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Density Management Diagrams:

A tool for assessing current and future functionality of protection forests.

Natural Hazards and Natural Disturbances in Mountain Forests
September 18-21, 2007, Trento, Italy

Introduction

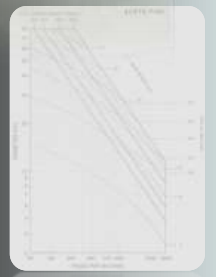
Pinus sylvestris *L. in Europe:*

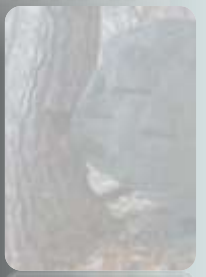
28.000.000 ha

Sub-boreal species

High plasticity (local ecotypes)

Multifunctional forests





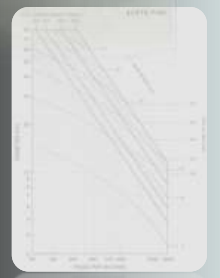
Introduction

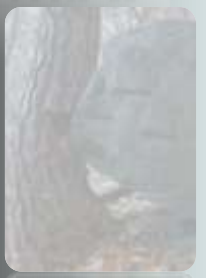
30% of Pine forests in Piemonte and Valle d'Aosta play a protective function (4,000 hectares of **direct protection forests**).

Source area
- Prevent triggering

Transition zone
- Reduce kinetic energy

Accumulation area
- Shorten distance traveled





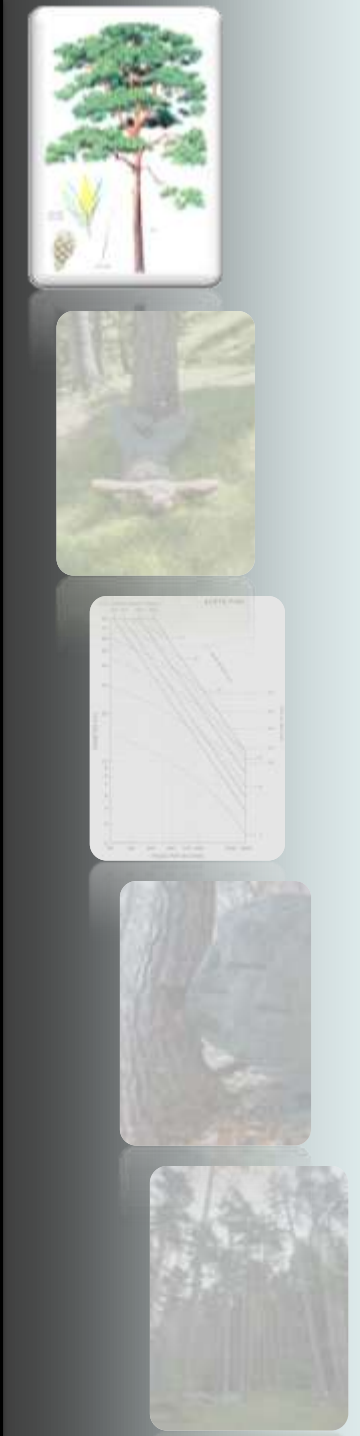
DMD: A tool to assess the functionality of protection forests

Introduction

Density Management Diagram (DMD):

- Graphical model of stand development
- Based on self-thinning & allometry

- Support tool for management decisions
- Natural forest + plantations (seldom in EU)



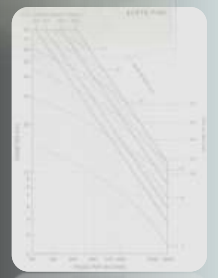
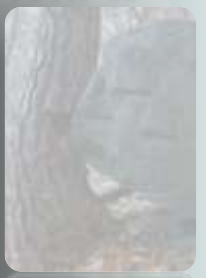
Research aim

How to build a DMD & manage S.Pine for rockfall protection

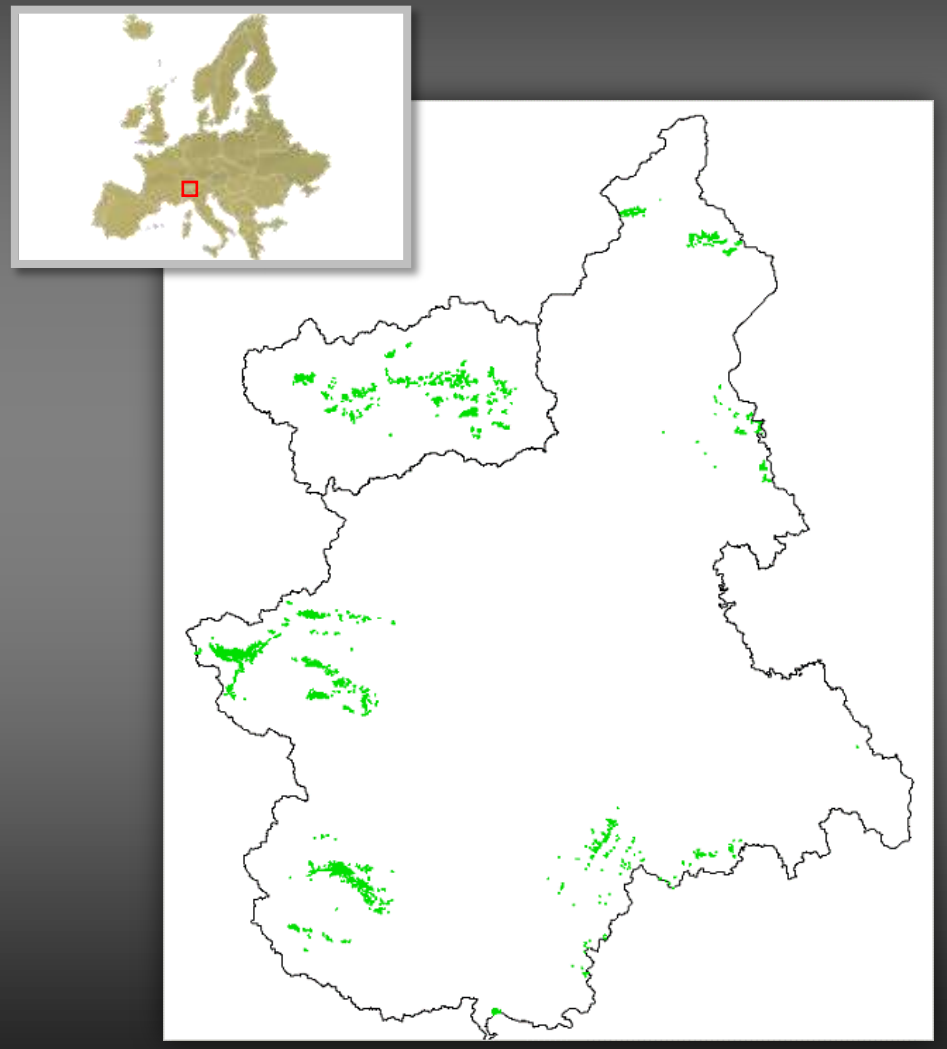
i. Species' self-thinning line
ii. Other allometric equations
iii. Optimum stand structure
iv. Suitability zone on DMD

v. Case study




Study Area



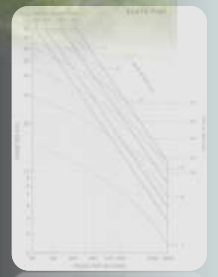
Source: IPLA 2003, 2004

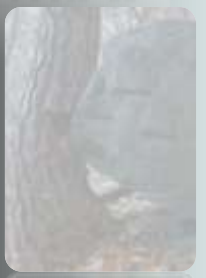
Regional Forest Inventory

Base grid size: 500m

***P.sylvestris*: 457 sample plots (radius 8-15 m)**

UTM location
Elevation, slope, aspect
Forest cover type
Development stage
Canopy cover
CWD
Seedling count
Health status
Management aim
Mgmt. priority





DMD: A tool to assess the functionality of protection forests

Methods

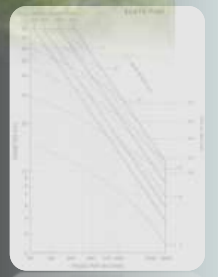
Self-thinning rule (Yoda et al. 1963)

(for pure, even-aged stands):

Density-dependent mortality onsets as trees grow bigger.

Site's carrying capacity and disturbance regime determine size-density relationship.

Species-specific maximum represents reference for strongest competition

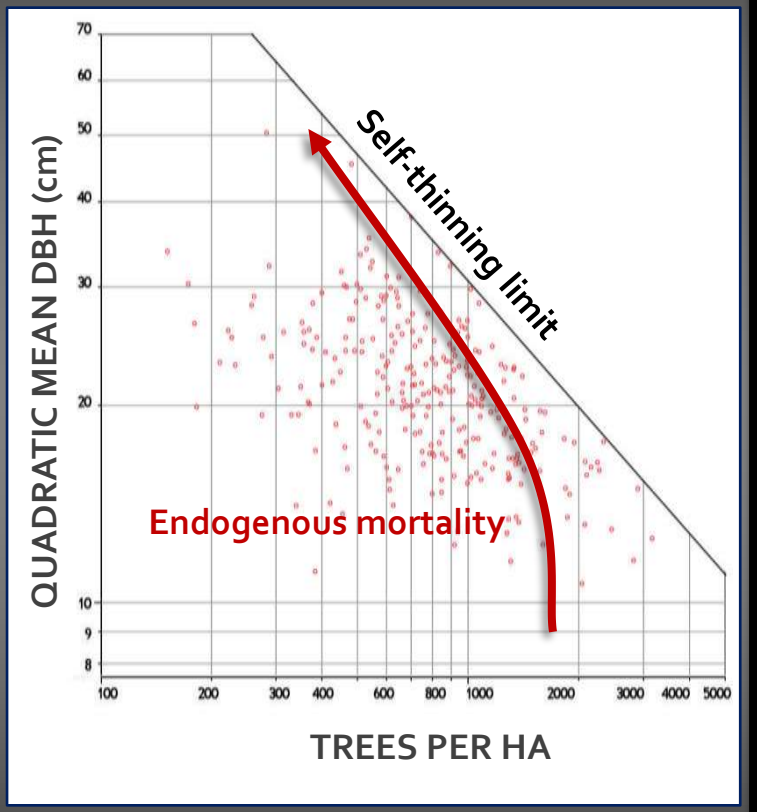


DMD: A tool to assess the functionality of protection forests

Methods

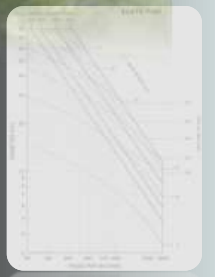
Self-thinning limit for:

- Pure stands (BA_{pine} >70%)
- Even-aged stands
- Undisturbed (< 10% stumps)



Fixed slope (Reineke 1933)
Intercept on 98th p-ile of Stand Density Index distribution

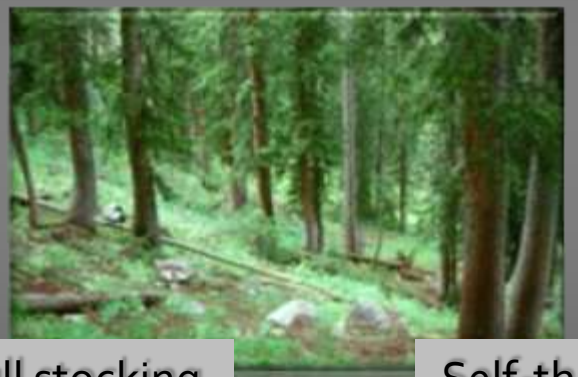




Methods

Relative density (SDI stand / SDI max) assesses intensity of competition in each stand.

Crown closure



Full stocking

Self-thinning

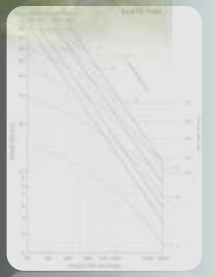
Maximum

25%

35%

60%

98%



DMD: A tool to assess the functionality of protection forests

Methods

Dominant height

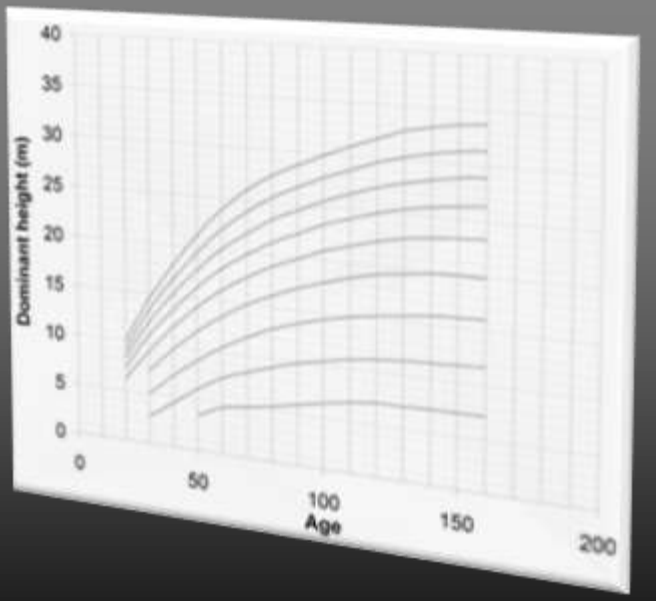
As a function of density and mean tree size

Stand volume

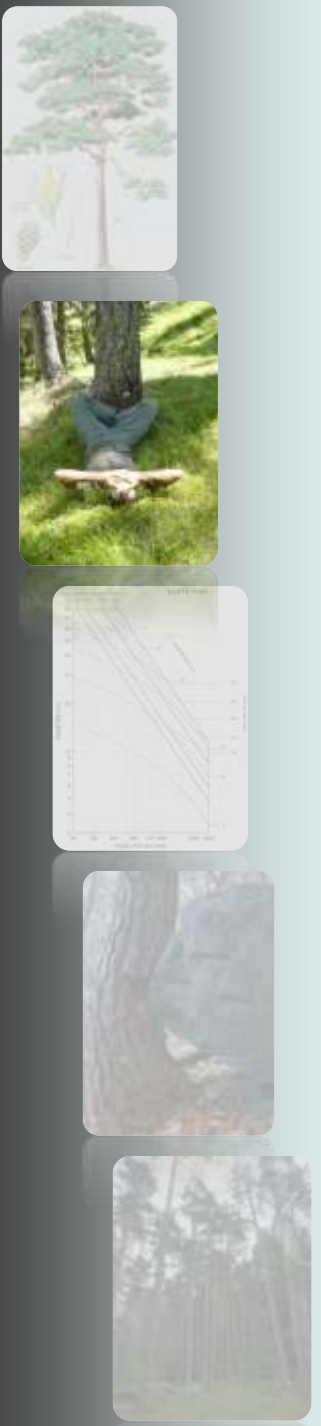
Yield-density effect

Site index

Time required to reach given stand structure



Source: Wiedemann 1949

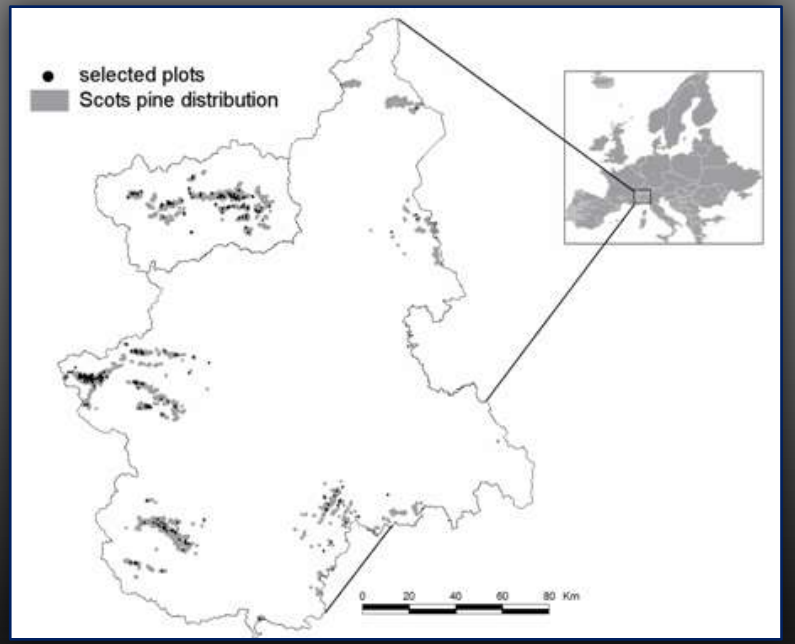


DMD: A tool to assess the functionality of protection forests

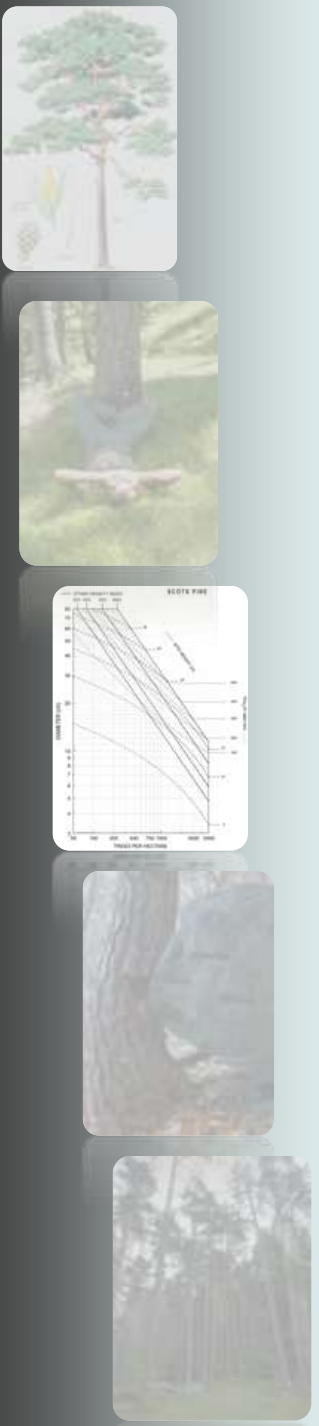
Results: plotting the DMD

	Mean	Min	Max	St.Dev.
QMD [cm]	21.4	10.7	50.4	5.8
Trees ha^{-1}	932	152	3318	525
Basal area [m^2 ha^{-1}]	30.52	3.77	84.22	14.70
% Scots pine on BA	92.5%	70%	100%	8.3%
Top height [m]	13.5	5	31	3.9
Volume [m^3 ha^{-1}]*	202.47	13.18	743.43	140.89

**Volume equations were available only for 118 plots.*

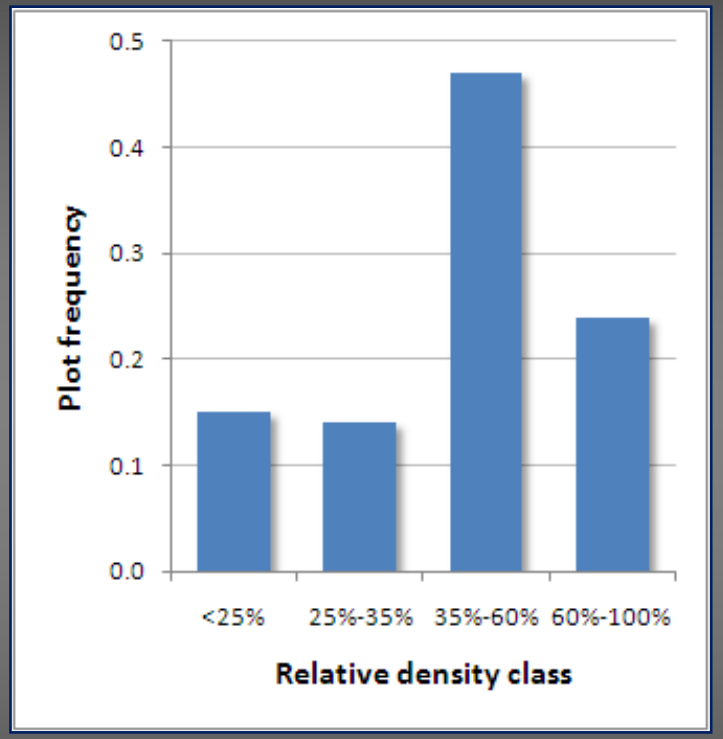


Selected plots (n =210) covered most of Scots pine distribution

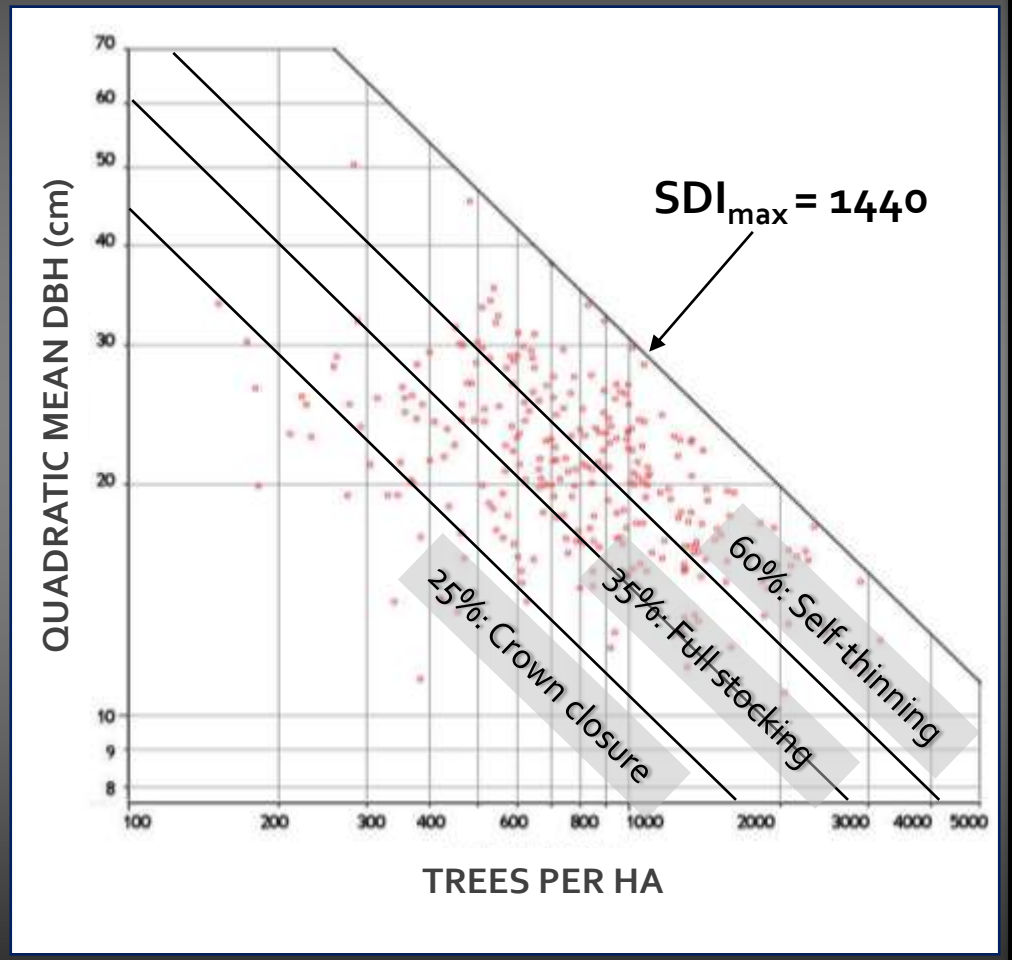


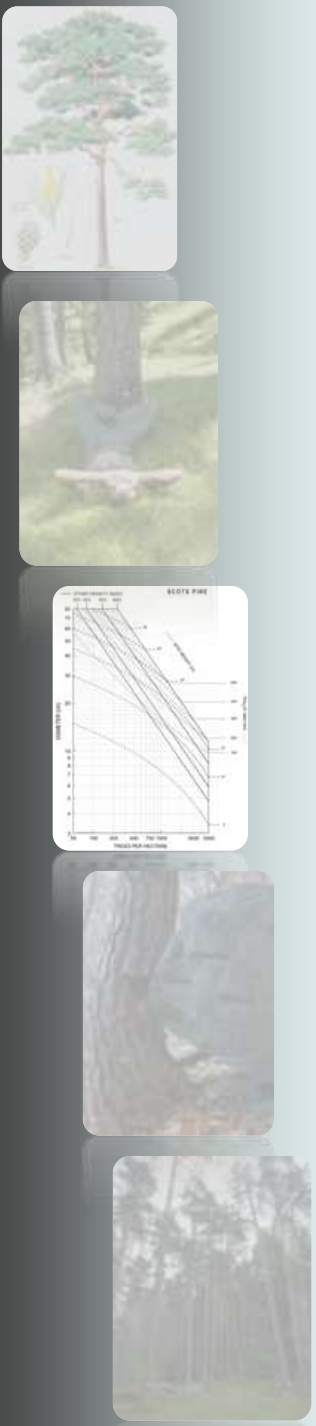
DMD: A tool to assess the functionality of protection forests

Results: plotting the DMD



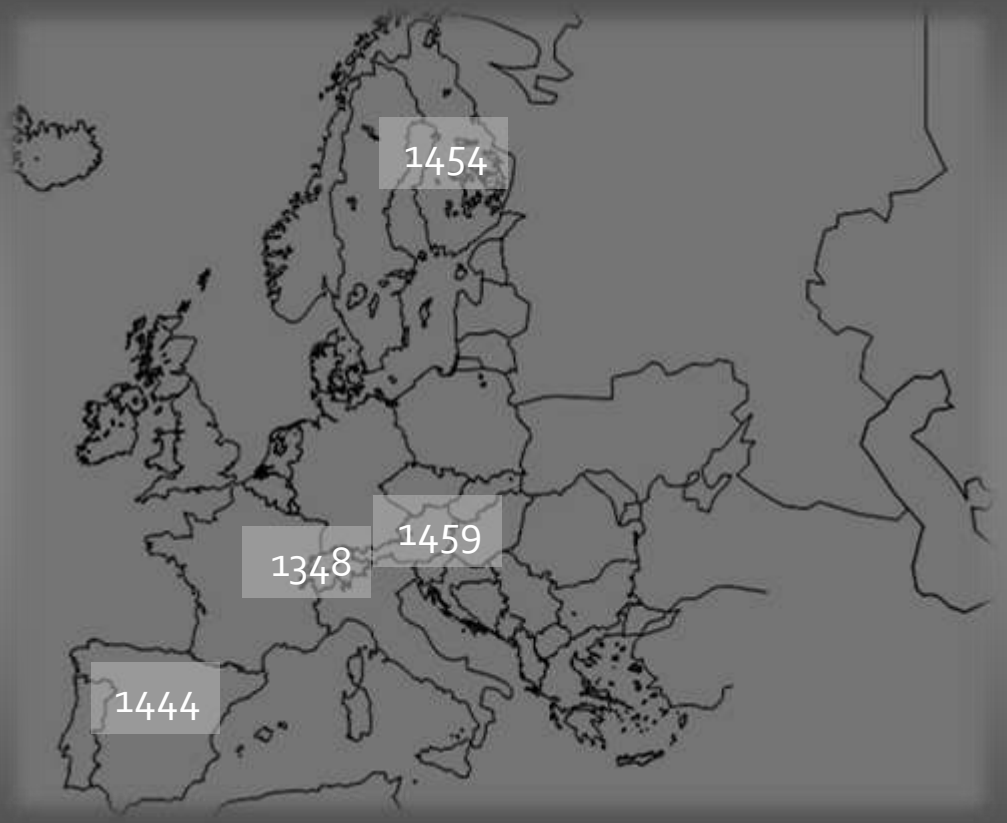
19% of Pine stands in active self-thinning stage





DMD: A tool to assess the functionality of protection forests

Results: plotting the DMD

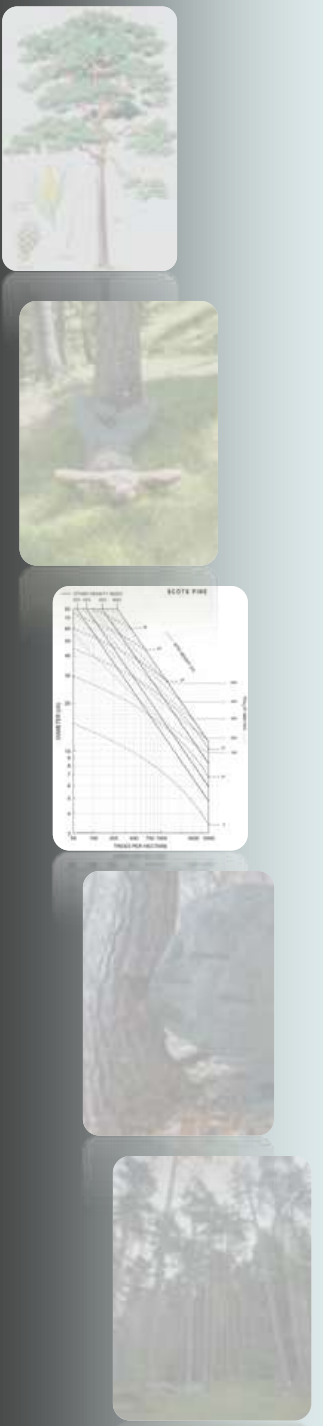


Sources: Del Rio et al. 2001 (E); Palahí et al. 2002 (SF); Monserud et al. 2004 (A); WSL 2005 (CH)

SDI_{max} consistent with independent estimates…

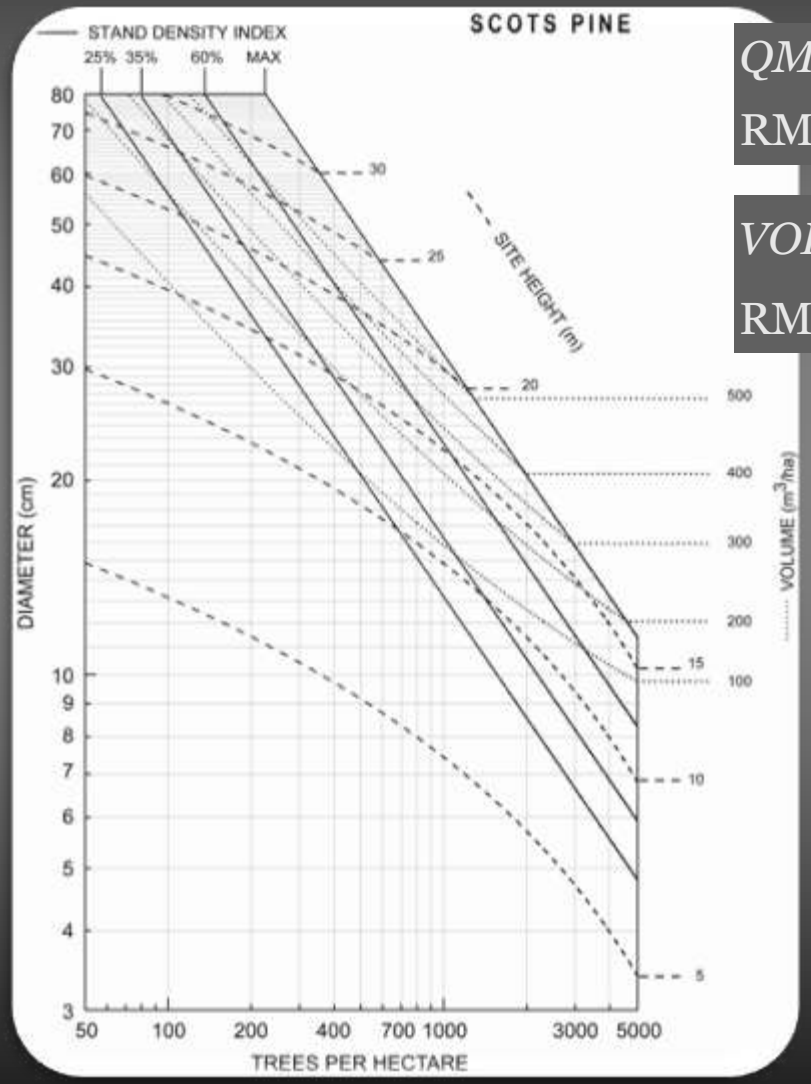
… but 12% to 74% higher than SDI from European yield tables.

Mean SDI of each cover type show significant differences.



DMD: A tool to assess the functionality of protection forests

Results: plotting the DMD



$$QMD = H_{100}\ \ 4.927 - 0.498 \ln N$$

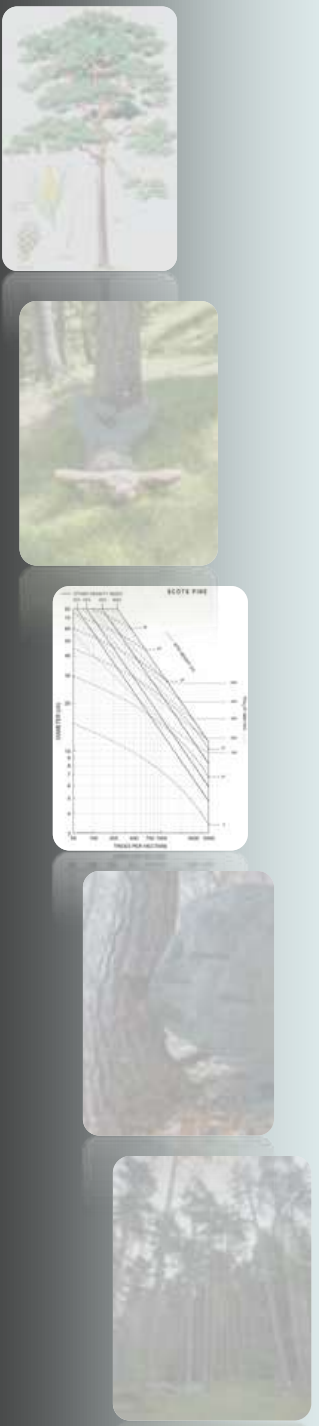
RMSE=0.75 m

$$VOL = 0.002N\ \ QMD - 5.713^{\ 1.808}$$

RMSE=263.27 m^3 ha^{-1}

User can plot each stand using any pair of structural parameters

(density, QMD, relative density, top height, volume).



DMD: A tool to assess the functionality of protection forests

Managing for rockfall protection

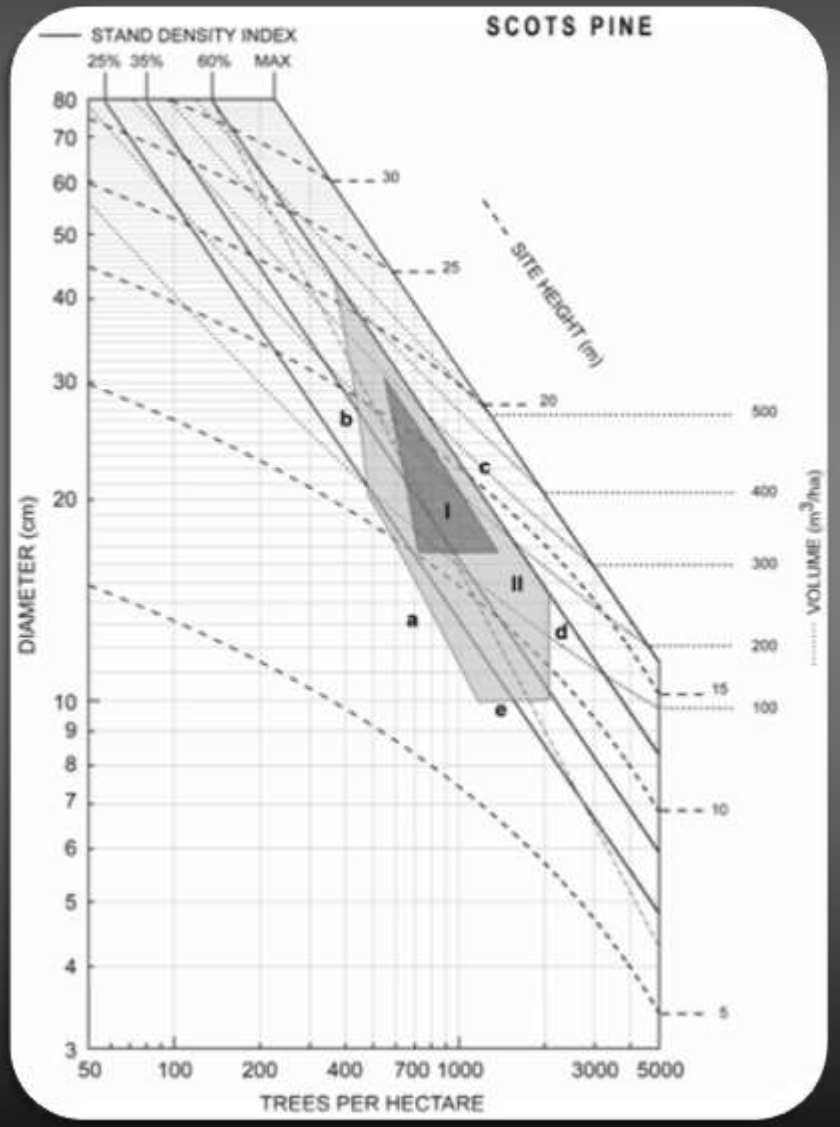
Management priority:

attain and sustain stand structures allowing acceptable reduction of the rockfall hazard.

Management aim → **Structure variables** → **ZONE OF ACTIVE MGMT.**

DMD: A tool to assess the functionality of protection forests

Managing rockfall protection



a. Canopy cover > 60%

Computed from dbh–crown width curves

b. Mean tree free distance < 30 m

As a function of density and boulders Ø

c. Live crown ratio >0.3

A relative SDI of 0.50 should ensure a mean live crown ratio higher than 40%

d. H/D ratio < 80 in dominant trees

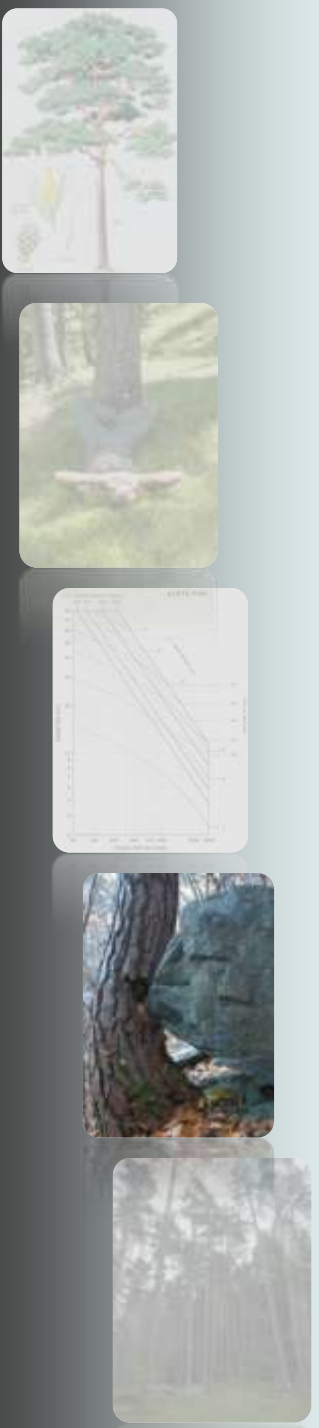
Computed from local dbh–height curves

e. QMD > ⅓ x boulders Ø

SDI: 600 to 1000, to avoid both excessive openness and stability threats (fulfilled)

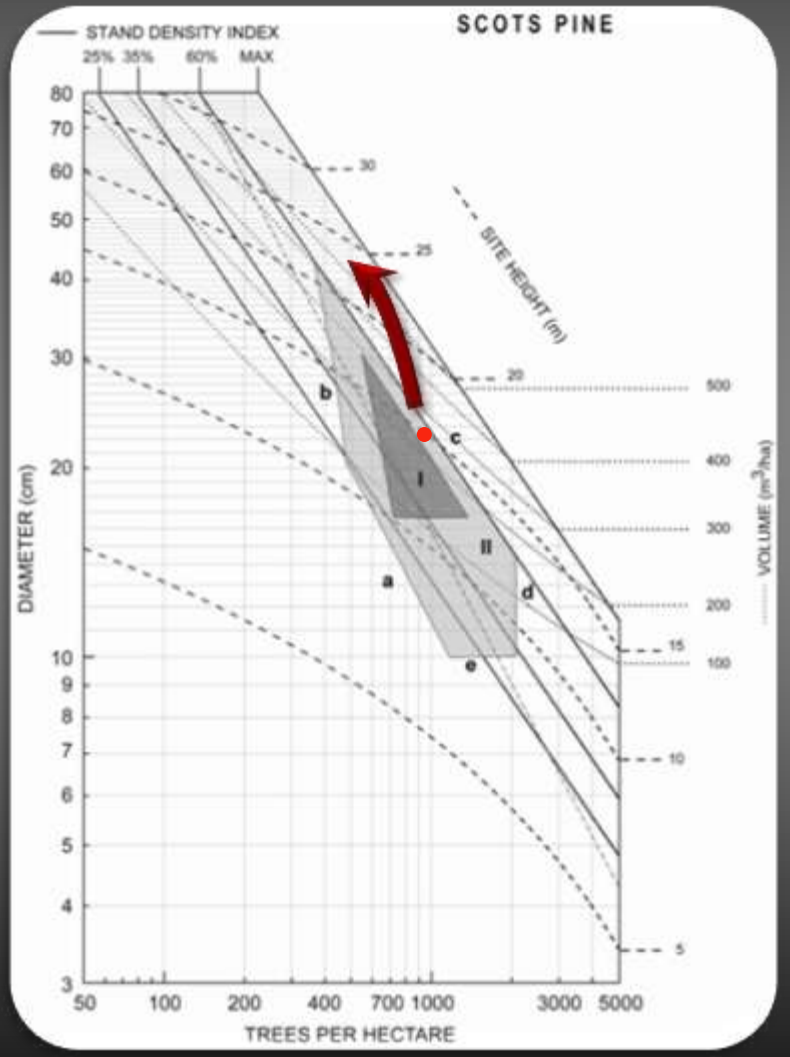
I: core area (maximum protection)

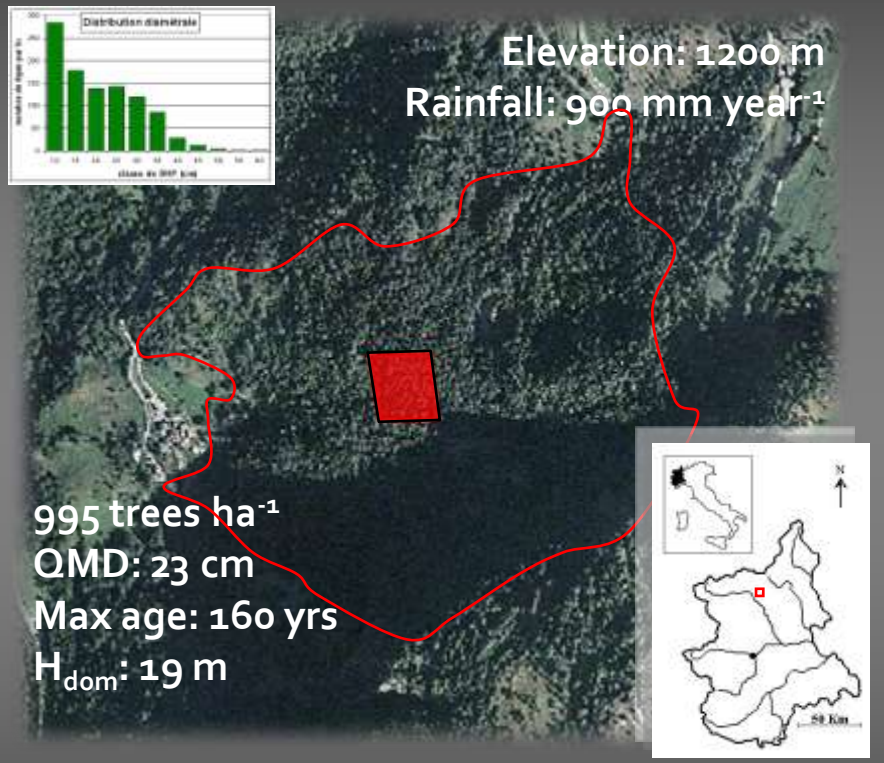
II: minimum acceptable protection



DMD: A tool to assess the functionality of protection forests

Managing for rockfall protection





Case study:

Bois de Liex (AO)



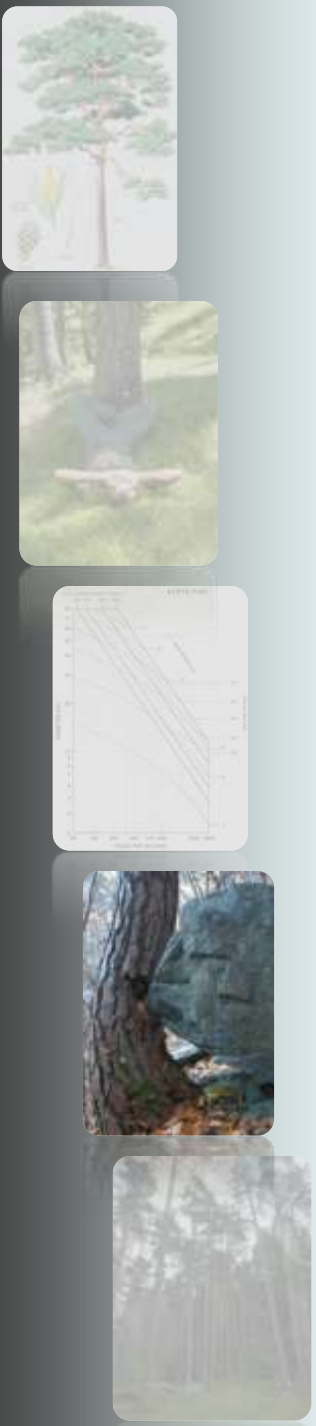


DMD: A tool to assess the functionality of protection forests

Managing for rockfall protection

The stand is near the outer edge of the zone of minimum protection, and is moving to a zone of INTENSE COMPETITION (relative SDI= 0.62).

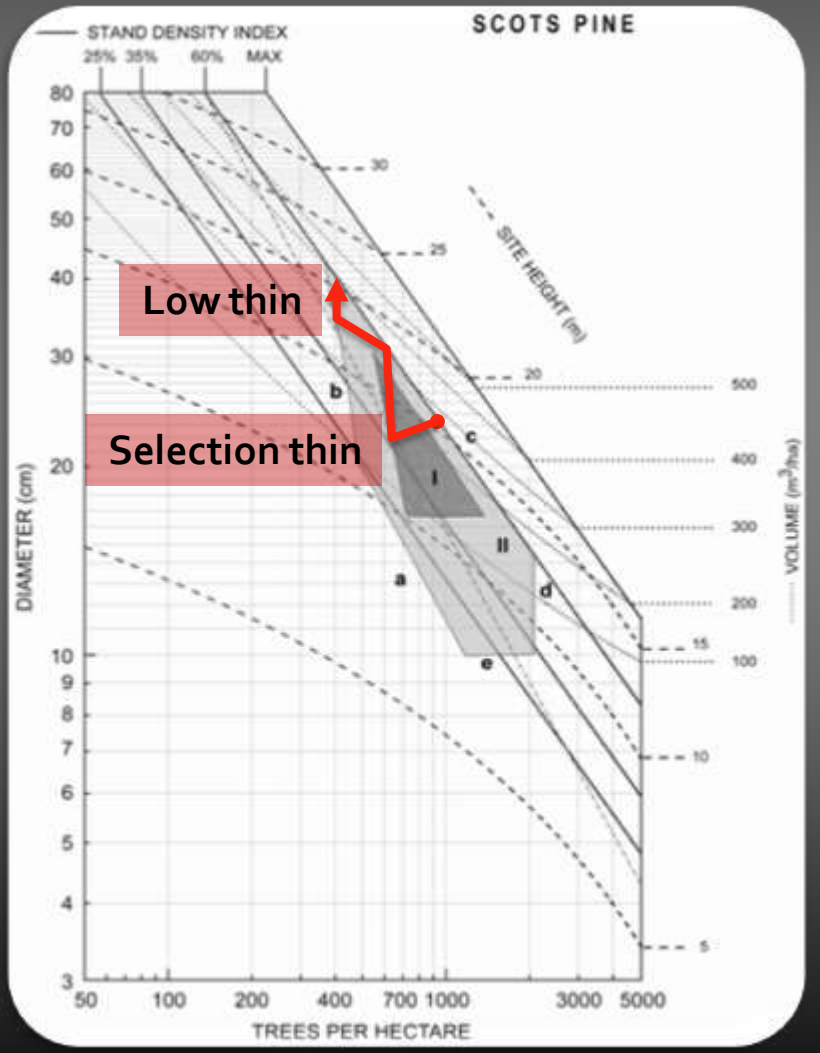
Management			No management
Single entry low thinning	*Double entry low thinning*	*Strong selection thinning*	



DMD: A tool to assess the functionality of protection forests

Managing for rockfall protection

DMD-based silvicultural entries optimize time in *zone of max protection*.

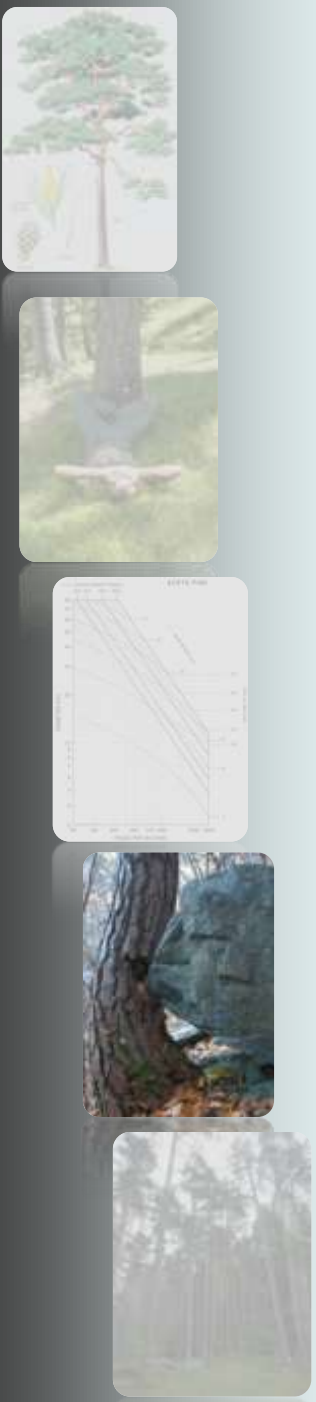


DMD: A tool to assess the functionality of protection forests

Managing for rockfall protection

	Age[a]	H_{100} (m)	N (TPHa)	QMD (cm)	VOL[b] (m^3 ha^{-1})
Starting conditions	80	**16**	**995**	**22.7**	**330**
i) Natural development[c]	150	20	796	32	587
Time in optimal + minimal zone	*0+0 years*				
ii) After low thinning	80	16	895	23	310
Time in optimal + minimal zone	*0+5 years*				
iii) After selective thinning	80	13	641	22	199
Time in optimal + minimal zone	*13+20 years*				
iv) Before low thinning 2	95	17	600[d]	30	384
After low thinning 2	95	17	400	33	316
Time in optimal + minimal zone	*10+35 years*				

[a] Estimated mean stand age (different than the maximum age measured in the field). Time lapses are computed by using SI 18.
[b] Volume estimated by DMD isolines (starting volume differs from true value).
[c] Estimated trajectory of natural mortality driven by self-thinning, up to a dominant height of 20m.
[d] Density is allowed a slight reduction from the predicted value even during competition-free stand development, due to the purported influence of rockfall disturbance.

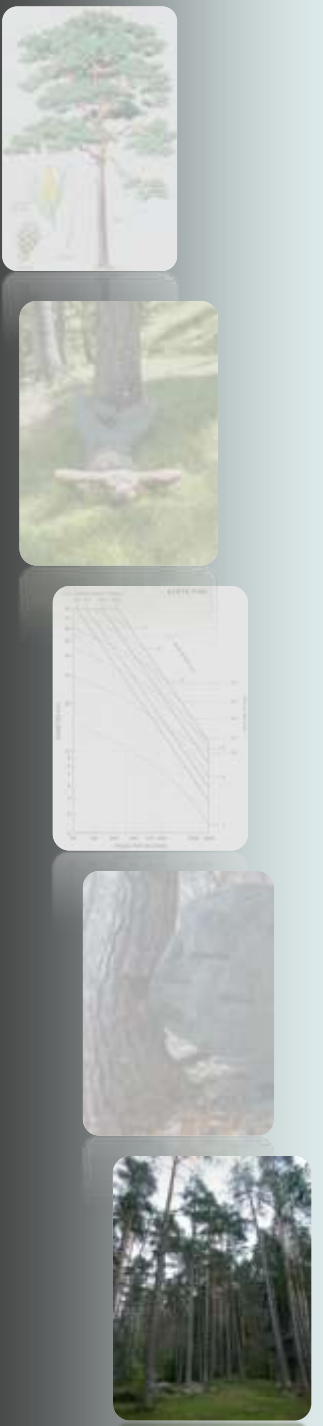


DMD: A tool to assess the functionality of protection forests

Discussion

- A moderate low thinning (constant dominant height) removing 10% VOL would extend functionality in time, albeit a little.
- A selective thinning would further prolong stand suitability for optimal and minimum rockfall protection. The proposed action involves removing 40% VOL, obtaining commercial material.
- An additional low thinning at the limits of the suitability zone, would maintain constant crown closure throughout the rotation, preserving slender trees from sudden isolation (provided 95yrs old pines are responsive).

In the minimum protection zone it might be necessary to set up **temporary support measures** such as wooden fences or lying logs.



Discussion

What a DMD <u>does</u> do:

- On-the-fly assessment of a stand's developmental stage (even in the field)
- Ready representation of management goals (e.g. timber, habitat suitability, understory…)
- Compares silvicultural alternatives both for large-scale forest planning and for single stands.

DMD: A tool to assess the functionality of protection forests

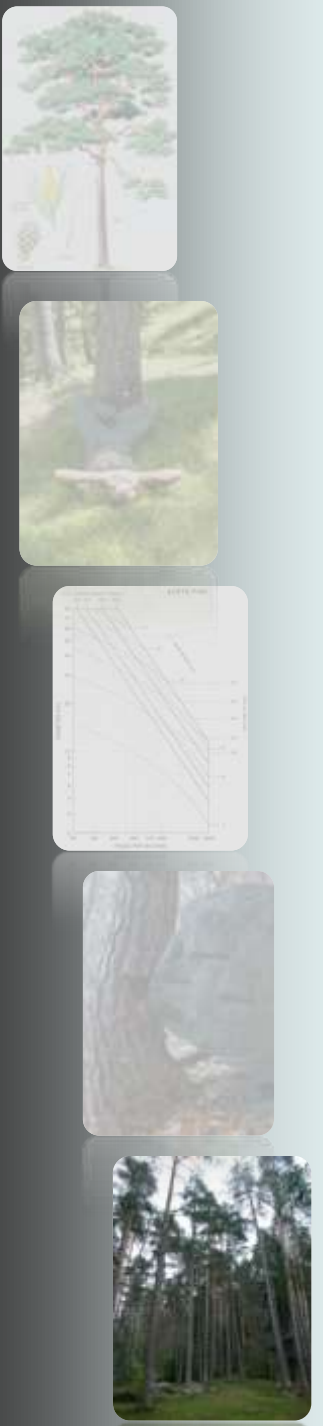
Discussion

What a DMD does <u>not</u> do:

- True representation of each stand
  (e.g., Local site indices and allometry)
  Accuracy vs. **Generality**

- Model stand dynamics beyond one generation
  (i.e., resilience by means of regeneration)

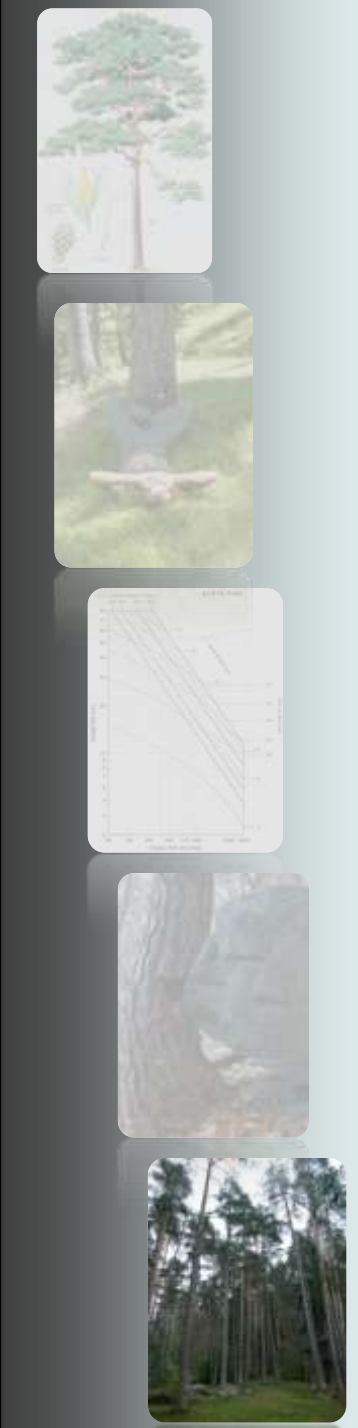
- Incorporate management effects on allometry



Discussion

What a DMD can do:

- Model dynamics of mixed stands/plantations
- Incorporate effects of changes in environmental conditions (shifting self-thinning or allometric relationships)
- Model stand susceptibility and consequences of natural or anthropic disturbances (eg, beetles, fire, windstorm…)



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Thank you for your attention.

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Natural Hazards and
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Challenges and Opportunities for Silviculture
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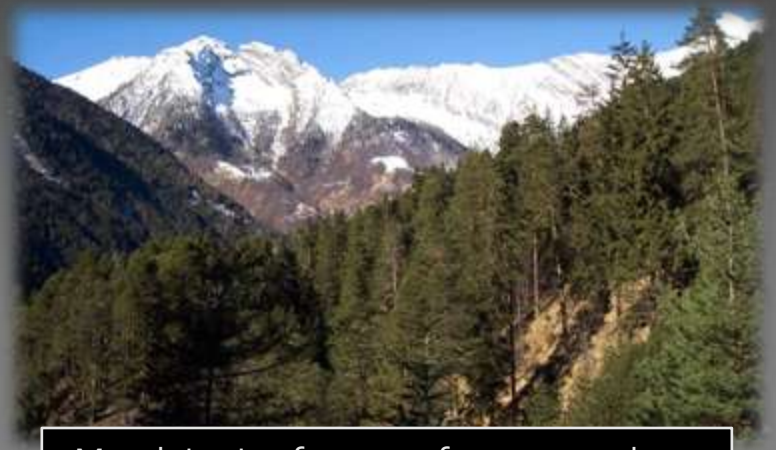
Study Area



Mesalpic pine forest on former meadows

Continental pine forest on rocky outcrops

Continental dry pine forest

Remnant pine stands on *Langhe* ridges

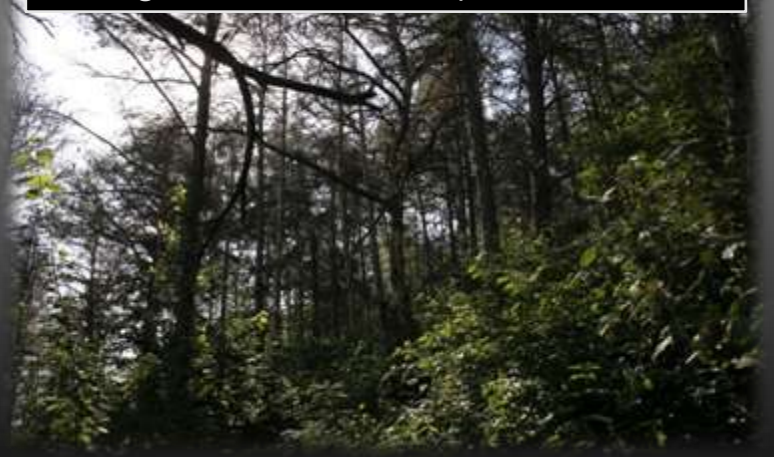
DMD: A tool to assess the functionality of protection forests

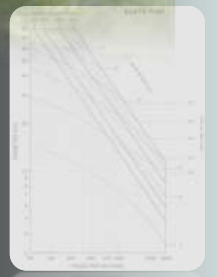
Study Area

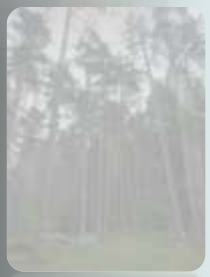
Self-thinning mortality

Traditional resin tapping

Drought-induced mortality and succession

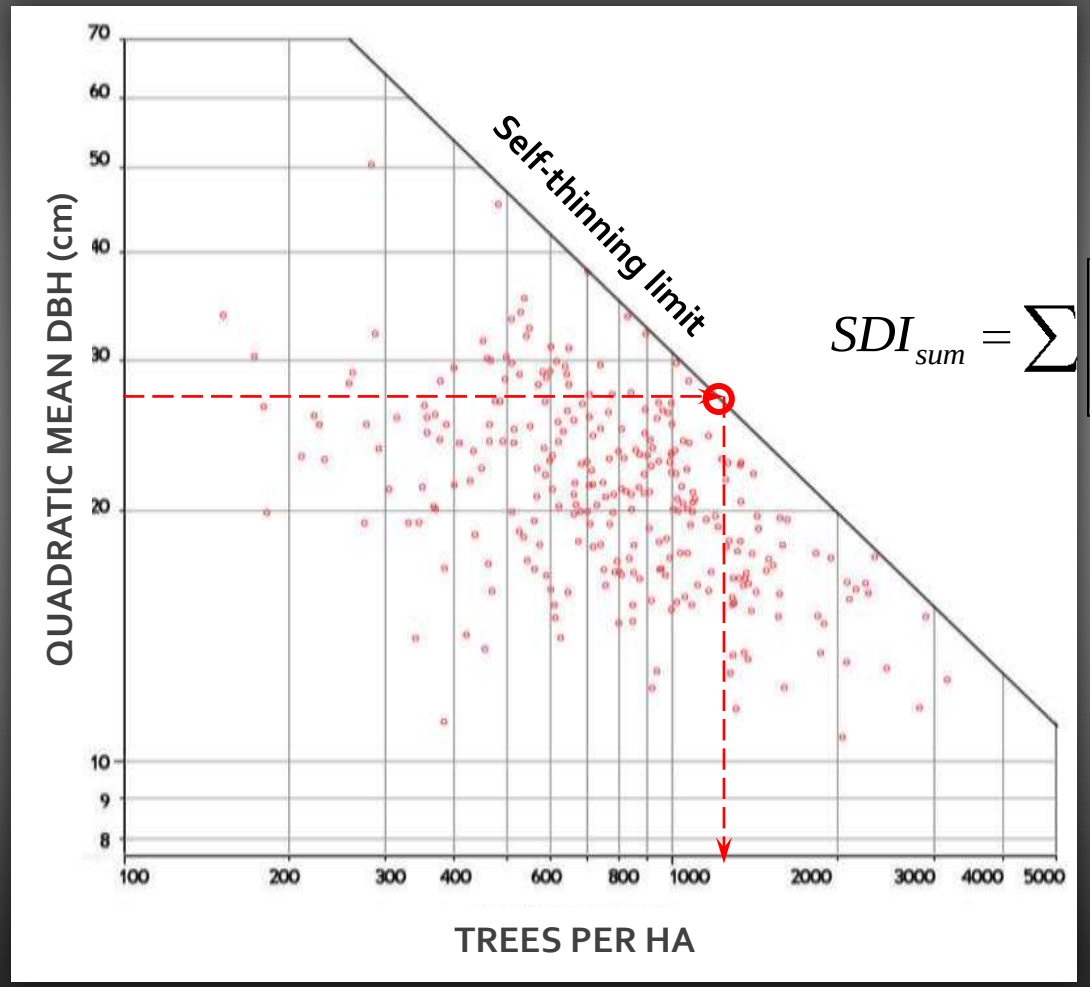






DMD: A tool to assess the functionality of protection forests

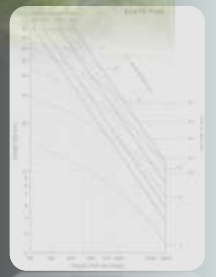
Methods



$$SDI_{sum} = \sum \left[N_i \cdot \left(\frac{D_i}{25} \right)^{1.6} \right]$$

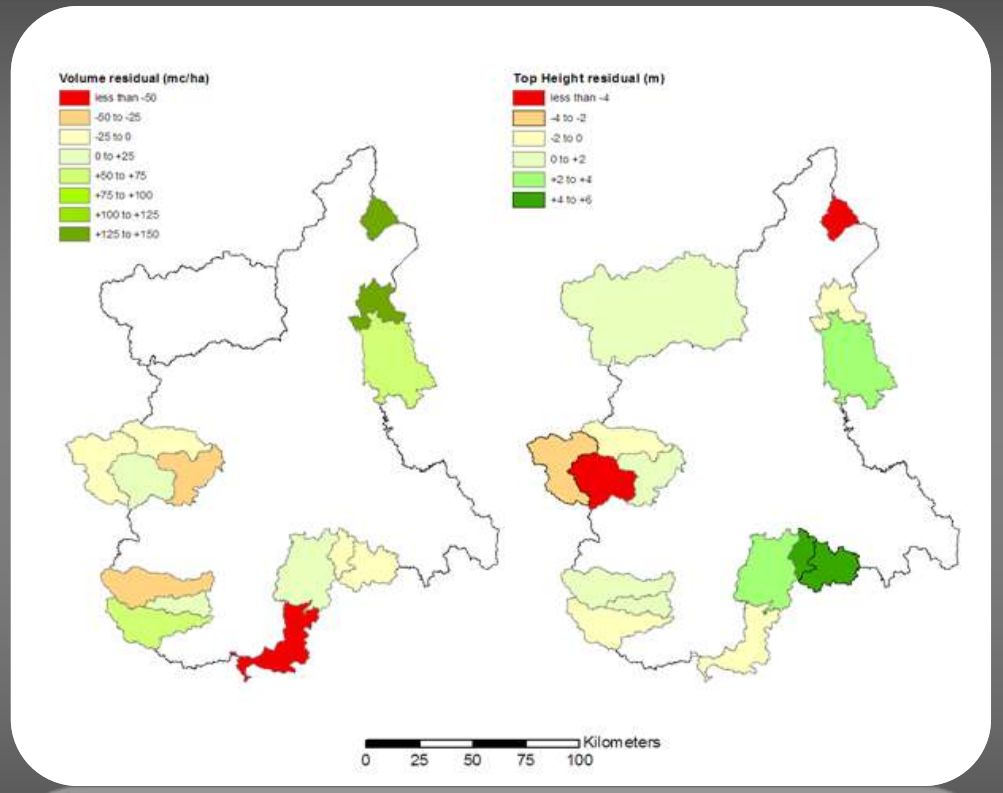
SDI represents the density of 25-cm stems needed to express the observed crowding.





DMD: A tool to assess the functionality of protection forests

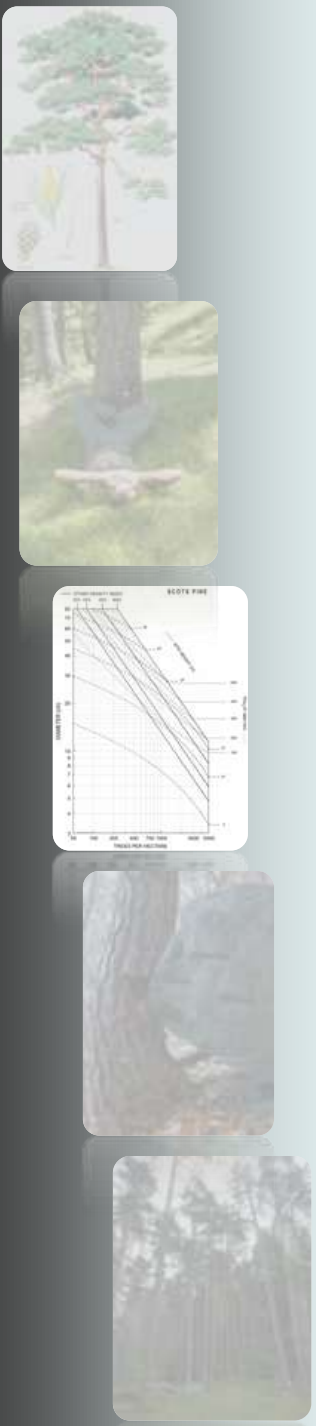
Results: plotting the DMD



Volume and top height residuals showed local differences.

Height bias varied according to fertility and management practices.

Volume bias likely relates to inaccuracies in volume equations provided for single trees.



DMD: A tool to assess the functionality of protection forests