Supplementary Materials
SUPPLEMENT S1: Figures

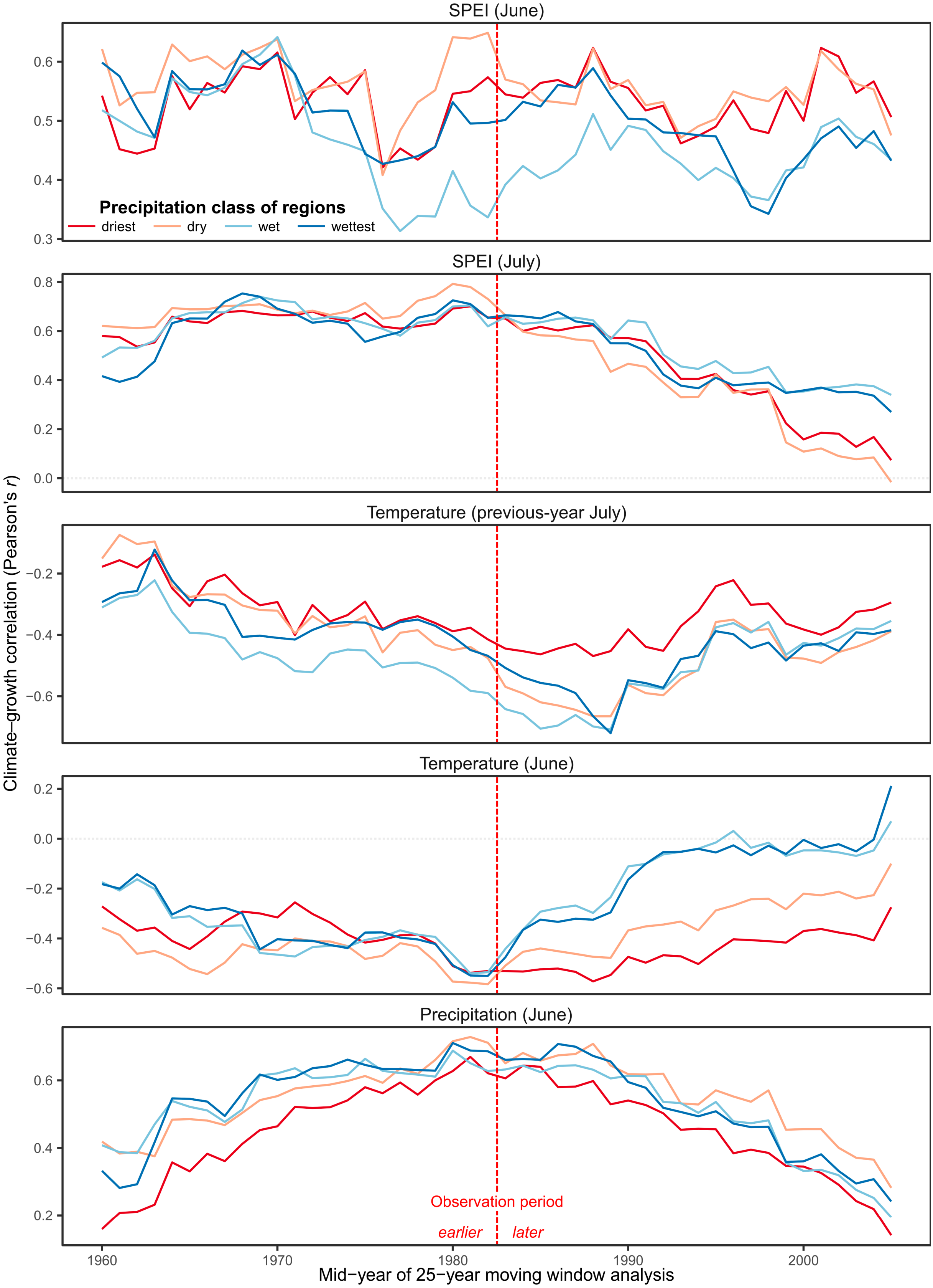

Figure S1. Moving-window (25-year) climate–growth correlation analysis for the 1948–2017 period (mid years of moving windows 1960–2005) of the five most influential growth-limiting climate factors calculated for the four MGSP classes. Modified from [17], with permission of the publisher.

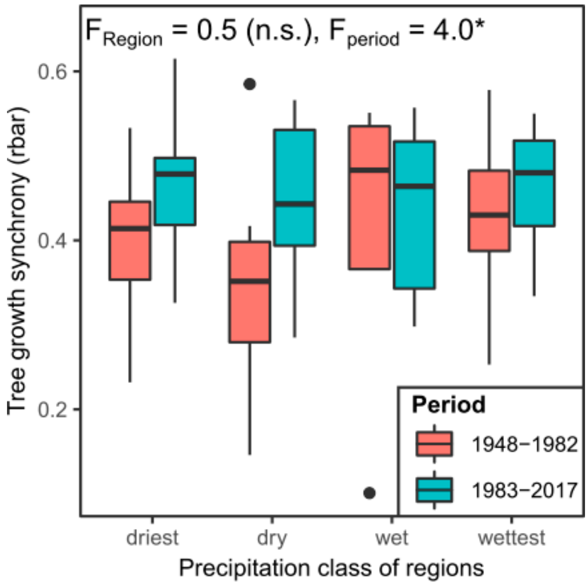

Figure S2. Change in within-population tree growth synchrony from the 1948–1982 to the 1983–2017 period (rbar value) in 30 beech stands assigned to four MGSP classes (driest to wettest). The difference between periods is significant, the differences between classes (regions) are not.

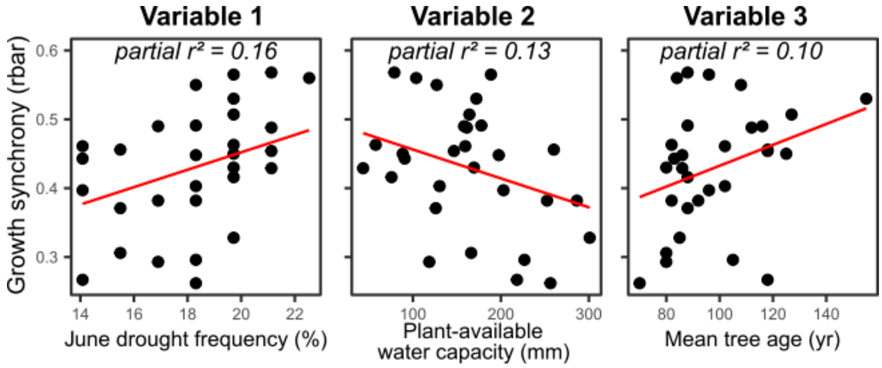

Figure S3. Partial plots of a multiple regression model explaining within-stand growth synchrony (*adj.* $R^2 = 0.32$; $p = 0.004$) (calculated for the full observation period 1948–2017) with climatic, edaphic, and stand structural properties of the study sites. June/July drought frequency is the percentage of years with SPEI < -1. August water balance is August precipitation minus potential evapotranspiration. Modified after [17], with permission of the publisher.

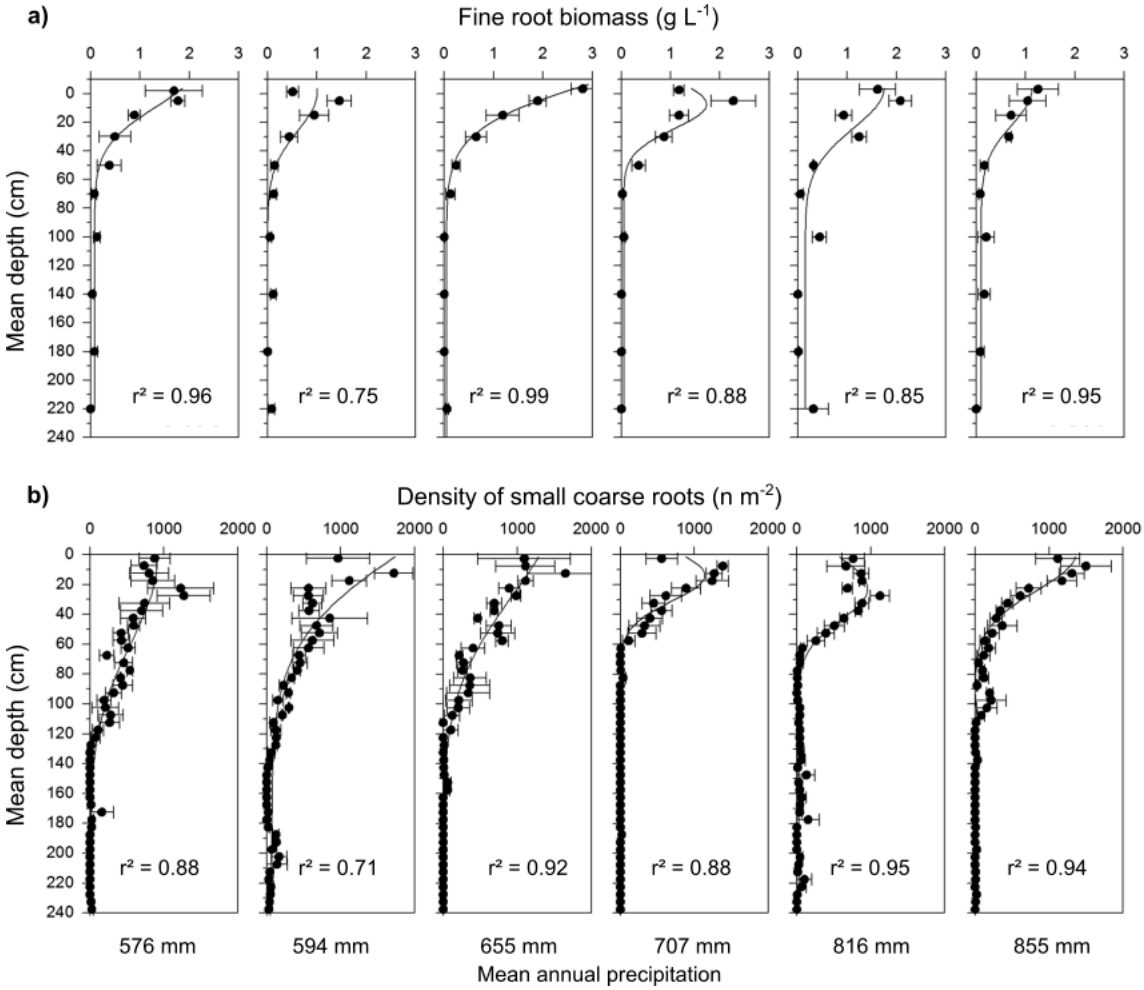

Figure S4. (a) Density of fine root biomass (diameter < 2 mm, g dm L^{-1}) and (b) of small coarse roots (diameter 2-5 mm, roots per m^2) in dependence on soil depth in six beech forests along a steep precipitation gradient in the center of the study region (means ± SE of each three soil pits per stand). After [46], with permission of the publisher.

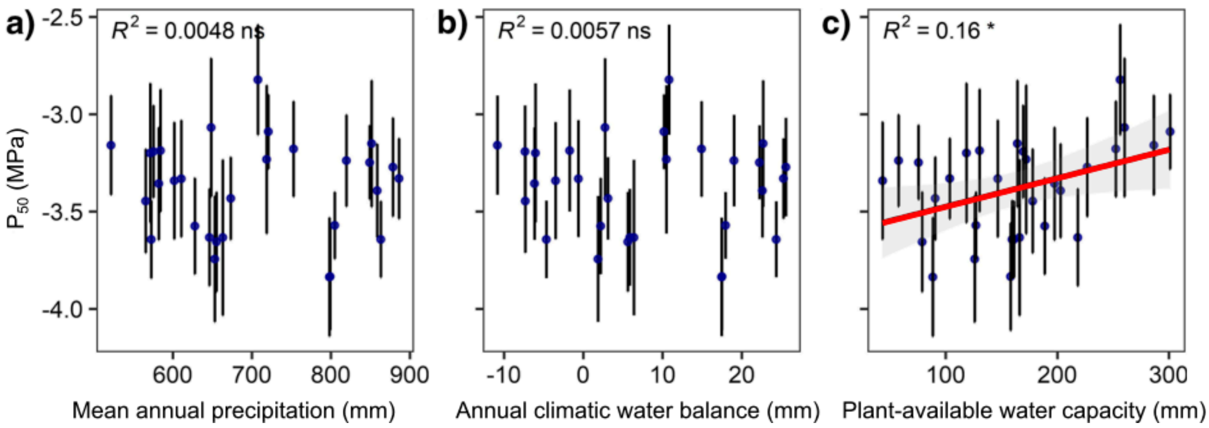

Figure S5. Dependence of embolism resistance (P50) of sun-canopy branches on (a) mean annual precipitation, (b) climatic water balance (full year), and (c) the soil storage capacity for plant-available water (c) in the 30 stands across the study region. Modified after [22], with permission of the publisher.

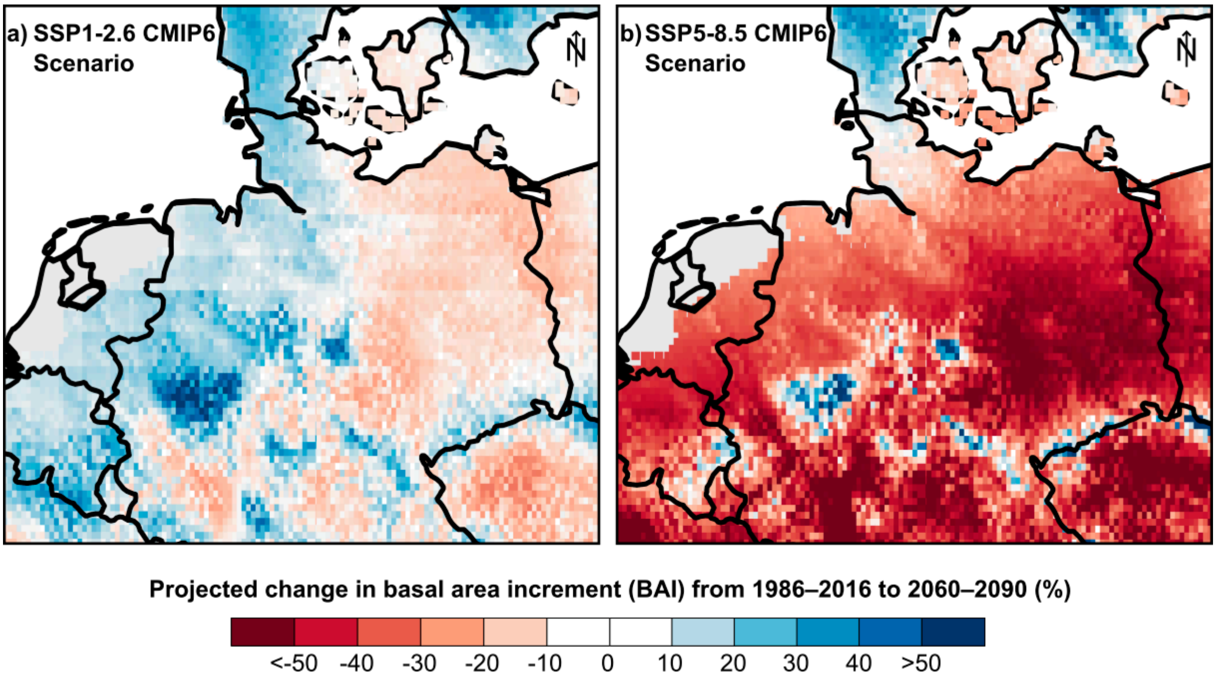

Figure S6. Expected relative change in basal area increment of beech trees in northern Central Europe from the 1986–2016 to the 2060–2090 period under projections of the mild SSP1-2.6 CMIP6 (a) and the more extreme SSP5-8.5 CMIP6 climate scenarios (b) based on dendrochronological data from 324 beech sites in Europe and a generalized linear mixed effects model of beech growth in Europe in dependence on climate. Modified after [75], with permission of the publisher.

SUPPLEMENT S2: Tables

Table S1. Stand structural and climatic characteristics of the 30 studied beech forests in northern Germany. Given are means (± SE) of the stands. MAP – mean annual precipitation, MGSP – mean growing season precipitation, MAT – mean annual temperature (period 1983-2017). Precip. class: WW (wettest; 419-448 mm MGSP), W (wet; 364-418 mm), D (dry; 329-358 mm), DD (driest; 306-328 mm). Sites are ranked according to MGSP.

Location (Site ID)	Tree age (yr)	DBH (cm)	Tree height (m)	MAP (mm)	MGSP (mm)	MAT (°C)	Precip. class
Nordholz (Nor)	84±2	43±1	30.4±0.3	848	448	9.6	WW
Drangstedt (Dra)	96±3	53±2	36.8±1.7	843	445	9.6	WW
Brekendorf (Bre)	105±2	47±2	27.3±0.4	848	439	9.0	WW
Sahlenburg (Sah)	88±2	40±2	26.8±1.0	830	437	9.7	WW
Sellhorn (Sel)	112±4	43±1	32.7±1.5	826	429	9.0	WW
Heidmühlen (Hei)	127±5	47±2	28.6±0.6	821	420	9.2	WW
Wiesmoor (Wie)	82±2	44±1	27.4±0.3	802	419	9.7	WW
Haake (Haa)	125±9	47±2	28.4±0.4	786	418	9.7	W
Klövensteen (Klöv)	116±2	47±1	31.7±0.5	778	415	9.6	W
Unterlüß (Unt)	108±4	46±1	28.8±0.5	786	403	9.1	W
Malente (Mal)	92±4	56±3	29.4±0.4	746	387	9.1	W
Grinderwald (Gri)	85±5	44±1	27.0±0.4	719	387	9.9	W
Göhrde (Göh)	155±6	45±2	26.8±0.5	700	377	9.2	W
Haffkrug (Haf)	70±2	44±2	28.2±0.5	686	364	9.2	W
Tessin (Tes)	80±2	44±1	30.9±0.3	645	358	9.0	D
Dübener Heide (Düb)	83±3	41±2	26.5±0.4	644	358	9.5	D
Klötze (Klö)	118±4	49±2	33.7±0.8	643	353	9.4	D
Kaarzer Holz (Kaa)	88±4	46±1	28.7±0.6	632	352	9.2	D
Medewitz (Med)	88±3	45±2	28.2±0.4	621	348	9.5	D
Prora (Pro)	118±6	49±1	28.4±0.5	623	337	9.1	D
Eggesiner Forst (Egg)	102±5	44±1	27.1±0.4	576	331	9.1	D
Potsdam (Pot)	86±4	35±1	20.9±0.3	575	330	9.9	D
Zempow (Zem)	96±3	40±1	28.8±0.3	594	328	9.0	DD
Summt (Sum)	86±21	42±1	28.1±0.2	580	325	9.8	DD
Chorin (Cho)	80±3	47±2	29.8±0.7	570	324	9.6	DD
Zeuthen (Zeu)	80±1	40±1	27.9±0.5	562	323	9.7	DD
Warenthin (War)	118±5	43±2	28.3±0.5	581	322	9.2	DD
Calvörde (Cal)	102±3	43±1	26.5±0.3	573	322	9.7	DD
Mosigkauer Heide (Mos)	88±2	45±1	28.7±0.4	544	321	10.0	DD
Halle (Hal)	82±3	46±1	24.9±0.5	498	306	10.0	DD

Table S2. Pearson correlation analysis of the relationship between mean tree height, mean tree age and mean DBH on mean annual precipitation (MAP), mean growing season precipitation (MGSP), climatic water balance (CWB) and plant-available soil water storage capacity (AWC) in the 30-sites sample. Pearson correlation coefficients in italics, p values in bold (no significant correlations present).

	MAP	**MGSP**	**CWB**	**AWC**
Tree height	*0.29*; **0.062**	*0.28*; **0.065**	*0.30*; **0.052**	*0.04*; **0.423**
Mean age	*0.20*; **0.144**	*0.17*; **0.188**	*0.22*; **0.117**	*-0.001*; **0.495**
Mean DBH	*0.25*; **0.090**	*0.23*; **0.111**	*0.26*; **0.085**	*0.18*; **0.176**

SUPPLEMENT S3: Methods of dendrochronological analysis

The climate sensitivity of growth was analyzed by correlating the ring-width index (RWI, tree-ring series detrended with a 30-year smoothing spline and low-frequency cut-off at 50%) chronologies with time-series of monthly climate variables, using a 1000-fold bootstrapping procedure for significance testing (R package treeclim, [20]). Monthly precipitation total and mean monthly temperature data were derived for each study site from the gridded (1 km²-resolution) climate datasets of the Climate Data Center (CDC) of the German Weather Service (DWD, Offenbach, Germany). Potential evapotranspiration (PET) was calculated with Thornthwaite's formula. The 3-months-Standardized Precipitation-Evapotranspiration Index (SPEI) as a locally standardized derivative of the monthly climatic water balance (CWB; monthly precipitation minus PET, P–PET) was used for characterizing abnormally dry and wet years or months and for displaying long-term trends in CWB. The mean correlation of all RWI series within a site (*rbar* value) and the average inter-annual growth variability (CV: coefficient of variation in tree-ring series) were used as measures of growth synchrony within a stand and general growth sensitivity to variation in common environmental forcing. Multiple regression models with climatic (temperature, precipitation, P-PET), edaphic (sand content, soil water storage capacity, soil chemical factors) and stand structural parameters (stem density, tree age and height, DBH, competition intensity) as predictor variables were built to explain the direction of long-term growth trends, growth synchrony and interannual growth variability in the 30-stand sample. For further methodological details see [17].