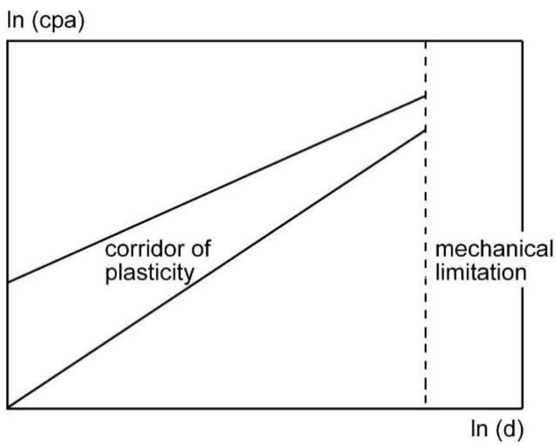
Supplementary Materials

[1] Supplement Table S1 Allometric factors a0 and allometric exponents a1 resulting from the 95 % quantile regression models 5 $\ln(cr_k) = a_0 + a_1 \times \ln(d_k) + \varepsilon_k$ and $\ln(cpa_k) = a_0 + a_1 \times \ln(d_k) + \varepsilon_k$. The tree species codes correspond with Figure 10.

Model	species	sp. code	a_0 (cr~d)	a_1 (cr~d)	a_0 (cpa~d)	a_1 (cpa~d)
5	Norway spruce	10	-0.588	0.502	-0.030	1.004
5	silver fir	20	90	0.416	0.966	0.831
5	Scots pine	30	-1.294	0.711	-1.440	1.421
5	European larch	40	-1.266	0.687	-1.385	1.373
5	European beech	50	0.068	0.487	1.280	0.973
5	sessile/common oak	60	-1.452	0.817	-1.758	1.634
5	Douglas-fir	70	-0.845	0.639	-0.545	1.279
5	sycomore maple	81	-0.371	0.509	0.403	1.018
5	common ash	82	-0.806	0.609	-0.468	1.217
5	hornbeam	83	-0.008	0.466	1.129	0.933
5	white birch	84	-0.728	0.582	-0.311	1.165
5	lime tree	85	-0.050	0.450	1.044	0.900
5	wild cherry	88	-0.911	0.632	-0.677	1.264
5	red alder	91	-1.001	0.636	-0.857	1.272

[2]



Supplement Figure S1 Visualization of a concept for the changing cpa-d relationship of trees with progressing size development. In the young state the crown extension can vary in a broad allometric corridor and is mainly determined and restricted by the neighborhood and competitive situation of the tree. With progressing size development the variation of the crown extension decreases and is mainly restricted by the species-specific wood density. Thus the crown dimensions of trees with different development histories approach the same species-specific limitation and may converge. The limitation of the branch length and crown expansion by the wood density contributes to understanding the characteristic convergence of the upper and lower cpa-d boundary lines (see e.g. Figure 4 and 9).

[3] Supplement Explanation S1 Detailed derivation of the standardized observed and expected N-dq values shown in Figure 16.

3.1 Derivation of the observed N-dq values for the mixed stands (shown in Figure 16b)

For this visualization we calculated the total tree numbers of the mixed stands as follows $N_{1,2} = N_{1,(2)} + N_{(1),2}$. The common quadratic mean tree diameters of the mixed stands were calculated as weighted mean as follows

$$dq_{1,2} = (N_{1,(2)} \times dq_{1,(2)} + N_{(1),2} \times dq_{(1),2}) / (N_{1,(2)} + N_{(1),2})$$

Note, that the resulting observed $N_{1,2} - dq_{1,2}$ values calculated in this way were used for visualization of the observed N-dq developments of the mixed stands in Figure 16b.

3.2 Derivation of the standardized expected N-dq values for quantitative comparison between mixed-species and monospecific stands (shown in Figure 16c)

For the comparison of the N-dq development between mixed species stands (N. spruce/E. beech, s. oak/E. beech, S. pine/E. beech, and Douglas-fir/E. beech) and the neighbouring monocultures we used the N-dq development of the respective E. beech monocultures as observed N-dq development.

The standardized expected N-dq values for the mixture were derived as follows

$$N_{\underline{1},2} = N_{1,(2)} + (N_{(1),2} \times (dq_{1,(2)} / dq_{(1),2})^{\alpha_{N(1),2,dq(1),2}}) / DEC_{sp1 \rightarrow sp2}$$

with $DEC_{sp1 \rightarrow sp2} = SDI_2 / SDI_1$ derived from the two monocultures of the triplets and $\alpha_{N(1),2,dq(1),2}$ being the self-thinning slope of tree species 2 in the mixture. The underscore of 1 in indicates that the tree numbers were standardized on tree species 1, that was E. beech in this case. The resulting (E. beech-) standardized observed $N_{\underline{1},2}$ tree numbers were plotted over the tree diameters $dq_{1,(2)}$ of E. beech in the mixed stand.

In case of the mixture of Scots pine and s. oak we chose s. oak as standard species and used the N-dq development of the s. oak monocultures as observed N-dq development. The tree numbers of

S. pine were standardized to oak analogously by $N_{1,2} = N_{1,(2)} + (N_{(1),2} \times (dq_{1,(2)} / dq_{(1),2})^{\alpha_{N(1),2,dq(1),2}}) / DEC_{sp1 \rightarrow sp2}$ with species 1 being s. oak and species 2 being S.pine. The resulting (s. oak-) standardized observed $N_{1,2}$ tree numbers were plotted over the tree diameters $dq_{1,(2)}$ of s. oak in the mixed stand.

In the equation $N_{1,2} = N_{1,(2)} + (N_{(1),2} \times (dq_{1,(2)} / dq_{(1),2})^{\alpha_{N(1),2,dq(1),2}}) / DEC_{sp1 \rightarrow sp2}$ the various terms have the following meaning

$N_{1,2}$ total tree number in the mixed stand, standardized to species 1

$N_{1,(2)}$ tree number of species 1 in the mixed stand

$N_{(1),2} \times (dq_{1,(2)} / dq_{(1),2})^{\alpha_{N(1),2,dq(1),2}}$ tree number $N_{(1),2}$ of species 2 in the mixed stand extrapolated to the mean tree diameter of species 1 in the mixed stand

$DEC_{sp1 \rightarrow sp2}$ equivalence coefficient that standardizes the tree number of species 2 to the tree number of species 1, assuming the same quadratic mean tree diameter $dq_{1,(2)}$. For even more detailed derivation of this approach see Pretzsch (2019) [19] and Pretzsch and del Río (2019) [83].