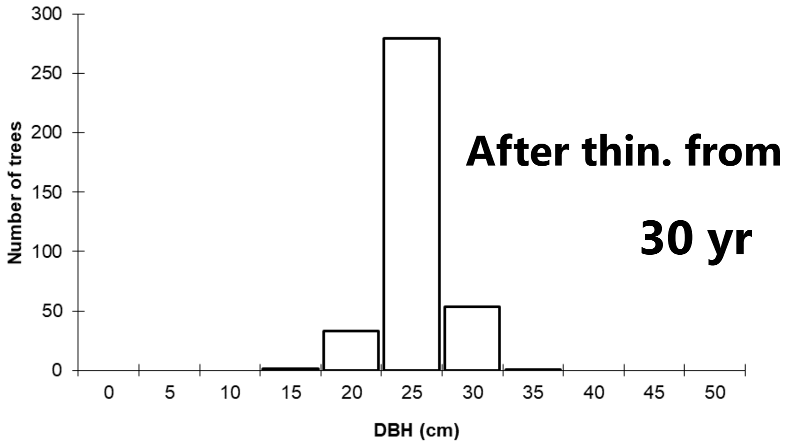
After thin. from below

30 yr



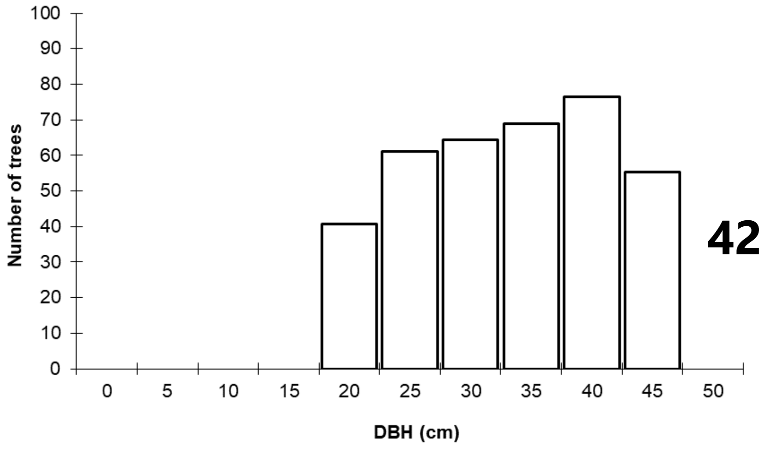
42 yr

1250-S-BB(30)B42



After thin. from above

30 yr



42 yr

1250-S-BA(30)A42

Advantages of thinning from above over thinning from below

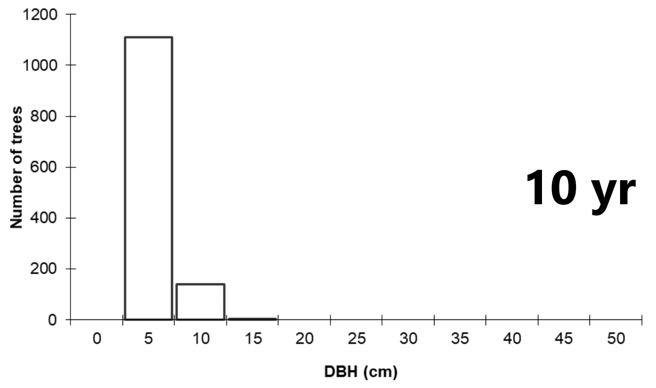
- Allows obtaining better trees in the term of exploitability, of larger average dimensions, with better stem, without prejudice to the total volume.

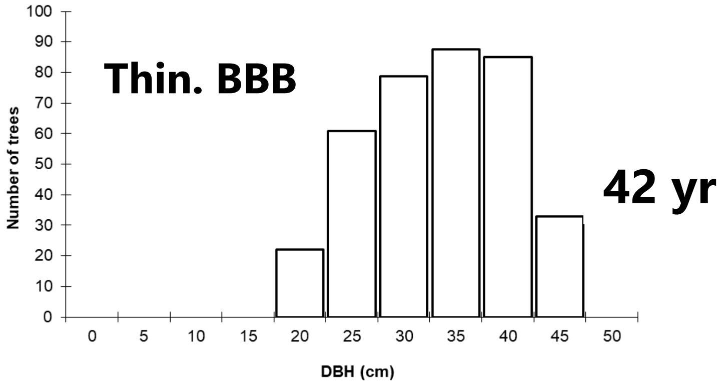
- Obtaining more valuable woody material in intermediate cuts, as a result of the vertical levels where the intervention is mainly focused, therefore capable of conferring positive profitability to the thinning operations.

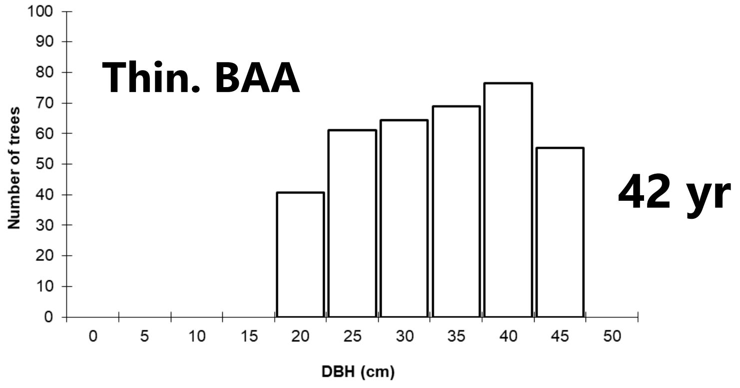
Simulation results

No evident effects were noticed on average diameter.

Total volume was high with thinning from above.







Next steps

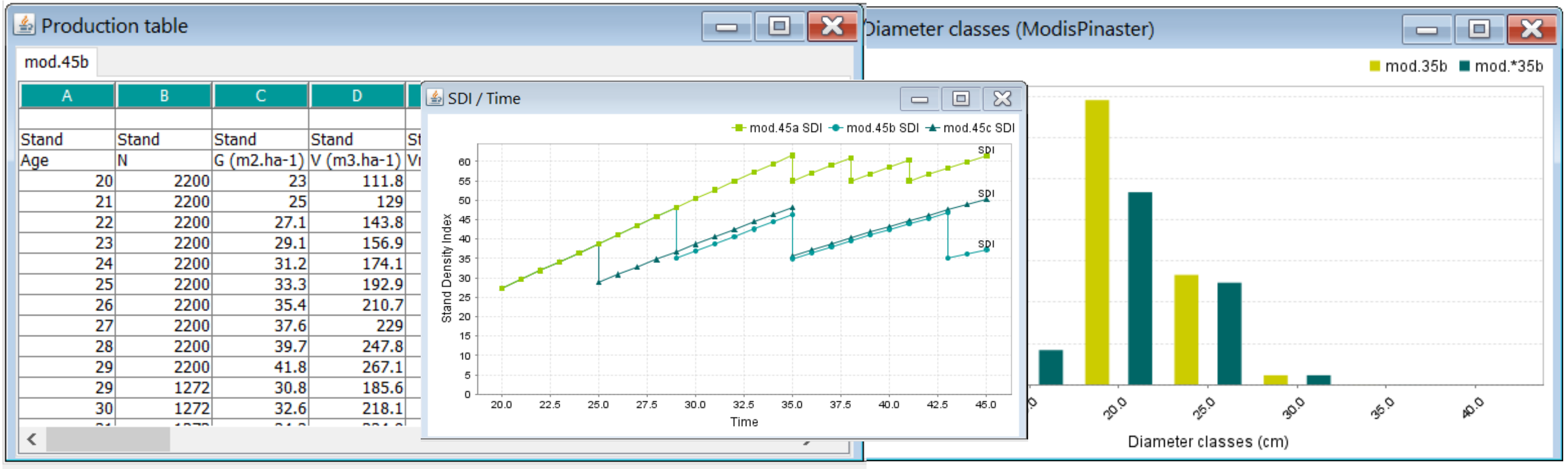
Continue the research and pursue simulations for:

- **Higher initial densities** in tree number
- (2500 and > 5000 trees ha^{-1}).

- Simulate tree removal in thinning from below and above with the iterative diagram. Analyse the results.
- **Model the pattern of thinning from above.**

- Create new functionality/module in ModisPinaster to simulate this type of thinning.

Abstraction



Stand Age	Stand N	Stand G (m2.ha-1)	Stand V (m3.ha-1)
20	2200	23	111.8
21	2200	25	129
22	2200	27.1	143.8
23	2200	29.1	156.9
24	2200	31.2	174.1
25	2200	33.3	192.9
26	2200	35.4	210.7
27	2200	37.6	229
28	2200	39.7	247.8
29	2200	41.8	267.1
29	1272	30.8	185.6
30	1272	32.6	218.1

Are we missing the reality?

Playtime (1967)
Jacques Tati

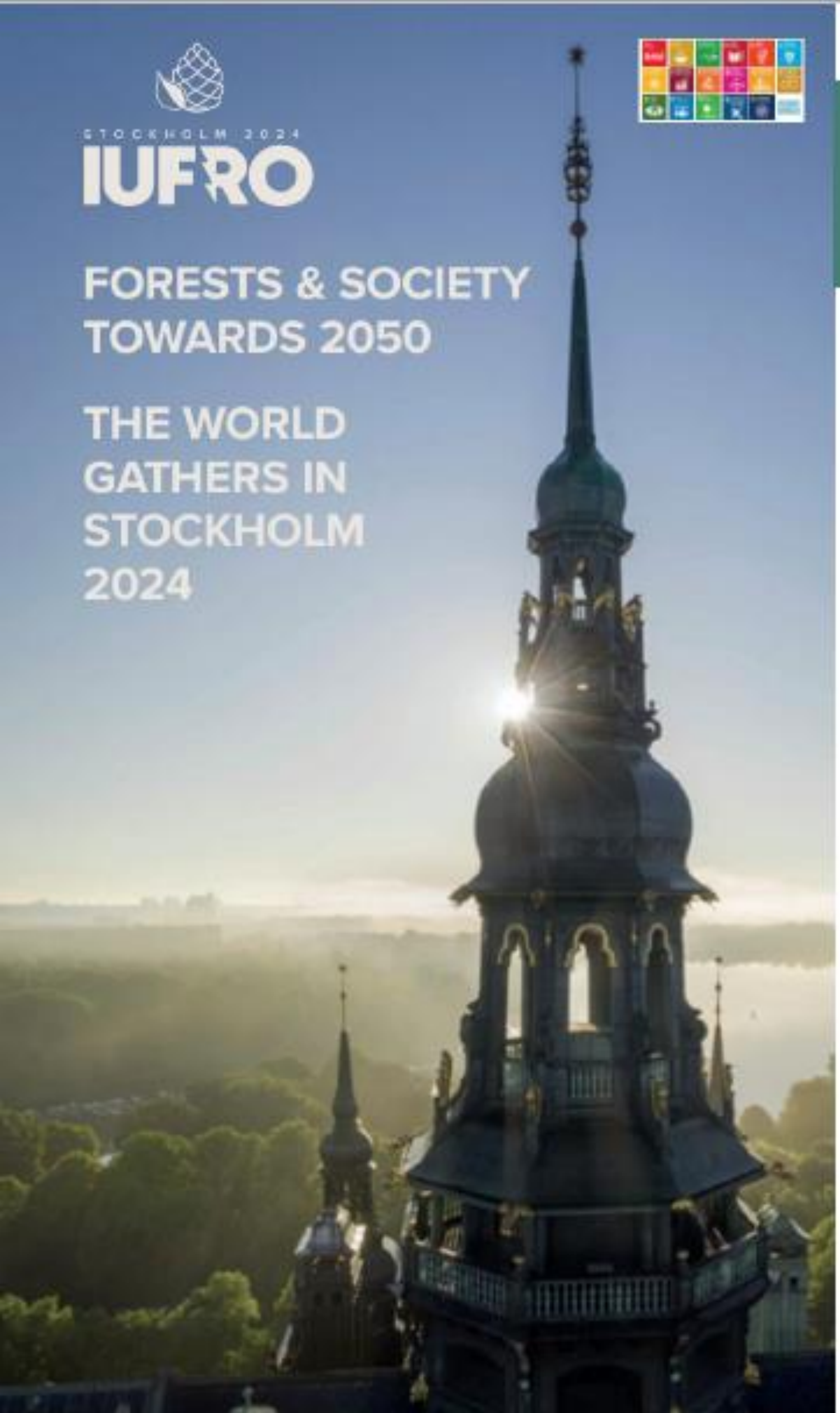
We are developing and gaining knowledge with the use of the simulators.

ModisPinaster has been supporting the design of silvicultural guidelines and helping with sustained decision making, in real cases and to prepare forest managers to adapt to changes.

Merci pour votre attention

Merci à Céline Meredieu et François de Coligny d'avoir rendu possible l'abstraction en incluant ModisPinaster dans la plateforme Capsis.

Merci à tous ceux qui contribuent au projet CAPSIS.
Merci aux organisateurs de l'événement Forem 2023.



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Abstracts will be accepted **until 2 June 2023**.
To apply follow the link: https://iufro2024.com/call-for-congress-abstracts/

Technical Theme 1
T1.5 Climate-smart pine forest management (Oral / Poster)

This session intends to address the issue of forest management adaptation to climate changes, with the focus on pine forests. Both adaptation and mitigation efforts are of interest. In this session we would welcome contributions that

(i) implement adaptive concepts into forest management

(ii) change stand structures and tree species composition in ways that make the resulting forest better adapted to the climate and maintain/increase genetic diversity

(iii) use natural forest dynamics for optimizing stand development

(iv) predicts, quantify and explore impacts of climate change on pine forests.

Organizers:
Mikolaj Lula, Emma Holmström, Teresa F. Fonseca, Santiago C. González-Martínez, Miren del Río, Sven Mutke

STOCKHOLM 2024 IUFRO WORLD CONGRESS FORESTS & SOCIETY TOWARDS 2050

Co-organized by IUFRO WP 1.01.10