Appendix A: Plot basal area and water deficit analysis, and summary statistics on explanatory variables

Plot Basal Area and Annual Water Deficit Time Trend Analysis

To test for a trend in plot basal area, we fit a linear mixed model with a fixed effect for time and a random effect for plot (using "`lme`" in package "`nlme`" (R package version 3.1-117, Pinheiro et al. 2014; figure A1). The model is as follows:

$$\begin{aligned} BA_{jt} &= \beta_0 + pl_j + \beta_1 t + \alpha_j + \epsilon_{jt} \\ pl_j &\sim N(0, \sigma_{pl}^2) \\ \epsilon_{jt} &\sim N(0, \sigma^2) \end{aligned} \tag{A.1}$$

where t is the inventory year, BA_{jt} is plot basal area for plot j at time t, pl_j is a random intercept for each plot (identically and independently normally distributed with zero mean and variance σ_{pl}^2), β_0 is the intercept, β_1 is the linear time trend, and ϵ_{jt} is residual variation (independently and identically normally distributed with zero mean and variance σ^2). The time trend was significant: 0.567 $m^2/ha/year$, $p =$ 1.85e-18.

This significant time trend in plot basal area confirms that forest stand structure at BFRS is changing, distinguishing this second-growth system from the old-growth systems in van Mantgem and Stephenson (2007), van Mantgem et al. (2009). This significant time trend does raise the question of potential confounding between these variables in the survival model in the main paper. We wish to test a fixed effect for basal area on survival as well as a fixed effect for time on survival. To investigate the time trajectories of tree crowding further, we fit a model with both a slope and intercept time random effect using "`lme`" . In this model, β_1 becomes $\beta_1 + pl2_j$, where β_1 is an average slope (time trend) and $pl2_j$ are plot effects (independently and identically normally distributed with zero mean and variance σ_{pl2}^2).

We found that the slope random effect was significant (p<<0.01 in a likelihood ratio test), but that the intercept random effect was a factor of three larger than the slope random effect (for standardized time and basal area variables, estimated slope standard deviation: 8.16, estimated intercept standard deviation: 25.0). The mean slope estimate was 6.00, and the mean intercept estimate was 61.1, implying that there were some plots with decreasing basal area as well as some with increasing basal area. Though there is potential in the survival model for the secular time trend to be somewhat confounded with the overall increase in basal area on all plots, it is still reasonable to expect that we can estimate basal area effects on survival along with a time trend in survival because there is variation in the plots' basal area trajectories with time.

We stress, though, that this is a relationship between the explanatory variables. It implies that the trajectory of crowding on different plots is different. This finding lends support to the idea that the secular time trend can be estimated alongside the basal area effect in the survival model. This relationship between time and basal area does not directly inform the effects of these variables on the survival of trees, as is modeled in the main paper.

The trend for annual climatic water deficit is small and not significant: -1.06 $mm/year$, p=0.29 (Figure A2). More negative deficits indicate a more stressful environment.

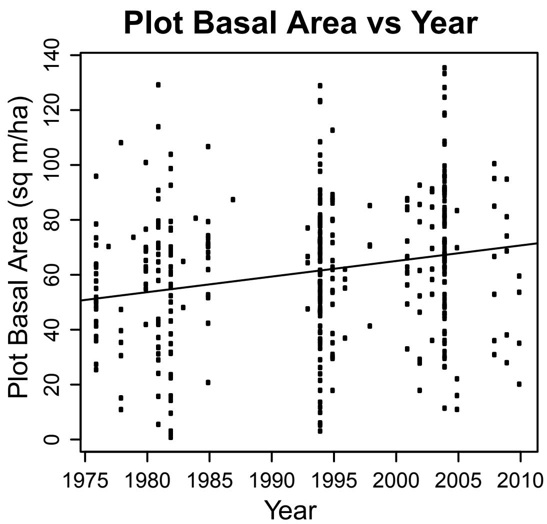

Figure A1: Plot basal area for each plot at each time. Trend line is for a linear mixed model with plot as a random effect and year as a fixed effect, using the mean value of the intercept to construct the basal area trend on an average plot.

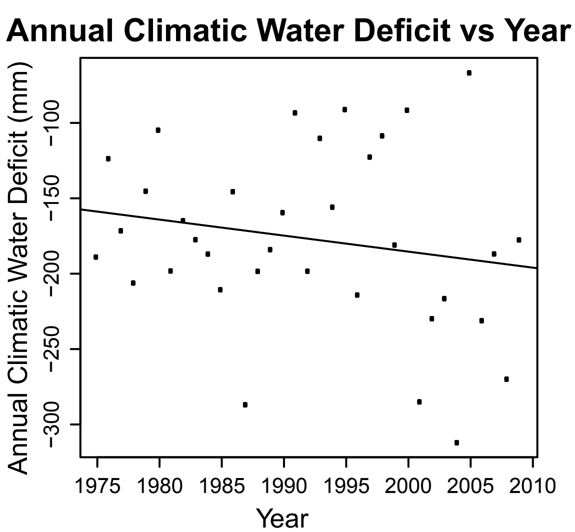

Figure A2: Annual climatic water deficit by year. Trend line is for a linear model with year as predictor.

Table A1: Explanatory variable summary statistics

Covariate Name	Mean	Std.Dev	Max	Min	Level	Units
Topographic Slope	15.87	10.57	50.00	1.00	Plot	%
Elevation	1314.05	33.86	1450.85	1264.92	Plot	m
Annual Climatic Water Deficit	-176.86	60.29	-66.67	-311.93	Year	mm
Plot Basal Area	60.86	17.02	135.48	0.90	Plot/Year	m^2/ha
Insolation	632013.81	35113.15	692878.06	499531.88	Plot	Wh/m^2
Tree Size (DBH)	29.71	20.21	170.43	0.25	Tree/Year	cm

Table A2: Correlations between explanatory variables. Pairwise correlations between variables replicated at different levels are calculated independently of each other; e.g. each tree size is paired with the plot basal area of the plot the tree resides in and all trees on that plot will share the same basal area; but the level of replication between plot basal area and elevation is different: elevation is repeated over years because it does not change with time while plot basal area does.

	DBH	Basal Area	Elevation	Insolation	Top. Slope	Water Def.	Year
DBH	——	0.153	0.015	-0.016	0.051	-0.089	0.034
Basal Area	——	——	0.141	-0.050	-0.010	-0.196	0.185
Elevation	——	——	——	0.284	0.046	X	X
Insolation	——	——	——	——	-0.176	X	X
Top. Slope	——	——	——	——	——	X	X
Water Def.	——	——	——	——	——	——	-0.196

Note: Comparisons between variables of completely different levels (e.g. water deficit and insolation) were omitted (indicated with an "X").

References

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