Appendix S1.

Model description: competition indices and growth curves.

We used a simple rule to model competition, motivated by "Zone Of Influence (ZOI)" models (Bella 1971). The ZOI describes a circular area, determined by the size of the plant, from within which the plant potentially can draw resources and within which it can compete with other plants. Plants compete when their ZOI's overlap. Each tree *i* competed with a circular zone of influence $\mathrm{ZOI_i}$ with radius r_{zoi} which was proportional to its height h_i (i.e, $r_{zoi} = r\, h_i$). We tested three competition indices which considered increasing detail.

The first competition index was the fraction of the $\mathrm{ZOI_i}$ of tree *i* not overlapped by the $\mathrm{ZOI_j}$ of all other trees *j*. This index did not distinguish between the cases where a part of the ZOI of the focal tree is overlapped by only one neighboured tree or at the same time by more than one neighboured tree. This was considered by the second competition index.

The second competition index is based on the overlap area O_{ij} of the zones of influence of the focal tree *i* and all other trees *j*. It relates the zone of influence $\mathrm{ZOI_i}$ of the focal tree (competitive power of the target tree) to the sum of the overlap areas O_{ij} of the focal tree *i* with all other trees *j* (= total competitive power exerted over the zone of influence of the target tree):

$$c_i = \frac{\mathrm{ZOI_i}}{\mathrm{ZOI_i} + \sum_{i,i \neq j} O_{ij}} \qquad \text{(eqn. A1)}$$

For example, if three trees overlapped 20%, 30%, and 40% of the $\mathrm{ZOI_i}$ of the target tree, the competition index yielded $c_i = \mathrm{ZOI_i} / ((1.0 + 0.2 + 0.3 + 0.4)\, \mathrm{ZOI_i}) = 1/1.9 = 0.53$. If the $\mathrm{ZOI_i}$ of the target tree *i* was not overlapped the index yielded $c_i = 1$ (i.e., no competition). However, if the competitive power exerted over the $\mathrm{ZOI_i}$ of the target tree was much larger than its own competitive power, the competition index yielded values $c_i << 1$ (with an asymptotic value $c = 0$). Note that this competition index yields asymmetric competition. For example, if the $\mathrm{ZOI_i}$ of a smaller tree *i* is totally overlapped by a larger tree *j* the relative effect of the larger tree on the smaller one ($c_i = 0.5$) is much stronger than the relative effect of a smaller tree on a larger one ($c_j = \mathrm{ZOI_j} / (\mathrm{ZOI_i} + \mathrm{ZOI_j}) \approx 1$ if $\mathrm{ZOI_i} << \mathrm{ZOI_j}$). However, the second competition index does not distinguish the competitive strength of trees of different height.

The third competition index assumes that the relative competitive strength of a tree *i* depends proportionally on its height h_i:

$$c_i = \frac{h_i \times \mathrm{ZOI_i}}{h_i \times \mathrm{ZOI_i} + h_j \times \sum_{i,i \neq j} O_{ij}} \qquad \text{(eqn. A2)}$$

The competition indices were calculated with the help of a grid that divides the plot into cells of 1 × 1 m. Only trees taller than 2 m (adult trees) were considered to exert competition on neighbouring cells. For non-adult trees the first competition index simplified to $c = 1$ where no adult tree was neighboured and to $c = 0$ otherwise, and the second competition index simplifies to the reciprocal of the number of trees whose ZOI overlap the cell z_i of the non-adult focal tree *i*.

To select an appropriate competition index that best describes our data we first calculated an empirical competition index for each tree, which was defined as the residual of tree height extracted from the average elevation-height regression. The underlying idea was that the degree of competition experienced by an individual can be estimated as the effect of neighbouring individuals on the size of the target individual (Schwinning & Weiner 1998).

Next, we calculated the value of the theoretical competition indices for each tree, and tested which best explained the empirical competition index. This was carried out by simple linear regression between the residuals (dependent variable) and the competition index (independent variable).

We found that the second competition index worked best in all cases compared with the other two indices (Fig. A1). This result indicates that the number of trees which compete is important (remember that the first competition index was only the proportion of cells of the ZOI which were not overlapped by competing trees), but that the competitive strength of trees of different height is sufficiently considered by relating the ZOI of the trees to its height. The scaling factor *r* which relates the ZOI to tree height had at site O a strong impact on the regression: the value *r* = 0.2 yielded the best fit with R^2 = 0.29 whereas larger values of *r* yielded increasingly (and consistently) poorer fits. In contrast, the scaling factor *r* had a non-consistent and weaker impact on the regression for site T. A reason for this may be that larger trees were relatively more frequent at site O than at site T (at site O we found 117 adult trees, approximately half of them were higher than 5 m, compared to 83 adult trees at site T of which only one third was higher than 5 m) and therefore the competition index at site O could better discriminate between values of the scaling factor *r* which relates the ZOI to tree height. We thus selected a value *r* = 0.2.

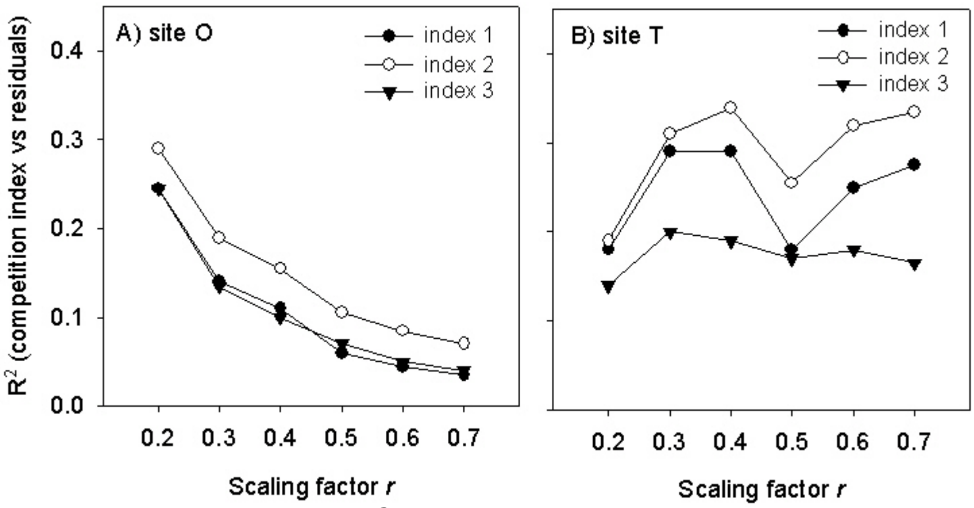

Fig. A1. Amount of variability (R^2) of tree height explained by the three different competition indices at sites O and T, in dependence on the scaling factor *r*. Height residuals were obtained from elevation-height regressions to remove the influence of the altitudinal gradient on tree height. Next, the height residuals (dependent variables) were regressed against the different competition indices (independent variable).

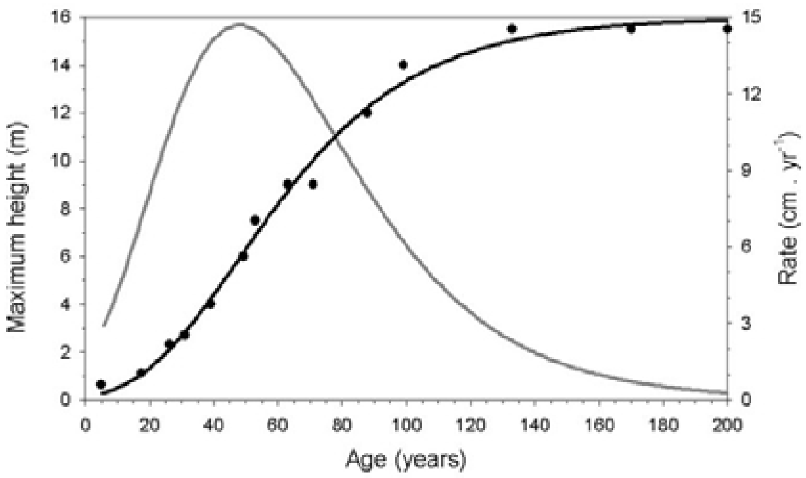

Fig. A2. Maximum annual longitudinal growth at the two treeline ecotones as a function of age. The Gompertz function (black line) was fitted to data of maximum tree height for 10-yr. classes pooled from sites O and T (black points). The annual rate of maximum longitudinal growth (grey line) was estimated as the increase of tree height divided by time.

Appendix S2

Comparison between observed and simulated treelines.

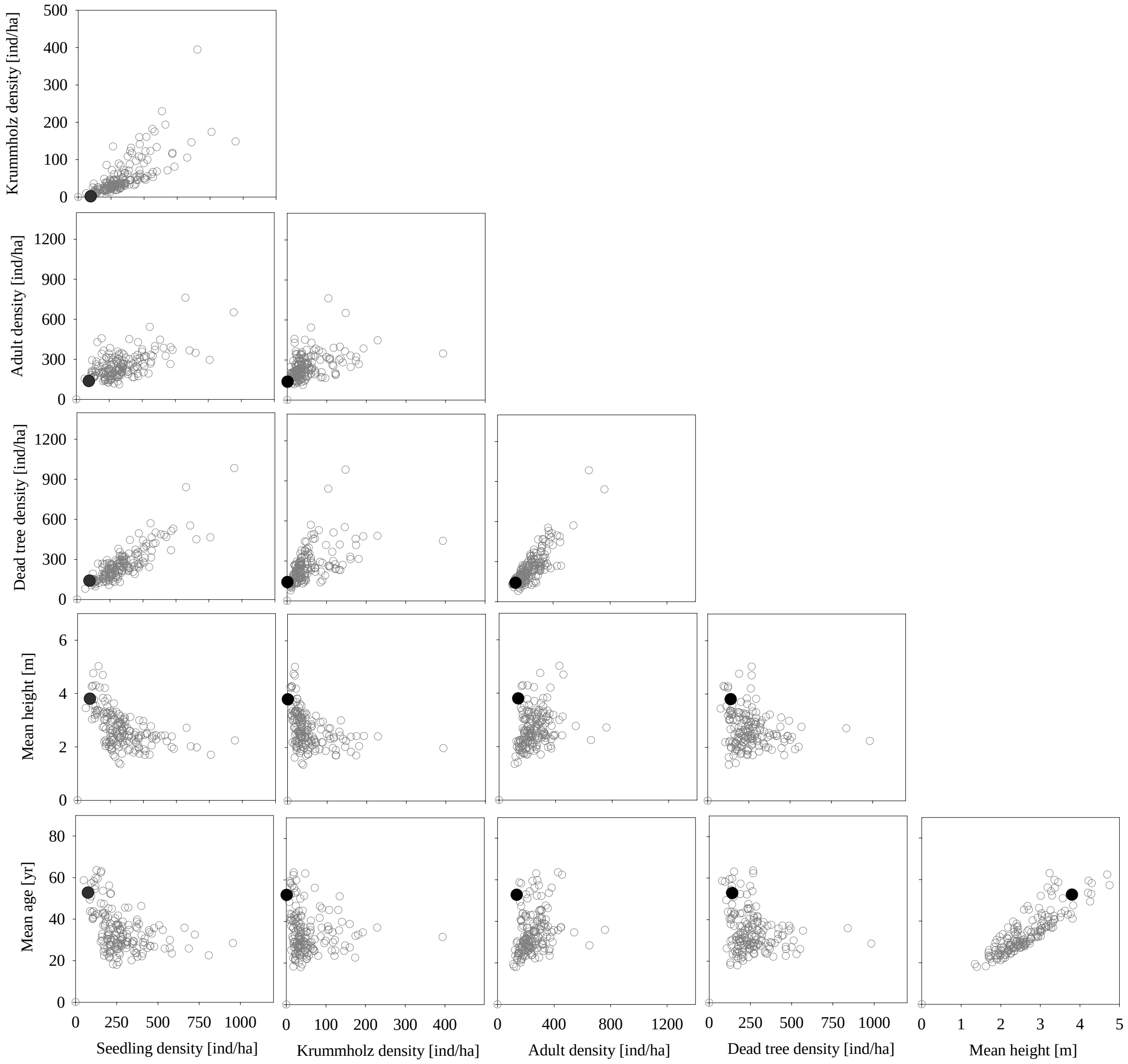

Fig. A3. Comparison between the observed smooth treeline at site T and the 164 simulated treelines with smooth transitions in both height (abruptness < 0.3) and adult density (abruptness < 0.35). Observed data: filled circle, simulation results: open circles.

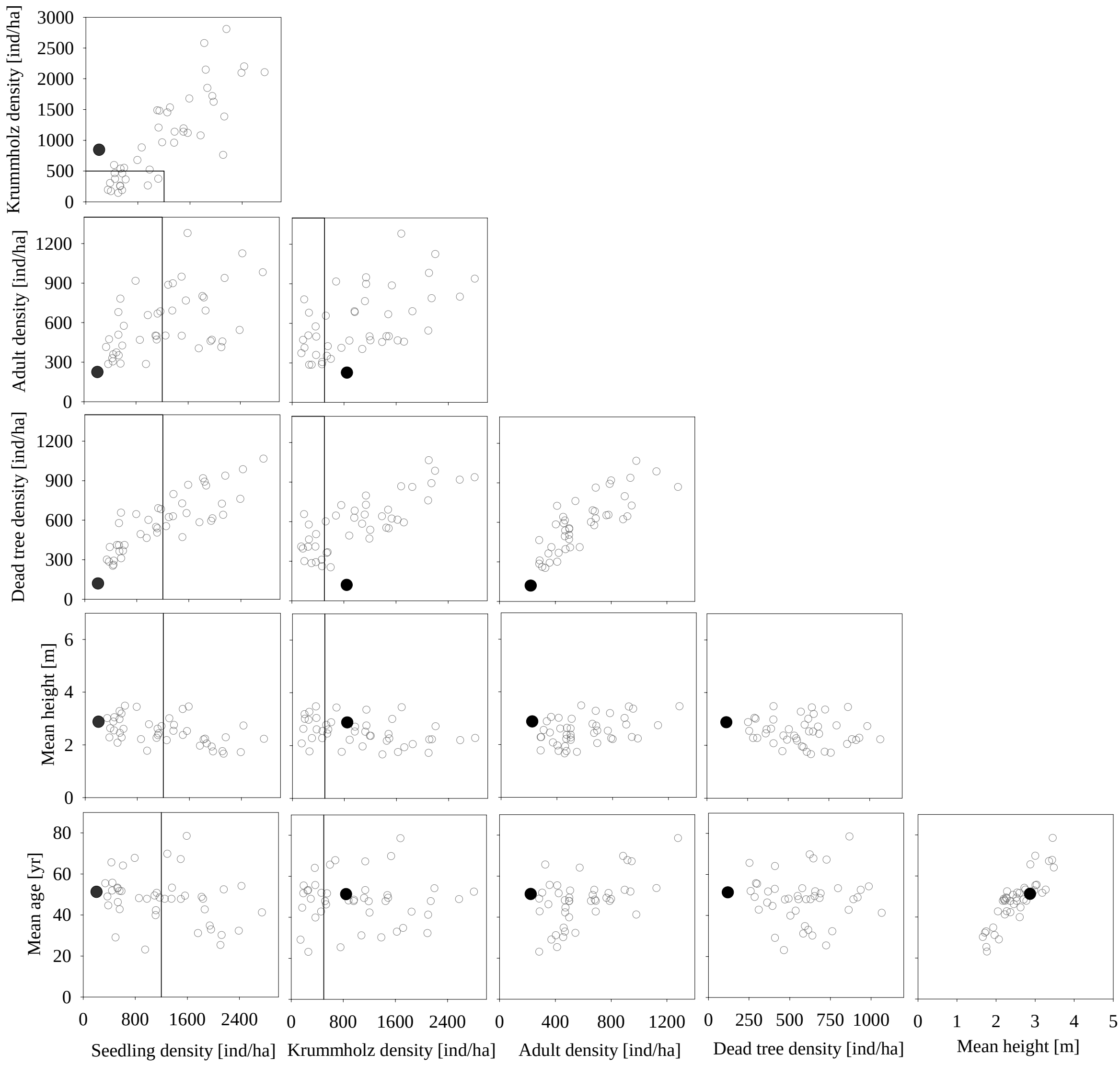

Fig. A4. Comparison between the observed abrupt treeline at site O and the 43 simulated treelines with abrupt transitions in adult density. Observed data: filled circle, simulation results: open circles. For comparison, the vertical lines and the box indicate the ranges of seedling and krummholz density shown in figure A3.