2005 SAF National Convention
October 19-23, 2005 – Fort Worth (TX)

Pinus sylvestris L. forests in western Italian Alps

Competition dynamics and canopy structure

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Introduction

Scots pine *(Pinus sylvestris* L.) is the most widespread pine species in Europe (20 million ha, 20% of the EU forest area).

Early seral species
- Light-demanding
- Can grow on shallow, rocky soils
- Continental climate
- Drought-tolerant (south facing slopes)
- Lifespan: 300(450) years
- High site fertility leads to succession

ONE SPECIES, MANY ECOTYPES.

Introduction

7,500 years of human activity in the Alps led to marginalization and loss of forest land and to reduction of late successional forest cover types.

✓ Old scots pine forests over marginal / unaccessible areas.

✓ After post-war abandonment of alpine regions, young Scots pine forests extend beyond their natural range.

Introduction

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Introduction

In the last decades Scots pine stands of dry inner-Alpine valleys have suffered from **increasing dieback** (Rigling et al., 1999).

Possible causes:

- Climate change, increased summer drought
- Climate change-driven modifications in insect outbreaks
- Increased impact of root rot, vascular diseases, mistletoe
- Shifts in fire regimes

Introduction

Sudden death in springtime OR long and progressive decay, thinner crown, death of branches or top.

Single trees _ Clusters _ Whole stands

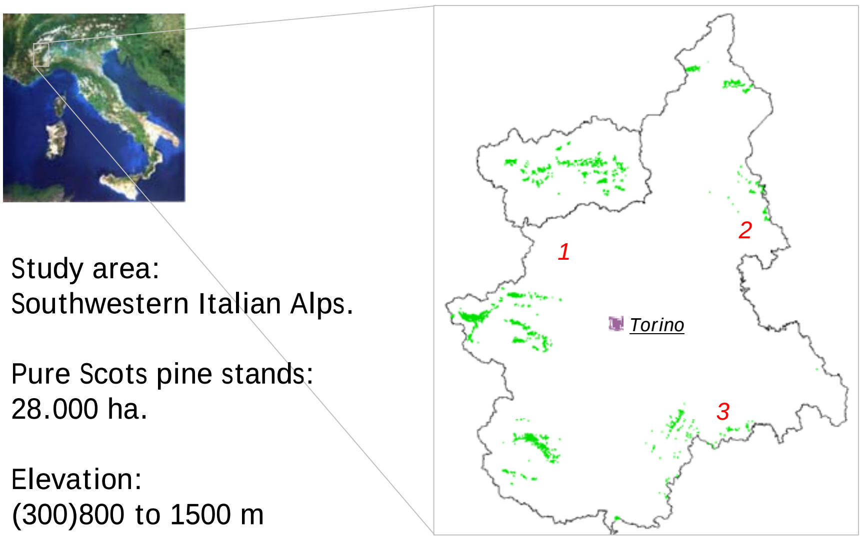
Research aims

Drought may be the triggering factor, but the impact of other driving factors and their interactions are unknown.

1. Quantitative assessment of the influence of **intertree competition** on individual dieback and mortality.

2. Methodology capable of separating **density-dependent** dieback from effects of other mortality factors (biotic or abiotic).

Materials and methods



Study area:
Southwestern Italian Alps.

Pure Scots pine stands:
28.000 ha.

Elevation:
(300)800 to 1500 m

Materials and methods

Regional Forest Inventory (IPLA, 2003):

Temporary sample plots (circular, R: 8-15 m according to stand density).
Grid size: 500m.

- *UTM, elevation, slope*
- *Forest cover type*
- *Stand structure & developmental stage*
- *Canopy cover (visual estimation in classes)*
- *Species and DBH for each tree in the plot (DBH >7.5 cm)*

- *Regeneration frequencies (tens of individuals, DBH <7.5 cm)*
- *Damage factors (if any)*
- *Average crown transparency or decoloration*
- *Main forest function and silvicultural recommendations*
- *Roads and Logging system*

Materials and methods

I.Competition dynamics at a regional scale

Reineke's (1933) Stand Density Index:

$$SDI = tpha\ (QMD/25)^{1.605}$$

Selected plots (n =245) were:

- Pure (Scots pine >70% basal area)
- Even-aged (no uneven-aged or irregular age structure)
- Not managed (n. stumps <10% n. living trees)

→ *SDImax, relative density*

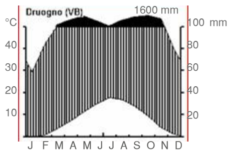
Materials and methods

II. Competition dynamics at a stand scale

3 Permanent Sample Plots (70x70 m) established in summer 2005 on sites with comparably high fertility.

n	*Site*	*UTM*	*Elevation*	*Slope*	*Aspect*	*Age*
1	S.Maria	5110657 N 457763 E	1050 m	40%	E	30
2	Toceno	5110964 N 458567 E	1050 m	80%	W	90-130
3	Trasquera	5118744 N 439503 E	1270 m	30%	SE	100-300

Walter-Raleigh climate diagram for the study sites.
Drought is not a problem!



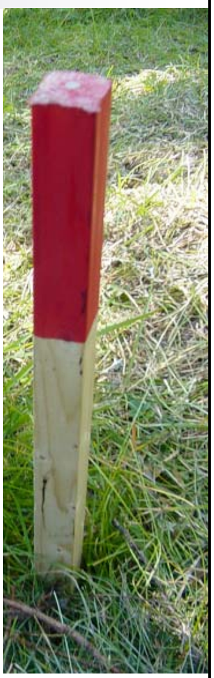
Materials and methods

Permanent Sample Plots (2005):

Living and dead standing trees (DBH >2.5 cm), logs and stumps (min. diameter >10 cm) were identified, labeled with plastic tags and mapped on x,y axes.

- *Species*
- *DBH, Total height*
- *Crown ratios (4)*
- *Crown radii (4)*

CAD-aided representation of single tree crowns;
Over 1,000 independent polygons exported to GIS.



Site 1 - S.Maria

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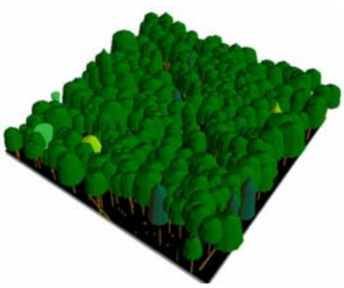
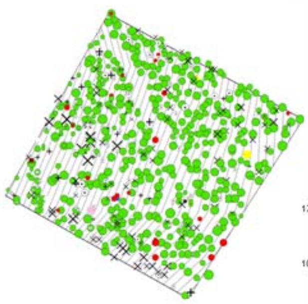
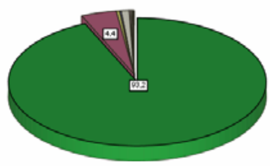
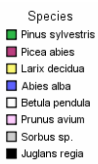
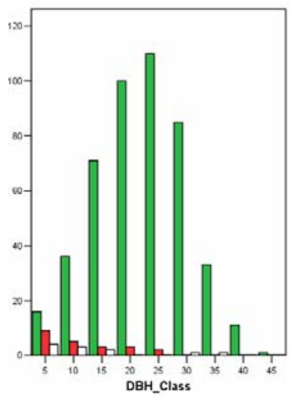
Site 1 - S.Maria











Stand density: 945 trees ha^{-1}
G: 39.9 m^2 ha^{-1} _ Canopy cover: 91%
Quadratic mean DBH: 23.2 cm
Dominant Height: 16.1 m
Age: 30 yrs

Recent colonization on former meadows.

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Site 2 - Toceno

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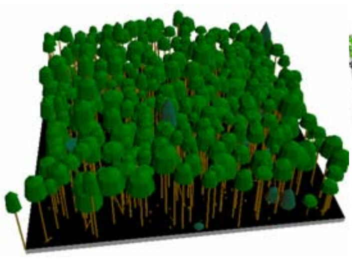
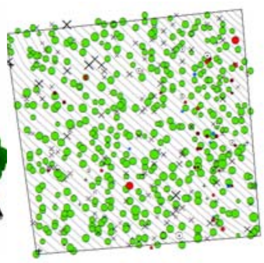
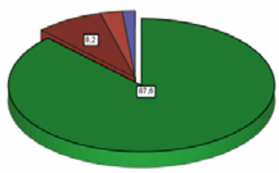
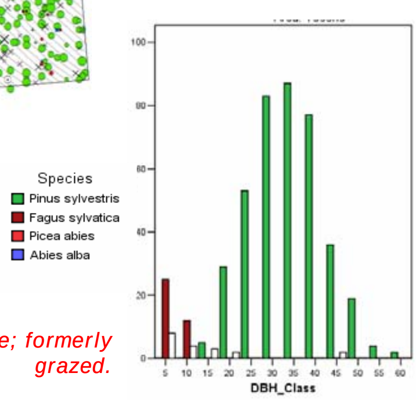
Site 2 - Toceno









Stand density: 838 trees ha^{-1}
G: 71.6 m^2 ha^{-1} _ Canopy cover: 78%
Quadratic mean DBH: 33.0 cm
Dominant Height: 21.1 m (Site Index)
Age: 90 yrs

Older colonization on previous meadows or fire; formerly grazed.

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Site 3 - Trasquera

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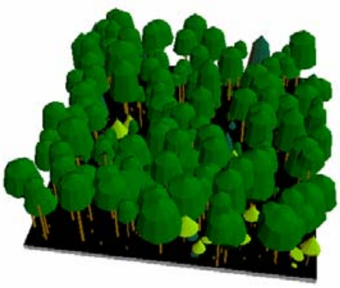
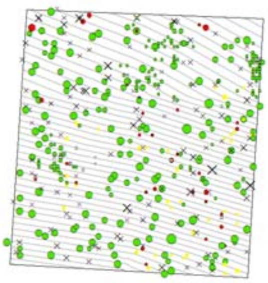
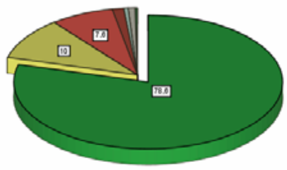
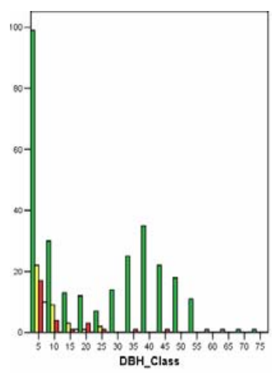
Site 3 - Trasquera









Stand density: 597 trees ha^{-1}

G: 34.2 m^2 ha^{-1} _ Canopy cover: 75%

Quadratic mean DBH: 27.0 cm

Dominant Height: 22.7 m

Age: 100-300? yrs

Occasional felling during last 20 yrs.

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Materials and methods

Q: How much intense is overall competition in PSP?
A: *Relative density measures.*

- SDI % (Long, 1985)
- Crown competition Factor (100%= full site occupancy)

Q: Which size classes were affected most and when?
A: *Size hierarchy analysis* on DBH distributions.

- Range, skewness
- Shape of distribution (normal, bimodal…)
- Size heterogeneity: Gini coefficient (0:min ÷ 1:max)

LIVE AND DEAD TREES (not from cutting).

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Materials and methods

Q: What are the spatial interactions between individuals and between species?
A: *Spatial Point Pattern Analysis.*

- Ripley's K(t) on live and dead trees

Random — Clustered — Regular (over-dispersed)

- Ripley's $\lambda_{12}(t)$ between different species – site 3
(patterns of attraction, repulsion or indifference)

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Materials and methods

Q: To what extent is competition responsible for Scots pine dieback? Where are the "hot spots" of competition in each stand?

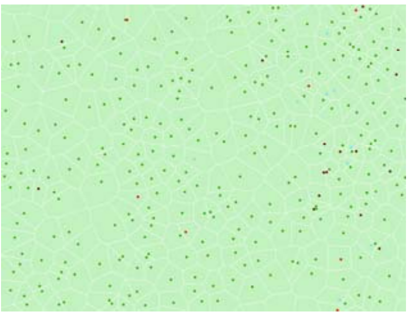
Assumptions:

- **Crown dimension is a good predictor of individual vitality, growth (photosynthetic capacity) and death probability.**
- **Crown dimensions are sensitive to competition and disturbing (biotic/abiotic) stress in a linear way.**
- **Density-related and density-independent mortality factors act separately (synergies are not considered).**

Materials and methods

A1: Linear regression model between measured crown projection area (CPA) and Area potentially available (APA) to each tree.

<u>Measure of APA</u>: power-weighted Voronoi polygons area.



Materials and methods

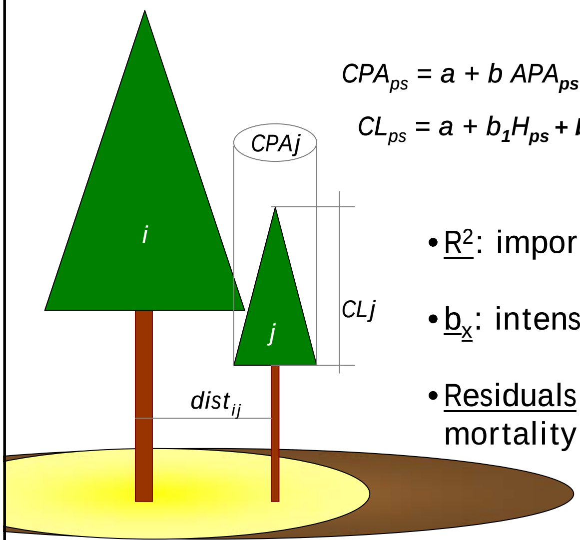
A2: Multiple regression model between measured crown length (CL), total tree height (H) and indices of competition for light and belowground resources.

$$CI_{light} = \pm \sum_{i=1}^{n} \frac{d_i}{d_j} \frac{1}{dist_{ij}}$$ (Tomé and Burkhart, 1989)

$$RCI_{root} = \frac{\sum_{i=1}^{n} BA_i}{\pi \times 20^2}$$ (Laroque et al., 2002)

Note: competition radius for light: 10 m (*buffer zone*);
competition radius for belowground resources: 20 m.

Materials and methods



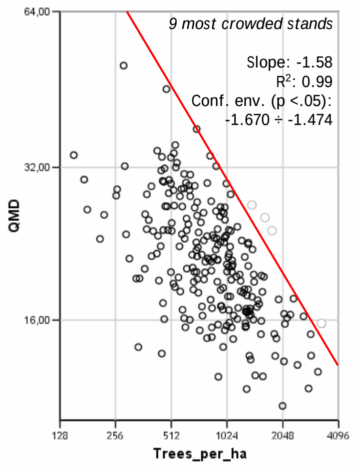
$CPA_{ps} = a + b\ APA_{ps}$

$CL_{ps} = a + b_1 H_{ps} + b_2 CI_{ps} + b_3 RCI_{ps}$

- R^2: importance of competition
- b_x: intensity of competition
- Residuals: Density-independent mortality (kriging interpolation).

Results

I. Competition dynamics at a regional scale



SDImax: 1373

ln(tpha) = 12.39 - 1.605 ln(Dm)

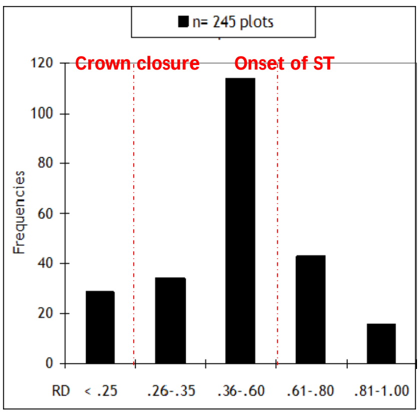
Some reference values:

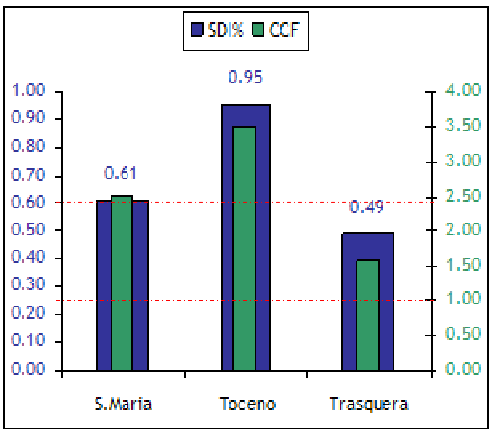
Hynynen et al. (1993)	840
Pretschz, Biber (2005)	972
Sterba (1981)	1229
Del Rio et al. (2001)	1444
Monserud et al. (2004)	1459
Palahi et al. (2002)	1581
Swiss Forest Inv. (2005)	1620

12% to 36% higher than Yield tables' levels.

Results

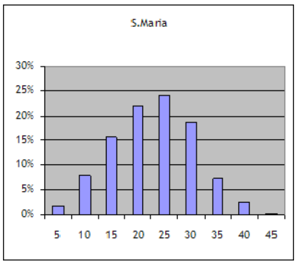
II. Relative stand density

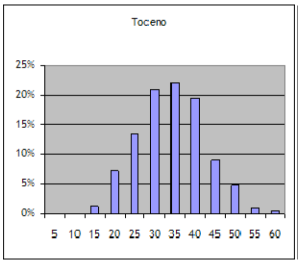


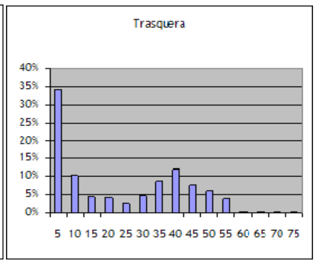


Results

III. DBH Distribution analysis (Scots pine only)







QMD	23.2	QMD	33.0	QMD	27.0
Range	43.0	Range	40.0	Range	73.0
Skewness	-0.12	Skewness	0.17	Skewness	0.39
Gini coeff.	**0.20**	Gini coeff.	**0.14**	Gini coeff.	**0.44**

Discussion

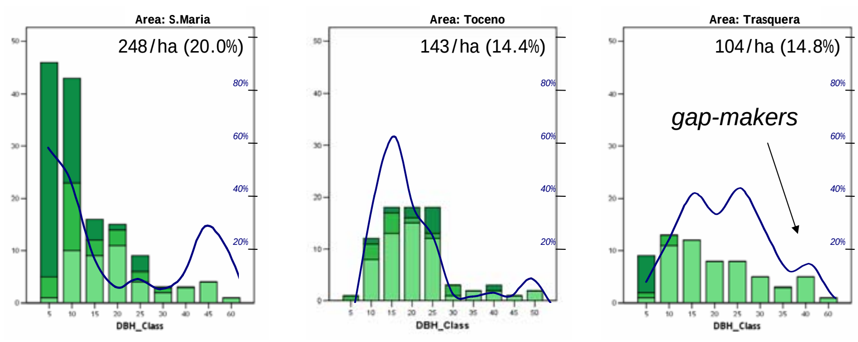
Size distributions:

1. Fast encroachment of homogeneous populations led to uniform distributions (cf. Fennoscandian Scots pine stands).
2. In even-aged populations, competition for light tends to increase size hierarchies until the onset of ST.
3. The onset of ST causes death of smaller plant and eventually leads to a more homogeneous stand.
4. No evidence of ST in two-storied plot.

Results

IV. Coarse Woody Debris

Stump
Log
Snag
% to actual DBH class



Clustered (0-30 m) | Random Point Pattern | Random Point Pattern

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Results

Upper bundary
Lower bundary
K(t)

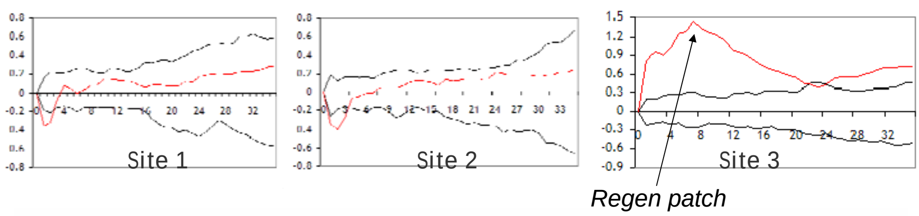
V. Spatial pattern

c: clumped
r: regular

+: attraction
- : repulsion

Univariate

Distanza (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
S. Maria - Pinus s.	r	r																					
Toceno - Pinus s.	r	r	r																				
Trasquera - Pinus s.	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c		



Bivariate

Distanza (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Picea vs. Pinus				+																	-	-	-
Larix vs. Pinus			-	-	-	-							-	-	-	-	-	-	-	-	-	-	-

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Discussion

Spatial patterns:

1. Initial distribution of seedling believed to be random (encroachment phase, external seed sources).
2. Random mortality due to ST leads to over-dispersed tree pattern: winners use the growing space in the most efficient way.
3. We expect the radius of *mortality-causing competition zone* to expand over time in the first developmental phases.

Results

VI. Crown Area and Crown Length prediction

	SDI %	R^2_{adj} CPA	β_{CPA}	R^2_{adj} CL	β_{asymm}	β_{symm}
Site 1	0.61	0.497	0.707	0.648	-0.394	-0.008
Site 2	0.95	0.451	0.674	0.401	-0.274	-0.082
Site 3	0.49	0.627	0.794	0.805	-0.141	-0.029
Overall	-	**0.519**		**0.657**		

All models: $p < 0.01$.

Discussion

Crown size:

- Symmetric (belowground) competition is not a main driving factor.

- Crown ratio in all sites is more sensitive to neighborhood competition than CPA (Rouvinen et al., 2002).

- Explained variance: 40-80%. Competition indices do not add much significance to models with just tree size (DBH or H) as an independent variable (1-8%).

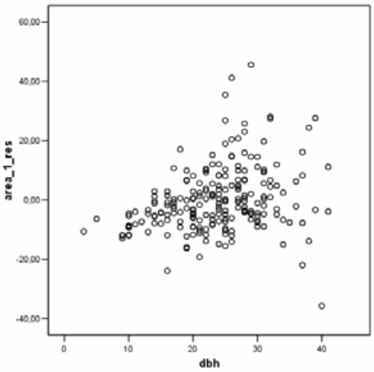
- *Unexpected result*: R^2 (importance of competition with respect to other driving dynamics) inverse-proportional to relative stand density.

    - Synergies between stress factors
    - CROWN SHYNESS (site-constant)

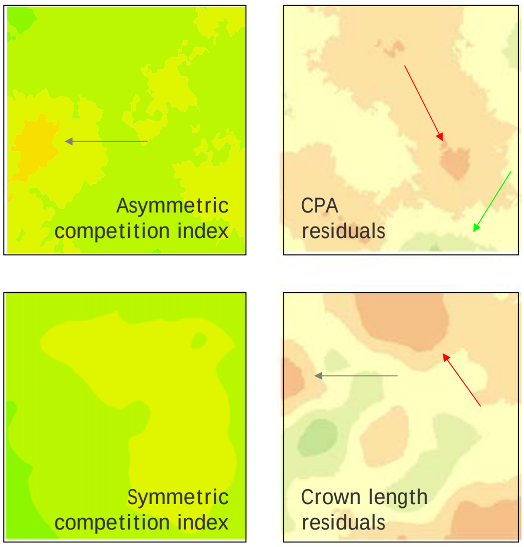
Results

VI. Crown Area and Crown Length prediction

	SDI %	Average CPA	Average Crown ratio
Site 1	0.61	22.47 m^2	0.47
Site 2	0.95	15.06 m^2	0.23
Site 3	0.49	29.57 m^2	0.55



Site 1 - S.Maria



What worked:

Potential identification of competition hot-spots and density-independent dieback distribution.

Quantitative measures for competition effect on crown shape and tree mortality.

What did not worked:

Statistical flaws in the model.

Difficult (if not impossible) to tell apart interacting factors.

Further steps

Improving model design:

- ✓ 3d crown representation, implementing of a light interception model
- ✓ Dendrochronological sampling

Validating model predictions:

- ✓ PSP in core dieback areas.
- ✓ Direct assessment of pathogens' impact on individual trees (crown transparency, insulates from wood tissue).

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Thank you for your attention.

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