International conference
Regenerating Mountain Forests

Prerequisite for Sustainable Management

Relationship between overstory and natural regeneration dynamics in mixed mountain forests in the Italian Alps.

A comparison of different competition indices.

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Introduction

Growth of individual trees on a particular site is influenced by a number of factors (*Tomé and Burkhart, 1989*):

1. **Micro-environmental and genetic influences**
   --> Tree size
2. **General environment of competition**
   --> Stand-level density measures
3. **Influence of local neighbours**

Introduction

Clements et al., 1929:

"Competition arises from the reaction of one plant upon the physical factors about it and the effect of these modified factors upon its competitors. When the immediate supply of a single necessary factor falls below the combined demands of the plant, competition begins."

Lambers et al., 1998:

"Interaction among organisms which utilize common resources that are in short supply, or which harm one another in the process of seeking a resource."

Introduction

Our hypothesis*:*
Overstory competition can play a decisive role in the process of sapling development and influence the future success of the ***established regeneration****.*

Practical models for objectively assessing the degree of inter- and intraspecific competition affecting mixed, multilayered stands in the Alps are still underdeveloped.

Introduction

Competition indices (CIs) are commonly used as predictor variables in tree and stand modeling.

1. *Distance dependent*
2. *Distance independent*
3. *Process-based*

STATE OF THE ART: no CI seem to be universally superior.

Aim of the research

- *To assess the effect of overstory competition on the establishment and future development of natural regeneration in mixed and multilayered mountain forest stands.*
- *To evaluate each species' competitive ability in dominant and regeneration layers under different stand structures and ecosites.*

MORE RESEARCH QUESTIONS:

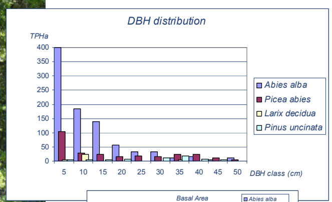
Does spatial information improve the precision of competition estimates?
Which is the main mechanism responsible for competition in heterogeneous stands (one-sided vs. two-sided)?

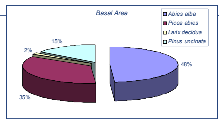
Study areas

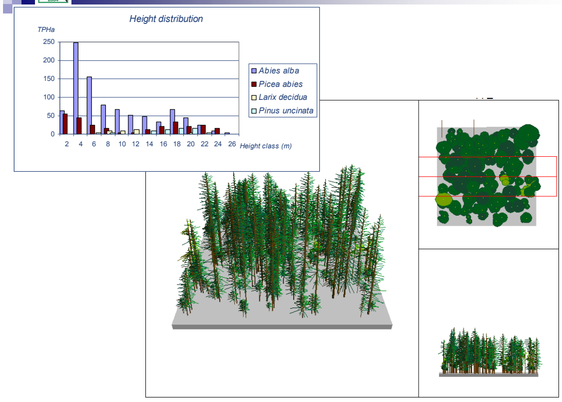
Teppas Forest

- 45°04.62 N, 6°67.60 E
- Elevation: 1720 m
- Aspect: N
- Mixed multilayered forest of the upper mountain belt.
- Silver fir (*Abies alba* Mill.)
  Noway spuce (*Picea abies* (L.) Karst.)
  Swiss mountain pine (*Pinus uncinata* L.)
  European larch (*Larix decidua* Mill.)

	TPHa	QMD (cm)	Average height (m)
Abies alba	788	15.96	12.94
Picea abies	244	24.22	23.48
Larix decidua	32	14.95	12.15
Pinus uncinata	64	30.88	18.14







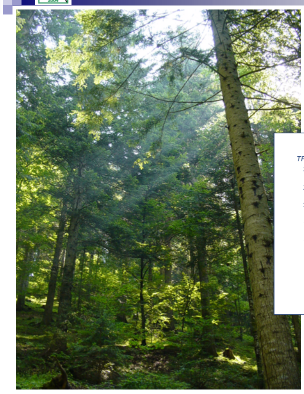
Study areas

Val Noana

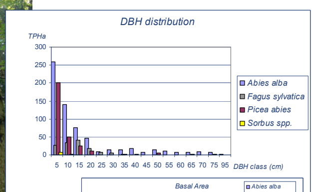
- 46°08.03 N, 11°50.32 E
- Elevation: 1093 m
- Aspect: N

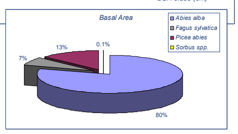
- Mixed multilayered forest of the lower mountain belt.

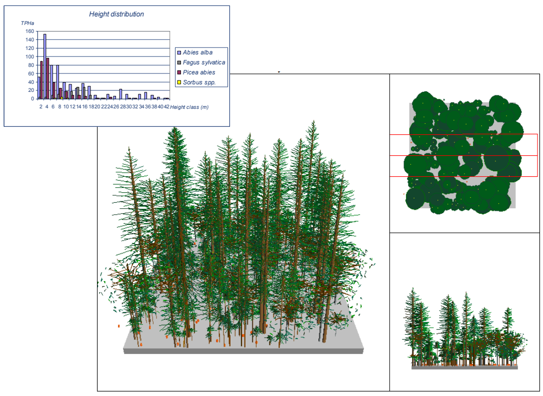
- Silver fir (*Abies alba* Mill.)
  Norway spuce (*Picea abies* (L.) Karst.)
  Beech (*Fagus sylvatica* L.)
  Rowan (*Sorbus spp.*)

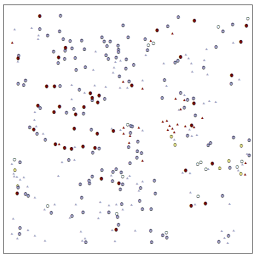


	TPHa	QMD (cm)	Average height (m)
Abies alba	1120	23.76	18.36
Fagus sylvatica	236	15.30	13.57
Picea abies	544	13.83	11.57
Sorbus spp.	16	6.54	7.43





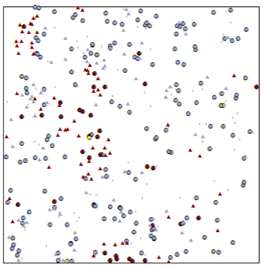




Teppas

Saplings *Abies alba:* 101 (404/ha)
Saplings *Picea abies:* 27 (108/ha)

Established saplings
(DBH >4 cm, Height <5 m)



Val Noana

Saplings *Abies alba:* 72 (288/ha)
Saplings *Picea abies:* 68 (272/ha)
Saplings *Fagus sylvatica:* 2 (8/ha)

Methods

- At each site we set up a Permanent Sample Plot (50x50 m). Inside each plot, standing individuals with a DBH > 4 cm have been identified, labelled and mapped.
- DBH, total height, crown ratio and crown depth in four directions have been measured for each tree. Topographic effect was not taken into account.
- Plot coordinates have been determined by means of a Global Positioning System (G.P.S.) and all data have been filed in a GIS.

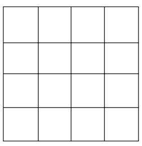
Methods

1. REGENERATION FREQUENCIES

To examine the influence of the overstory on regeneration establishment, we tested several stand-level CIs for their relationship with overall and specific sapling densities.

Each plot was divided into 16 quadrats (12.5x12.5 m). Within each site CIs were calculated separately for each species of competitors; these species indices were then used in a multiple regression model to predict sapling frequencies in each quadrat:

$$N_{x,site} = a + b_1 CI_x + b_2 CI_y + b_3 CI_z + .. b_n CI_n$$



Distance-independent CIs

(stand level)

- They do not utilize spatial information (tree coordinates) explicitly in their formulation; they are simple functions of stand level variables and/or dimensions of the subject trees. Easily calculated and less data-demanding.

Basal Area and BA-related functions
Stem density and canopy closure indices
Sum of individual tree characteristics (DBH, Height)
QMD, Reineke's SDI, Krajicek's CCF[1]

[1]*CCF calculated from Hasenauer's (1997) allometric equations for open-grown trees.*

Methods

2. SAPLING DEVELOPMENT

Since we did not take increment cores, individual crown characteristics were used as indicators for sapling potential growth.

Crown Ratio (CR), Crown Cross-sectional Area at crown base height **(CC)** and **Crown Surface Area (CSA)**[2] were considered as independent variables in multivariate regression models against either non-spatial or spatial individual competition indices.

$$Crown\_variable_{i,site} = a + b_1 CI_x + b_2 CI_y + b_3 CI_z + \ldots b_n CI_n$$

[2] CSA derived from CC and CR assuming a model solid shape, i.e. conic for conifers and parabolic for broadleaved.

Distance-independent CIs

(individual based)

Daniels (1976)

$$Da = \frac{D_j^2}{\sum_{i=1}^{n} \frac{D_j}{n}}$$

Glover and Hool (1979)

$$GH = \frac{D_j^2}{QMD^2}$$

Lorimer (1983)

$$L = \sum_{i=1}^{n} \frac{D_i}{D_j}$$

Simard and Sachs (2004)

$$NRI = \sum_{i=1}^{n} \left(\frac{BA_i H_i}{H_j} \right)$$

Distance-dependent CIs

- Usually based on the number (n), size (D) and distance (L) of individual competitors *i* within a fixed distance from the subject tree *j*.

Area overlap indices
Area potentially available (growing space indices)
Distance-weighted size ratio indices

EDGE CORRECTION METHOD:
buffer zone (only in Val Noana sample plot)

Distance-dependent CIs

(individual based)

Hegyi (1974)

$$H = \sum_{i=1}^{n} \frac{D_i}{D_j (L_{ij} + 1)}$$

Martin and Ek (1984)

$$ME = \sum_{i=1}^{n} \frac{D_i}{D_j} e^{\frac{-16 L_{ij}}{D_i + D_j}}$$

Alemdag (1978)

$$A = \sum_{i=1}^{n} \pi \left(\frac{L_{ij} D_i}{D_j + D_i} \right) \frac{\frac{D_i}{L_{ij}}}{\sum_{i=1}^{n} \frac{D_i}{L_{ij}}}$$

Schütz (1989)

$$S = 0.65 \frac{H_i - H_j}{CR_i + CR_j} + \left(0.5 - \frac{L_{ij} - (CR_i + CR_j)}{CR_i + CR_j} \right)$$

Zone of perception

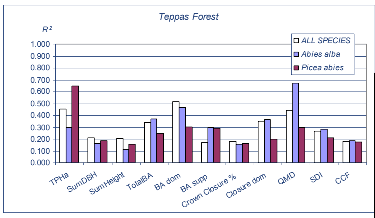
(*sensu* Burton, 1993)

- Fixed radius (Lorimer, 1983)
- Tree size-proportional radius (Hegyi, 1974)
- Angle count sampling, variable radius (Daniels, 1976)
- Optimization of R^2 between CI and tree performance (Ledermann and Stage, 2001)
- Spatial autocorrelation (Kenkel, 1989)

Analysis of the average influence zone was based upon Moran's I autocorrelation coefficient.

Results

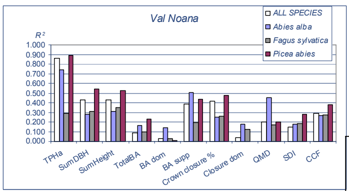
R^2: importance of competition
b_i: intensity of competition



	ALL	*Abies*	*Picea*
TPHa	0.455	0.300	0.652
SumDBH	0.214	0.164	0.190
SumHeight	0.206	0.113	0.160
TotalBA	0.337	0.372	0.247
BA dom	0.517	0.467	0.301
BA supp	0.169	0.297	0.290
Crown Closure %	0.183	0.156	0.166
Closure dom	0.350	0.363	0.200
QMD	0.443	0.671	0.295
SDI	0.267	0.284	0.213
CCF	0.185	0.189	0.178

No significative difference between species ($p = 0.639$)

Results



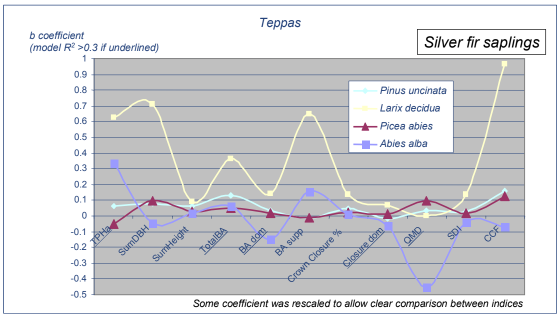
	ALL	*Abies*	*Fagus*	*Picea*
TPHa	0.857	0.743	0.289	0.888
SumDBH	0.427	0.283	0.309	0.539
SumHeight	0.428	0.308	0.349	0.529
TotalBA	0.089	0.162	0.099	0.229
BA dom	0.030	0.144	0.032	0.008
BA supp	0.388	0.505	0.191	0.438
Crown closure %	0.413	0.254	0.257	0.474
Closure dom	0.035	0.174	0.123	0.003
QMD	0.203	0.452	0.171	0.198
SDI	0.149	0.176	0.186	0.281
CCF	0.292	0.267	0.276	0.379

No significative difference between species (but $p_{beech} = 0.101$ vs. fir and 0.079 vs. spruce)

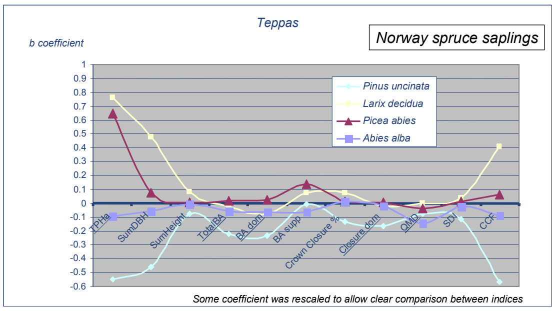
Results

- No significative difference between sites ($p_{spruce} = 0.279$)
- Dominant layer influence more effective in Teppas plot, suppressed layer influence in Val Noana plot.
- Stem density very effective, especially for Norway spruce
- Canopy cover more effective in Val Noana plot

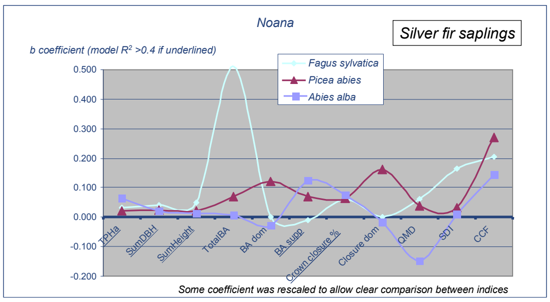
Results



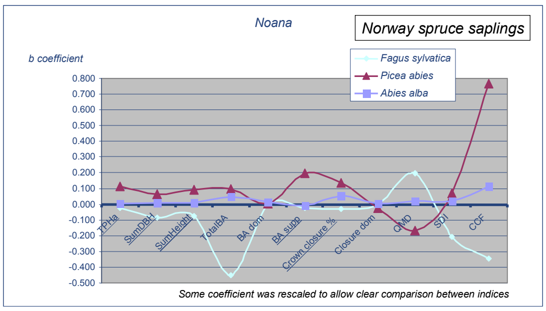
Results



Results



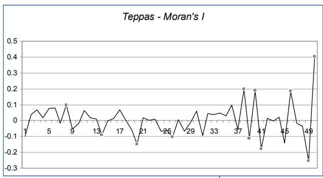
Results



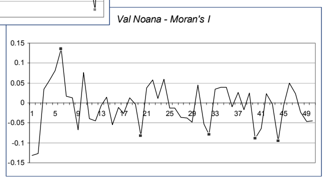
Results

- Similar pattern for fir and spruce saplings over sites
- Positive interaction of other species' overstory on fir saplings, negative interaction from fir overstory (crossed regeneration)
- Strong facilitation or competition effects may hide spatial inhomogeneities (i.e. spruce saplings) or microsite variations (i.e. Swiss mountain pine related coefficients)

Results



Influence area: 14 m

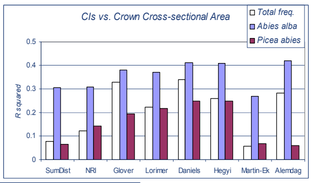


Spatial autocorrelation based on tree DBH (DBH >10 cm).

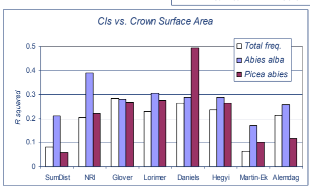
Influence area: 10 m (not significative)

Results

(Val Noana plot)



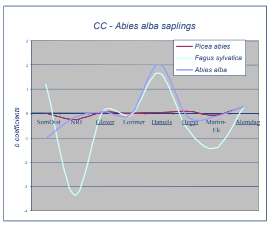
Highly significative difference between species ($p < 0.01$)

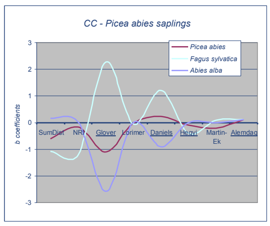


No significative difference between species ($p = 0.372$)

Results

(Val Noana plot)

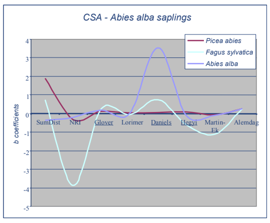


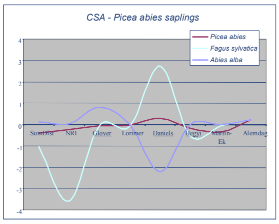


(model R^2 >0.25 if underlined)

Results

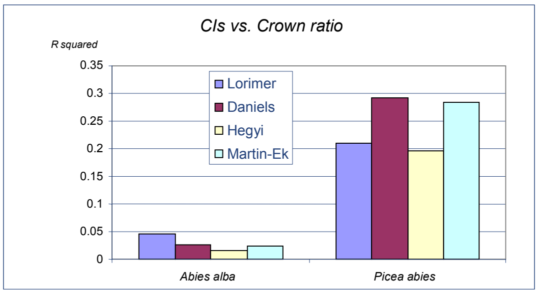
(Val Noana plot)





(model R^2 >0.25 if underlined)

Results



Discussion

- Different factors for sapling establishment and development
- Spatial vs. non spatial CIs (no significative difference)
- Beech seems to be strongest competitor, spruce neutral

- Species-specific competitive ability (also depending on chosen index). CI regression models must be evaluated taking into consideration:

- *Horizontal structure (tree spatial distribution)*
- *Vertical structure (tree height distibution)*
- *Tree size (DBH) distribution*
- *Relative species abundance*
- *Specific tolerance to suppression (Silver fir)*
- *Stand history and disturbing factors*

Discussion

CI analysis can give useful information about:

1. Shade tolerance
2. Competition mode
3. Resource allocation (mixed, multicohort stands)

Further development

- Dynamic analysis of competition
  (sapling age and growth rate)
- Evaluation of present and future competition levels
  (process-base indices)
- Factors influencing regeneration establishment

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Prerequisite for Sustainable Management

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Thank you for your kind attention.