Analysis of intraspecific competition in two subalpine Norway spruce (*Picea abies* (L.) Karst.) stands in Paneveggio (Trento, Italy)

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Abstract

As a consequence of the recent change in human land-use intensity in mountain territories in the Italian Alps, many Norway spruce (*Picea abies* (L.) Karst.) subalpine forests have recently developed without significant anthropogenic disturbance. Even so, their structure and dynamics are still influenced by past human activity. In order to analyze the interactions between past management and current stand dynamics, competition among trees was studied in two 1-ha permanent plots in the Valbona Forest Reserve, located within the Paneveggio-Pale di San Martino Natural Park (eastern Italian Alps). The plots were established in 1993 in two stands with similar age, density and structure but different management history. Tree measurement was repeated in 2005.

We carried out the analysis both on the stand- and on the individual tree scale. We computed maximum Stand Density Index (SDI) for Norway spruce in Paneveggio Park (SDI_{max} 1380) based on an ancillary sample plot network. The intensity of stand-level competition and its course through time was assessed in each study area computing percent relative SDI (SDI%) for the two inventory years.

Competition at individual level was studied using known individual-based competition indices (CIs) as well as a new set of Crown Area Indices (CAI), all of them based on tree variables such as dbh, height, crown area and inter-tree distance. We assessed the performance of each index by evaluating its explanatory power in forecasting individual tree basal area growth (Δg) in a 10-year period.

In the more recently thinned plot, competition did not induce mortality rates comparable to the second plot, that has been unmanaged for the last 60 years. We expect the intensity of competition-induced mortality of the two stands to increase its similarity in the next future.

Individual CIs based solely on tree diameter produced the best performance in plot 1 (e.g., Daniels' CI, $R^2_{adj} = 0.580$). In plot 2 different CIs, including tree height, crown area and inter-tree distance as base variables also, proved the most explanatory ones, including CAI_6 ($R^2_{adj} = 0.553$), which not consider dbh.

We attributed the differential role of tree spatial location and dominance-related descriptors in predicting growth to the time when the stand experienced the last anthropogenic disturbance. The competition relationships still experience the effect of the artificial alteration of forest structure: after human disturbance, mature Norway spruce subalpine forests need several decades to approach more natural dynamics.
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1. Introduction

Competitive dynamics between trees is a key factor in shaping forest stand evolution (Tilman, 1982; Brand and Magnussen, 1988). This process arises when neighboring plants share limited resources, leading to a reduction in survivorship and/or growth rate (Clements, 1929; Grime, 1979; Begon et al., 1996; Oliver and Larson, 1996). For this reason, competition has long been known as a primary process governing population size, community structure and diversity (Oliver and Larson, 1996; Newton and Jolliffe, 1998; Simard and Sachs, 2004; Simard and Zimonick, 2005).

In order to understand competitive dynamics, several competition indices (CI) have been developed through time to assess the competitive intensity taking place either in whole stand or acting on individual trees. Stand-level competition indices reflect the degree of tree crowding per unit area (Husch et al., 1982), allowing to compare competitive status in different stands (Hynynen and Ojansuu, 2003). Individual-based CIs reflect the local density of competitors interacting with an individual tree (Tomé and Burkhart, 1989). They quantitatively assess the intensity of competition experienced by focal trees

and allow to quantify the influence of neighboring individuals on the growth of the subjects (Hynynen and Ojansuu, 2003). They may or may not rely on spatial tree location, hence they are usually classified as distance-dependent or distance-independent (Biging and Dobbertin, 1995). The interpretation of the outcome of competition can depend critically on the way competition is measured (Freckleton and Watkinson, 1999). No index has been found universally superior, but rather CIs need to be tested on local species and conditions to determine their applicability (Burton, 1993; Weigelt and Jolliffe, 2003). Moreover, the natural course of competition through time is often influenced by exogenous disturbance events, either natural or anthropogenic. All forest stands in the Italian Alps have been affected by humans in some way, either through direct periodic harvesting or by more subtle forms of land-use. Nevertheless, in the last decades there has been a noticeable reduction of the anthropogenic disturbance and, as a consequence, many forest stands have developed naturally even if their composition and structure still reflect past human activity (Guisan and Theurillat, 2000; Bachofen and Zingg, 2001; Motta and Lingua, 2005).

The Norway spruce (*Picea abies* (L.) Karst.) forest in Paneveggio-Pale di San Martino Natural Park (Trentino Alto Adige, Italy) represents an example of the aforementioned process. Historical evidence shows that the forest has been intensively managed for centuries. Following World War II, the frequency of silvicultural operations decreased and, in the Valbona valley, came to a complete end in 1990, when a forest reserve was established (Motta et al., 2006). The present study focuses on two long-term forest monitoring plots located inside the reserve, characterized by a varying time since last disturbance. Our aim was to analyze interactions between past management and current stand dynamics. We expected competition dynamics to be still influenced by past human activities in the more recently disturbed plot. This effect was expected to be observed both at stand and at individual level, i.e., on mortality rate and on individual growth rate respectively. The objectives of this work were: comparing competitive dynamics at the stand level (1) and at the individual level, analyzing the influence of competition on tree growth using existing individual-based CIs (2) and new competition indices (3), devised using biologically represen-tative variables, i.e., the variables determining the competitive ability of the trees and shaping the outcome of inter-tree relationships.

2. Methods

2.1. Study site

The study is focused on two stands in the Valbona Forest Reserve (latitude 46°18′N, longitude 11°45′W), a 123 ha subalpine Norway spruce forest included in the Paneveggio-Pale di San Martino Natural Park (Trentino, Italy). The phytocoenosis is classified as *Homogyno-Piceetum subalpinum myrtilletosum* (Di Tommaso, 1983).

Rainfall is 1157 mm/year at Passo Rolle (2002 m a.s.l.), approximately 3 km from the study site, and 1104 mm/year at Paneveggio (1508 m a.s.l.), approximately 2 km from the study site. Annual mean temperature is 2.7 °C at Passo Rolle and 3.7 °C at Paneveggio. The bedrock is porphyry and sandstone, and soils are podsols and rankers.

Both stands are pure and monolayered; spatial pattern of adult tree stems is random (Motta, 2002). The first stand was established after a logging that removed parts of the previous stand around year 1820. This stand was affected by moderate and major disturbances during 19th century, and again during the period 1915–1924. The plot is located a few hundreds meters from a forest road, and was quite accessible for thinning and harvesting operations, that lasted until 1980–1984. The second stand was established after a logging around year 1790. This stand is relatively faraway from forest roads and has developed without anthropogenic influence since the 1940s, when all thinning and harvesting operations were over (Motta et al., 1999) (stand characteristics on Table 1).

2.2. Field measurements

During 1993, two 1-ha (100 × 100 m) sample plots were established and all live and dead standing trees with diameter at breast height (dbh) >7.5 cm, logs, and stumps were identified, labelled with numbered tags and mapped. Dbh was measured for each tree. The inventory was repeated in 2005. We measured diameter at 50 cm height, dbh, total height, crown radii in the

Table 1
Stand characteristics

	Plot 1 (1993)	Plot 1 (2005)	Variation %	Plot 2 (1993)	Plot 2 (2005)	Variation %
Elevation (m a.s.l.)	1695			1815		
Slope (%)	30			47		
Aspect	North			North		
Trees (n ha^{-1})	484	476	−1.7%	557	510	−8.4%
Basal area (m^2 ha^{-1})	55.9	64.6	+15.6%	65.9	73.7	+11.8%
Quadratic mean dbh (cm)	38.4	41.6	+8.3%	38.8	42.9	+10.6%
Mean height (m)		31.1			29.6	
Volume (m^3 ha^{-1})	820	946	+15.4%	874	977	+11.8%
Snag density (n ha^{-1})	0	9	[a]	53	101	+90.6%
Snag volume (m^3 ha^{-1})	0	5.5	[a]	21.9	59.9	+173.5%

[a] For Plot 1 it was not possible to calculate Snag density and Snag volume percent increment.