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Quantifying distance-independent tree competition for predicting Norway spruce mortality in unmanaged forests

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Background and Aims

Quantitative understanding of natural mortality dynamics of trees is a prerequisite for predicting stand growth and biodiversity under unconventional silvicultural regimes (e.g. unthinned, multi-layered).

The aim was to study how the competitive status of a Norway spruce tree influences its competition-induced mortality probability.

Material and Methods

Sizes of altogether 8362 trees on 57 plots (Fig. 1) were recorded in the first measurements. Dead and live trees were identified in the second measurement.

The social statuses of trees were estimated with competition indexes (CI), which were generalisations of frequently used BAL-index. Weight (Φ) of each competitor on the mortality probability of the subject tree was estimated using a logistic function (Fig. 2). Optimal forms for the weighting models were searched by repeated fitting of a mixed effects model.

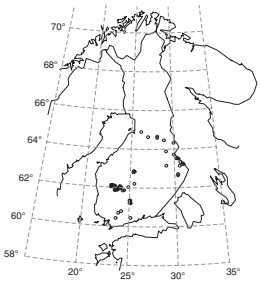

Fig. 1 Site locations, N= 57. Some of the sites are located close to each other, and cannot be visually distinguished from each other.

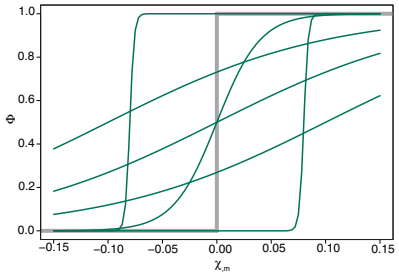

Fig. 2 Logistic weighting models (Φ) were functions of the size differences (χ) between the competitor and subject trees. Form of the function was optimised for competition indexes based on $\sqrt{\text{dbh}}$, dbh and dbh^2. Gray thick line is the weight-function used in BAL-index.

Results

Competition leading to spruce mortality was clearly one-sided, and there existed a distinct and steep threshold above which competitors started to influence the subject tree mortality probability (Fig. 3). This threshold was nearly size-independent for the competition index based on $\sqrt{\text{dbh}}$, which was also the best index in terms of AIC (Fig 3., left panels).

Constructed competition indexes performed much better than any tested models using direct measurements of tree and/or stand.

Due to the stochastic nature of mortality, considerable uncertainty remains in plot-wise predictions of mortality (Fig. 4).

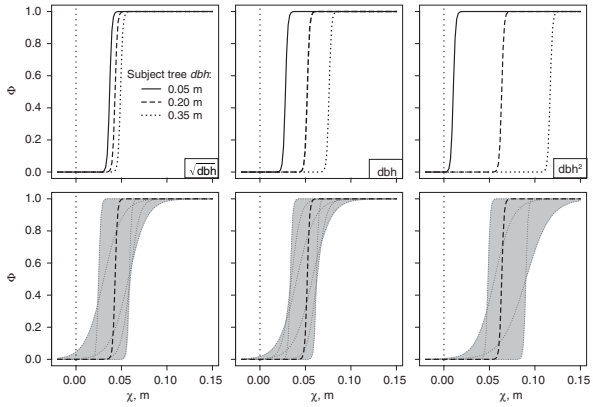

Fig. 3 Weighting functions (Φ) for sizes of competitors based on $\sqrt{\text{dbh}}$, dbh and dbh^2, which express how different sized competitors contribute to the mortality probability of subject spruces (top), and uncertainty of the Φ-function for medium sized subject spruces (dbh = 20 cm) (bottom).

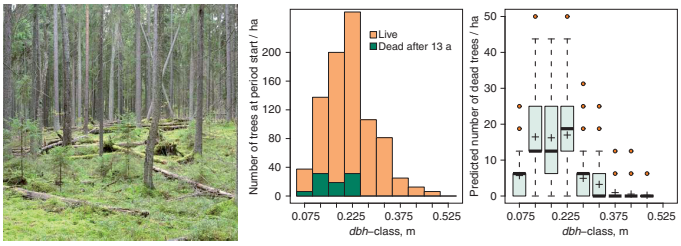

Fig.4 Measured mortality at one of the study plots during the monitoring period (left and middle panels). Simulated predictions using the best model (rigth) with uncertainty ranges.

Conclusions

Mortality probability of spruce trees can be estimated using a BAL-type of index where competitors larger by 4-5 cm in dbh influence with equal weigths and their $\sqrt{\text{dbh}}$. Whether our index works for other species in unmanaged conditions requires further studies.

Our simple competition index can be easily integrated to many stand growth models to provide mortality estimates under unconventional management. Estimates of tree mortality are needed to predict natural development of stands, dead wood carbon storages and diversity of dead-wood dependent species.

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