Supporting Information

Stahl et al. 10.1073/pnas.1300673111

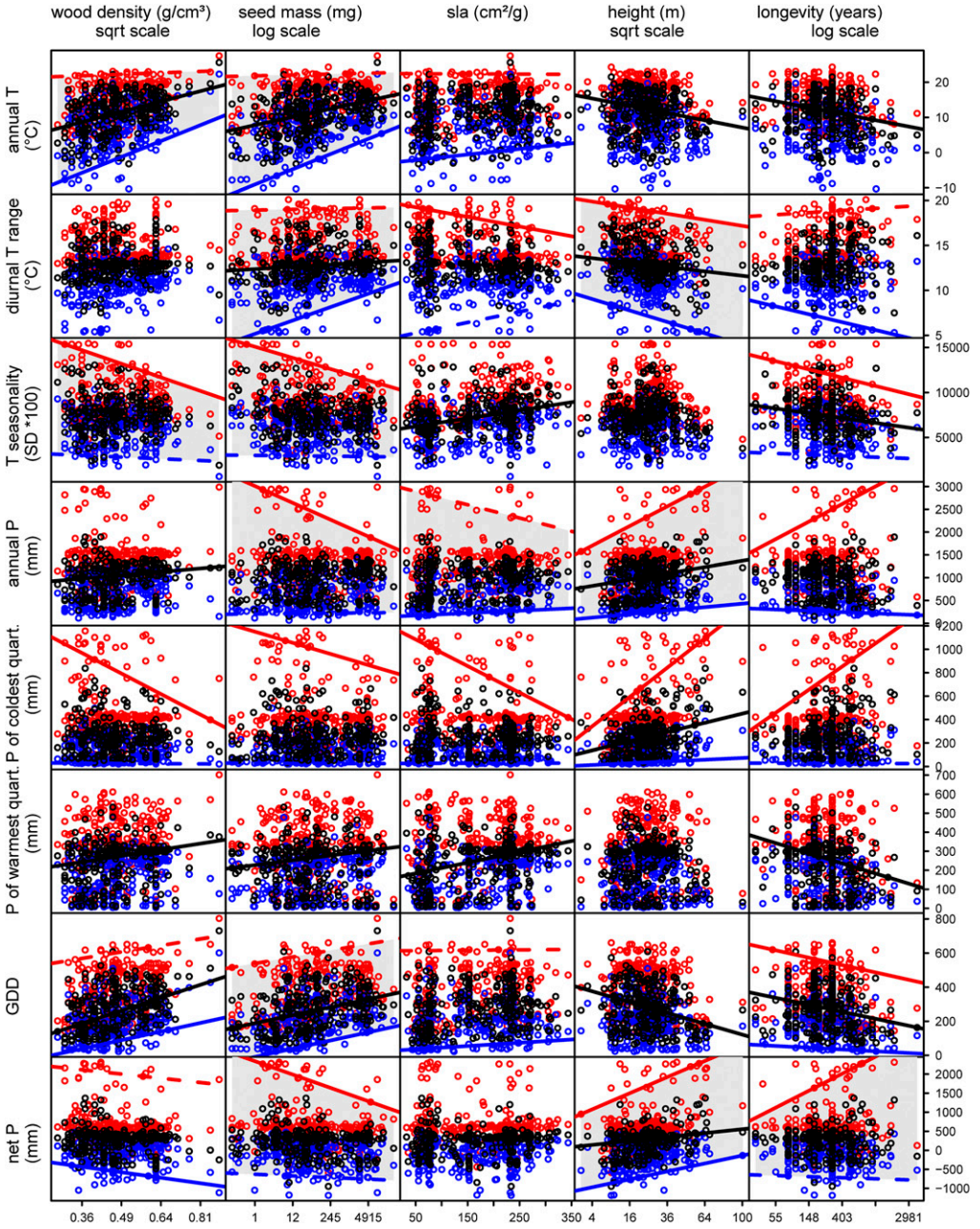

Fig. S1. Trait–climate range relationships based on climate ranges of 250 North American tree species distributed from the boreal to the subtropics for eight bioclimatic variables and five traits. For each trait–climate range relationship the response of the species-specific upper limits (red circles), lower limits (blue circles) and the medians (black circles) to the traits are quantified applying linear quantile regression as follows: for the upper limits the upper-most quantiles (95th and 90th), for the lower limits the lower-most quantiles (10th and 5th), and for the median the 50th quantile were estimated. To evaluate the responses in light of the proposed patterns in Fig. 1*C* (see *Methods* for rules), we displayed significant slopes (i.e., significant different from zero) as solid lines and nonsignificant slopes as dashed lines as follows: if the two upper and/or two lower slopes are both significant, the slopes of the 95th and the 5th quantile are shown, otherwise the significant slopes are shown, and only if both upper or both lower slopes are nonsignificant, the outermost nonsignificant slope is shown. Trait–climate range relationships are shaded gray when the two upper and/or two lower quantiles have significant slopes, indicating obvious significant response patterns. GDD, growing degree day; P, precipitation; sqrt, square root; T, temperature.

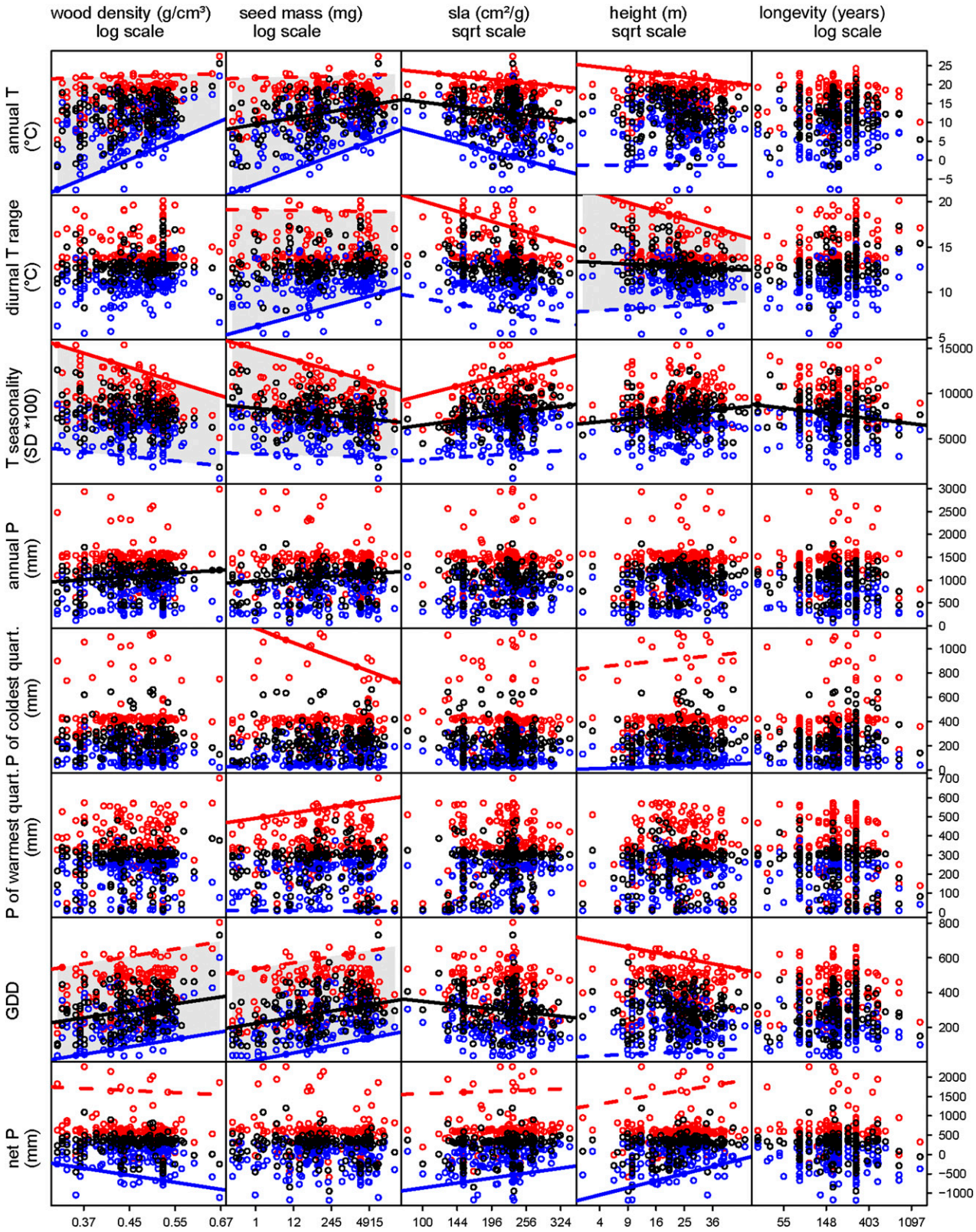

Fig. S2. Trait–climate range relationships based on climate ranges of 166 North American angiosperm tree species distributed from the boreal to the subtropics for eight bioclimatic variables and five traits. For each trait–climate range relationship the response of the species-specific upper limits (red circles), lower limits (blue circles), and the medians (black circles) to the traits are quantified applying linear quantile regression. For details, see Fig. S1.

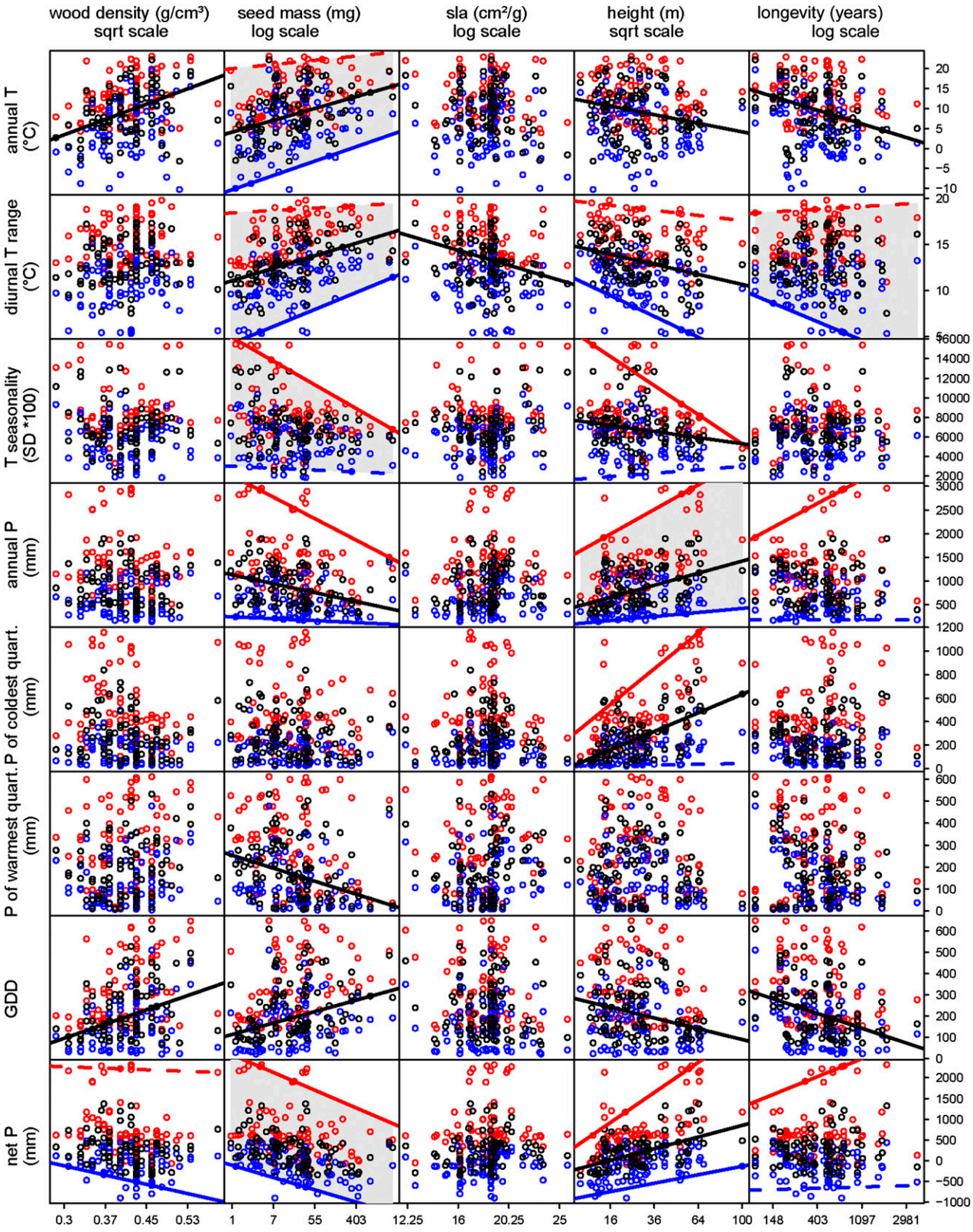

Fig. S3. Trait–climate range relationships based on climate ranges of 84 North American gymnosperm tree species distributed from the boreal to the subtropics for eight bioclimatic variables and five traits. For each trait–climate range relationship the response of the species-specific upper limits (red circles), lower limits (blue circles) and the medians (black circles) to the traits are quantified applying linear quantile regression. For details, see Fig. S1.

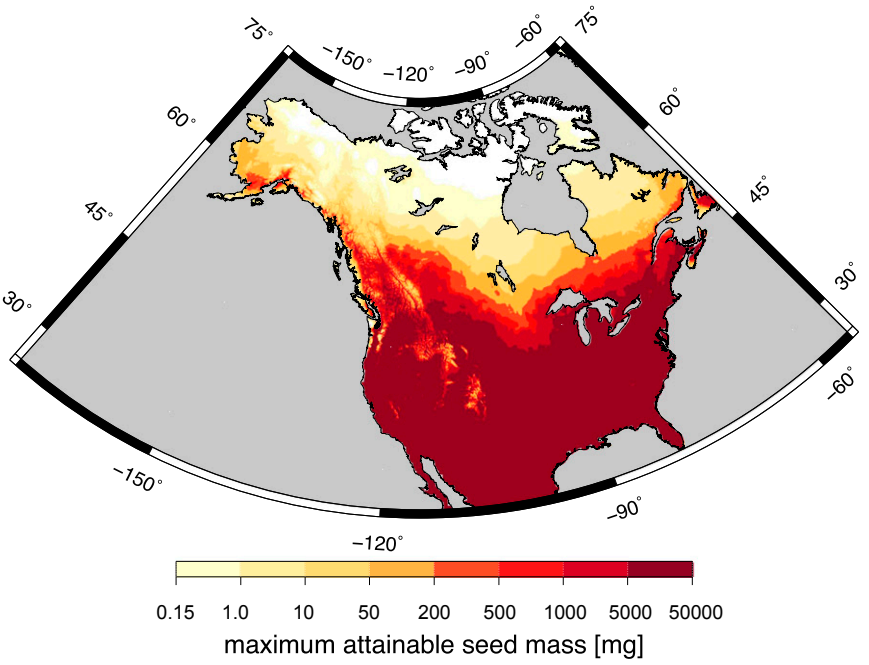

Fig. S4. Map shows maximum attainable seed mass values given the climate. Dark red depicts regions where seed mass values are climatically unconstrained, whereas the color gradient depicts "no-go areas" for North American trees depending on seed mass. The maximum attainable seed mass values shown are derived by applying quantile regression equation (Table S2) to gridded climate data and subsequent selection of the minimum seed mass value predicted per grid cell to visualize the strongest climate constraint on seed mass variation. Gridded climate data used: mean annual T, diurnal T range, T seasonality, annual P, and net P. The map has a resolution of 5 arcmin and is projected in Albers equal-area conic projection.

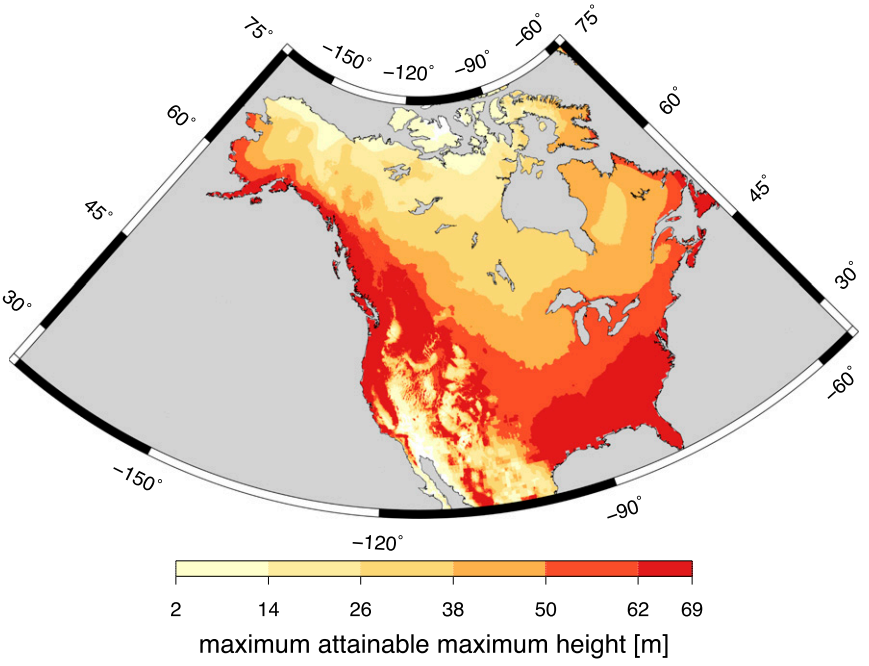

Fig. S5. Map shows maximum attainable maximum height values given the climate for 249 North American tree species (*Sequoia sempervirens* with 100.4 m is excluded). Dark red depicts regions where maximum height values are climatically unconstrained, whereas the color gradient depicts no-go areas for North American trees depending on maximum height. The maximum attainable maximum height values shown are derived by applying quantile regression equation (Table S2) to gridded climate data and subsequent selection of the minimum maximum height value predicted per grid cell to visualize the strongest climate constraint on seed mass variation. Gridded climate data used: T seasonality, annual P, and net P. The map has a resolution of 5 arcmin and is projected in Albers equal-area conic projection.

Table S1. Standardized slopes of linear quantile regression lines for the relationships between traits and climate range measures for 250 North American tree species presented in Fig. S1 and Fig. 2

Bioclimatic variable	Measure	τ	Wood density		Seed mass		SLA		Height		Longevity	
Annual T			**One sided**		**One sided**		One sided		No		No	
	Upper	0.95	0.06	n.s.	0.05	n.s.	−0.01	n.s.	−0.05	n.s.	−0.10	n.s.
	Upper	0.90	0.14	n.s.	0.07	n.s.	−0.11	n.s.	−0.14	n.s.	−0.15	n.s.
	Median	0.50	0.41	***	0.41	***	0.13	n.s.	−0.24	**	−0.25	*
	Lower	0.10	0.55	***	0.63	***	0.20	**	0.02	n.s.	−0.11	n.s.
	Lower	0.05	0.55	***	0.67	***	0.18	n.s.	0.01	n.s.	0.05	n.s.
Diurnal T range			No		**One sided**		Reverse		**Aligned**		One sided	
	Upper	0.95	0.15	n.s.	0.04	n.s.	−0.11	n.s.	−0.21	*	0.09	n.s.
	Upper	0.90	0.10	n.s.	0.03	n.s.	−0.42	**	−0.39	***	0.26	n.s.
	Median	0.50	0.02	n.s.	0.12	*	−0.11	*	−0.17	*	0.06	n.s.
	Lower	0.10	0.25	n.s.	0.62	***	0.11	n.s.	−0.47	*	−0.16	n.s.
	Lower	0.05	0.46	n.s.	0.72	***	0.47	*	−0.41	**	−0.33	*
T seasonality			**One sided**		**One sided**		No		**One sided**†		One sided	
	Upper	0.95	−0.49	***	−0.51	***	−0.02	n.s.	−0.75	***	−0.14	n.s.
	Upper	0.90	−0.45	***	−0.53	***	0.32	n.s.	−0.62	***	−0.29	*
	Median	0.50	−0.04	n.s.	−0.11	n.s.	0.36	***	−0.31	***	−0.20	**
	Lower	0.10	0.01	n.s.	−0.09	n.s.	0.20	n.s.	−0.06	n.s.	−0.08	n.s.
	Lower	0.05	−0.08	n.s.	−0.03	n.s.	0.26	n.s.	0.00	n.s.	−0.06	n.s.
Annual P			No		**One sided**		**One sided**		**Aligned**		Reverse	
	Upper	0.95	−0.40	n.s.	−0.69	***	−0.45	n.s.	0.54	***	0.56	**
	Upper	0.90	−0.26	n.s.	−0.75	**	−0.31	n.s.	0.54	**	0.48	*
	Median	0.05	0.16	*	0.12	n.s.	0.18	*	0.24	*	−0.18	n.s
	Lower	0.10	0.03	n.s.	0.01	n.s.	0.12	***	0.13	**	−0.06	**
	Lower	0.05	0.01	n.s.	0.02	n.s.	0.12	***	0.15	**	−0.05	n.s
P of the coldest quarter			One sided		One sided		One sided		One sided		One sided	
	Upper	0.95	−0.30	n.s.	−0.40	**	−0.31	n.s.	0.28	n.s.	0.28	n.s.
	Upper	0.90	−0.58	*	−0.38	n.s.	−0.77	**	0.69	***	0.64	***
	Median	0.50	−0.02	n.s.	0.08	n.s.	−0.06	n.s.	0.33	**	−0.02	n.s.
	Lower	0.10	0.00	n.s.	0.00	n.s.	0.01	n.s.	0.10	n.s.	−0.01	n.s.
	Lower	0.05	−0.02	n.s.	−0.01	n.s.	0.01	n.s.	0.04	*	−0.01	n.s.
P of the warmest quarter			No		No		No		No		No	
	Upper	0.95	0.05	n.s.	0.12	n.s.	−0.13	n.s.	−0.04	n.s.	−0.02	n.s.
	Upper	0.90	0.10	n.s.	0.09	n.s.	−0.11	n.s.	0.03	n.s.	−0.02	n.s.
	Median	0.50	0.21	**	0.20	***	0.37	***	−0.01	n.s.	−0.33	***
	Lower	0.10	0.03	n.s.	−0.04	n.s.	0.08	n.s.	0.01	n.s.	0.00	n.s.
	Lower	0.05	0.00	n.s.	−0.01	n.s.	0.02	n.s.	0.01	n.s.	0.00	n.s.
GDD			One sided		**One sided**		One sided		No		Aligned	
	Upper	0.95	0.21	n.s.	0.26	n.s.	0.01	n.s.	−0.08	n.s.	−0.16	*
	Upper	0.90	0.23	n.s.	0.09	n.s.	−0.05	n.s.	−0.10	n.s.	−0.23	n.s.
	Median	0.50	0.47	***	0.37	***	0.19	n.s.	−0.33	**	−0.25	*
	Lower	0.10	0.35	***	0.40	***	0.14	*	−0.07	n.s.	−0.10	*
	Lower	0.05	0.14	n.s.	0.42	***	0.07	n.s.	−0.01	n.s.	−0.07	*
Net P			One sided		**One sided**		No		**Aligned**		**One sided**	
	Upper	0.95	−0.17	n.s.	−0.66	**	−0.42	n.s.	0.53	**	0.65	**
	Upper	0.90	−0.44	n.s.	−0.81	**	−0.48	n.s.	0.64	***	0.49	*
	Median	0.50	−0.01	n.s.	0.01	n.s.	0.11	n.s.	0.19	***	−0.06	n.s.
	Lower	0.10	−0.32	*	−0.24	n.s.	0.10	n.s.	0.36	**	−0.12	n.s.
	Lower	0.05	−0.26	n.s.	−0.12	n.s.	0.01	n.s.	0.39	***	−0.06	n.s.

Slope estimates obtained from linear quantile regression relating the three measures defining the climatic ranges of 250 North American tree species (lower limit, upper limit, and median) obtained for eight bioclimatic variables against the five traits, respectively (see *Methods* for details). Both the measures and the traits were standardized to mean = 0 and SD = 1 to obtain comparable slope estimates. For the upper limits we estimated the upper regression quantiles ($\tau = 0.95$ and $\tau = 0.90$), for the lower limits we estimated the lower regression quantiles ($\tau = 0.10$ and $\tau = 0.05$), and for the median we estimated the 50th quantile. The type of proposed response patterns matched (see Fig. 1*C* and *Methods* for rules) is written above each trait–climatic relationship, with boldface identifying obvious patterns for which both outer quantiles (5th, 10th and/or 90th, 95th) show slopes significant different from zero (gray shaded areas in Fig. S1; see *Methods* for details). The significance levels of slopes were indicated as follows: n.s., not significant; ***$P < 0.001$; **$P < 0.01$; and *$P < 0.05$. SLA, specific leaf area.

†Estimates are based on heights larger than 22.3 m which comprises almost 80% of total considered maximum height range (146 species). See Fig. 2 for presentation.

Table S2. Intercepts and slopes of linear quantile regression lines for the relationships between traits and climate range measures for 250 North American tree species presented in Fig. S1

		Wood density				Seed mass				SLA				Maximum height				Longevity			
Bioclimatic variable	τ	β_0	SE	β_1	SE	β_0	SE	β_1	SE	β_0	SE	β_1	SE	β_0	SE	β_1	SE	β_0	SE	β_1	SE
Annual T	0.95																				
	0.90																				
	0.50	−9.0	4.5	29.4	6.1	8.1	1.0	0.8	0.2					17	1.8	−1.0	0.4	22	4.0	−1.8	0.76
	0.10	−30.8	4.8	45.2	6.9	−4.8	1.6	1.3	0.2	−2.9	1.1	0.02	0.01								
	0.05	−32.8	7.3	45.2	9.9	−8.3	1.0	1.4	0.3												
Diurnal T range	0.95													20.6	0.69	−0.34	0.17				
	0.90									19	0.4	−0.01	0.0	21.3	0.74	−0.62	0.13				
	0.50					12	0.2	0.08	0.04	13	0.3	−0.002	0.001	14.1	0.54	−0.24	0.10				
	0.10					6.8	0.7	0.43	0.09					12.3	1.71	−0.73	0.34				
	0.05					5.4	0.7	0.49	0.12	4.64	1.5	0.01	0.006	10.31	1.29	−0.64	0.24	11.7	2.2	−0.88	0.42
T seasonality	0.95	23,745	2,846	−15,083	4,053	14,876	472	−414	75					25,623	1,990	−2,078	305				
	0.90	21,895	2,300	−13,876	3,125	14,325	647	−430	99					22,105	2,279	−1,727	320	17,136	1,782	−916	351
	0.50									5,779	373	8.97	1.81	11,722	838	−718	135	10,364	1,011	−534	196
	0.10																				
	0.05																				
Annual P	0.95					2,949	166	−123	40.7					1,270	409	216	61.6	298	801	386	133
	0.90					2,720	412	−133	47.8					882	266	218	65.6	137	747	333	161
	0.50	534	212	745	273					905	137	0.82	0.59	682	178	69	31				
	0.10									176	30	0.50	0.17	92	63	35	12	418	70	−29	11
	0.05									145	25	0.53	0.17	48	71	38	14				
P of the coldest	0.95					1,135	48	−32	11												
quarter	0.90	2,022	525	−1,756	767					1,197	149	−2.3	0.8	91.8	214	125	32	−334	405	198	69
	0.50													58.6	69	39	13				
	0.10																				
	0.05													12.4	8	3.0	1.9				
P of the warmest	0.95																				
quarter	0.90																				
	0.50	50	85	323	109	231	19	8.4	2.2	155	21	0.56	0.08					556	71	−53	13
	0.10																				
	0.05																				
GDD	0.95																	761	125	−29	23
	0.90																				
	0.50	−268	120	758	160	196	18	16	3					440	43.5	−32	9	502	87	−41	17
	0.10	−265	71	505	113	18	7.6	15	1.7	26	6.3	0.19	0.07					135	48	−15	7.7
	0.05					−1.5	9.6	16.1	2.5									97	25	−10	4.1
Net P	0.95					2,281	168	−117	39					649	448	212	65	−674	1,008	447	167
	0.90					2,111	441	−143	54					57	278	258	71	−527	649	334	142
	0.50													39	92	52	16				
	0.10	438	438	−1,148	746									−1,023	167	96	32				
	0.05													−1,181	116	104	23				

Intercepts (β_0) and slopes (β_1) of significant ($P < 0.05$) linear quantile regression lines (Table S1) with their SE regressing the upper climate ranges limits ($\tau = 0.95$ and $\tau = 0.90$), the lower climate range limits ($\tau = 0.10$ and $\tau = 0.05$), and the median climate preference ($\tau = 0.50$) of 250 North American tree species (146 species for T seasonality versus maximum height, respectively; see Table S1 for further details) obtained for eight bioclimatic variables against the five traits, respectively (see *Methods* for details). Before applying linear quantile regression, traits were transformed to obtain normal distribution as follows: wood density was square-root transformed, seed mass was log transformed, maximum height was square-root transformed, and life span was log transformed.

Table S3. Intercepts and slopes of linear quantile regression lines for the relationships between maximum height and climate range measures for all North American tree species without *S. sempervirens* with maximum height of 100.4 m

		Maximum height of 249 tree species without *S. sempervirens* = 100.4 m			
Bioclimatic variable	τ	β_0	SE	β_1	SE
Annual mean T	0.95				
	0.90				
	0.50	18.5	1.6	−1.2	0.3
	0.10				
	0.05				
Diurnal T range	0.95	20.5	0.70	−0.31	0.16
	0.90	21.2	0.86	−0.58	0.16
	0.50	14.2	0.5	−0.27	0.10
	0.10	12.5	1.8	−0.77	0.36
	0.05	10.31	1.30	−0.64	0.24
T seasonality	0.95	26,700.55	2,280.67	−2,294.15	347.50
	0.90	22,726.80	2,710.90	−1,803.77	381.72
	0.50	11,633.98	885.80	−702.24	140.13
	0.10				
	0.05				
Annual P	0.95	1,270	394	215	61.2
	0.90	806	311	228	77
	0.50	677	180	71	31
	0.10	112	59	32	12
	0.05	53	79	37	16
P of the coldest quarter	0.95				
	0.90	68	201	131	30
	0.50	62	67	38	13
	0.10				
	0.05	12.4	8	3.0	1.8
P of the warmest quarter	0.95				
	0.90				
	0.50				
	0.10				
	0.05				
GDD	0.95				
	0.90				
	0.50	440	47	−32	9
	0.10				
	0.05				
Net P	0.95	649	482	212	75
	0.90	57	267	258	65
	0.50	19	96	56	18
	0.10	−1,148	160	128	31
	0.05	−1,265	174	124	34

Intercepts (β_0) and slopes (β_1) of significant linear quantile regression lines (Table S1) with their SE regressing the upper envelope limits (τ = 0.95, 0.90), the envelope median (τ = 0.50) and the lower envelope limits (τ = 0.10, 0.05) of 249 North American tree species against maximum height.

Other Supporting Information Files

Dataset S1 (TXT)