Supplemental material

Appendix 1

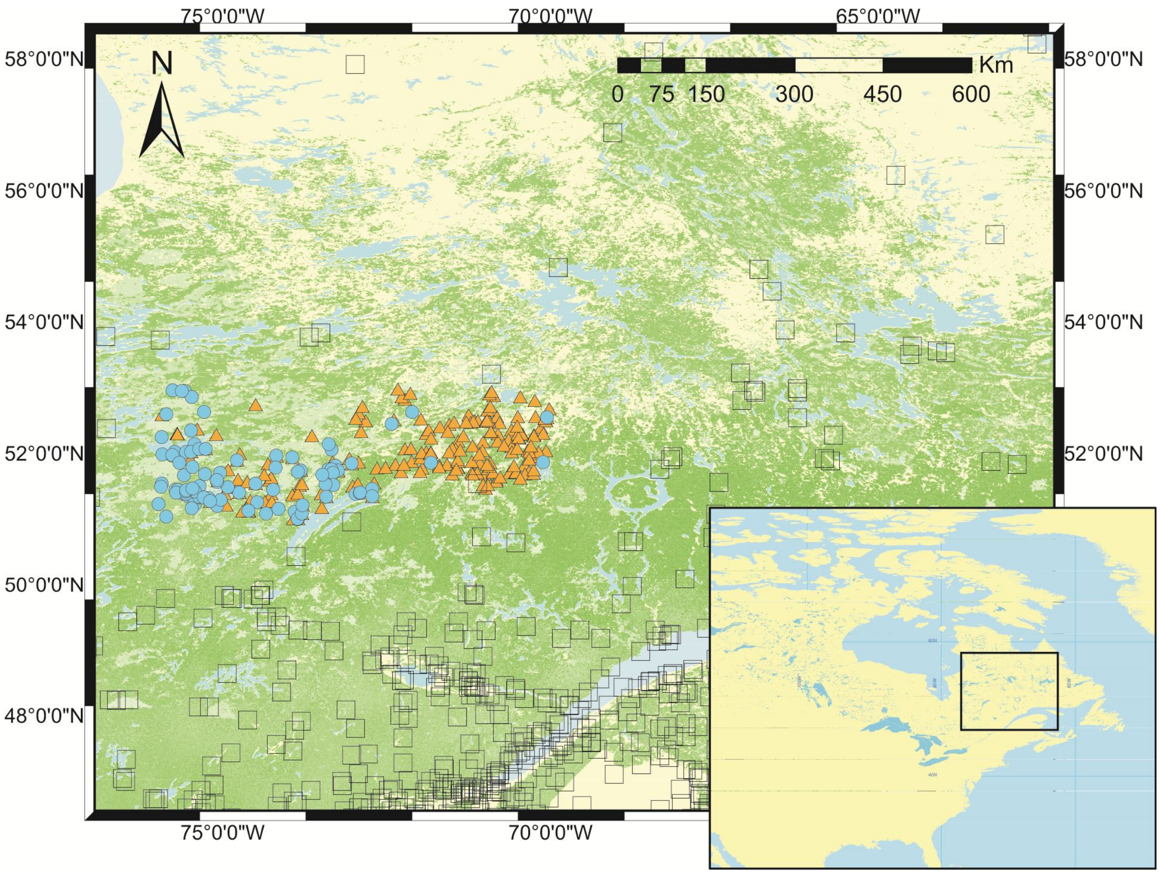

Fig. S1. Distribution of tree-ring sampling sites used in this study. Triangles and circles denote black spruce and jack pine dominated stands, respectively. The distribution of available weather stations across the territory is shown by squares. The background colours indicate the stand age distribution as of 2008 (data from Chen et al. 2003), with darker tones referring to mature and overmature stands.

Appendix 2

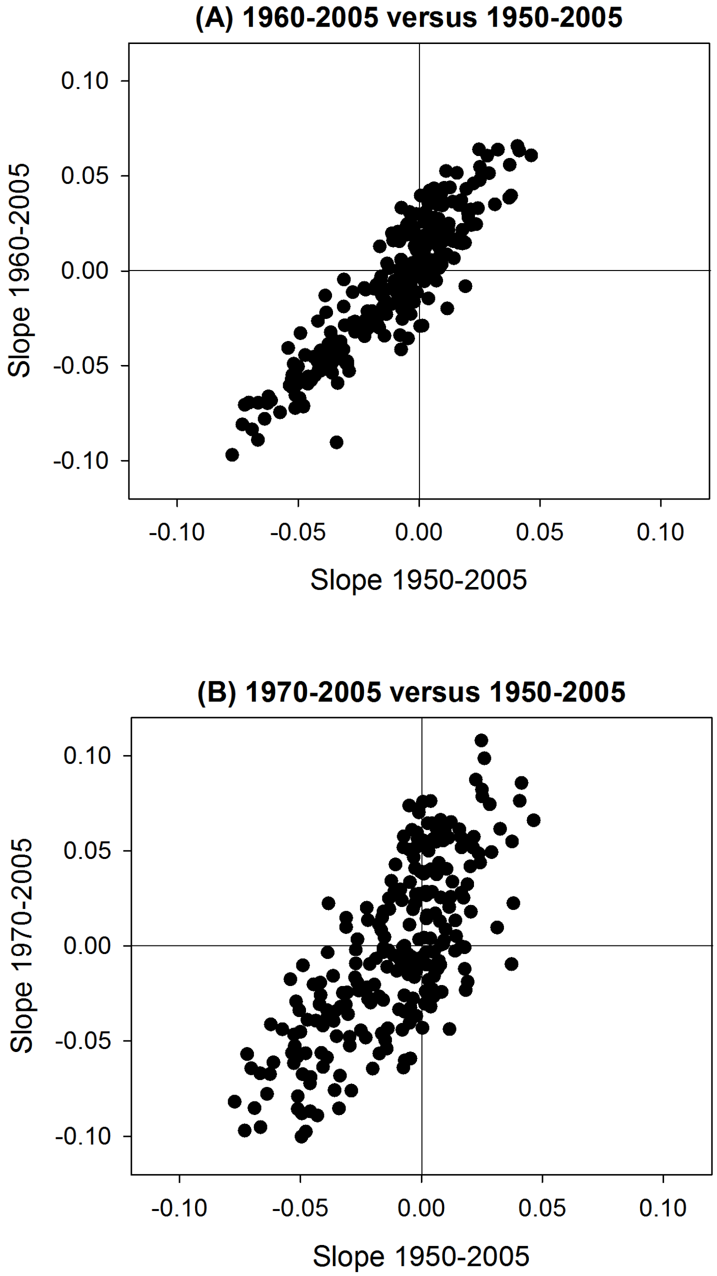

Fig. S2. Sensitivity analysis of linear fits to the 252 plot-level tree growth indices (TGI) of jack pine and black spruce. The two biplots show the slopes (standardized units) of the linear trends over 1950–2005 against those of a) 1960–2005 and b) 1970–2005.

Appendix 3

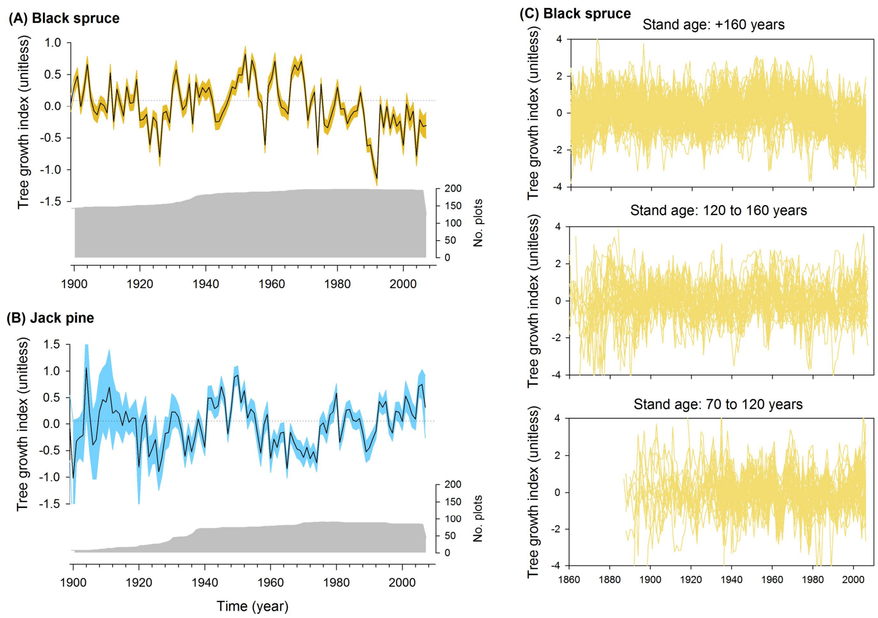

Fig. S3. (a-b) Species-specific TGI times series averaged across all plots with 95% confidence intervals. Also shown is the number of sample plots used across time. c) Individual black spruce plot-level TGI time series; three stand age groups are shown.

Appendix 4

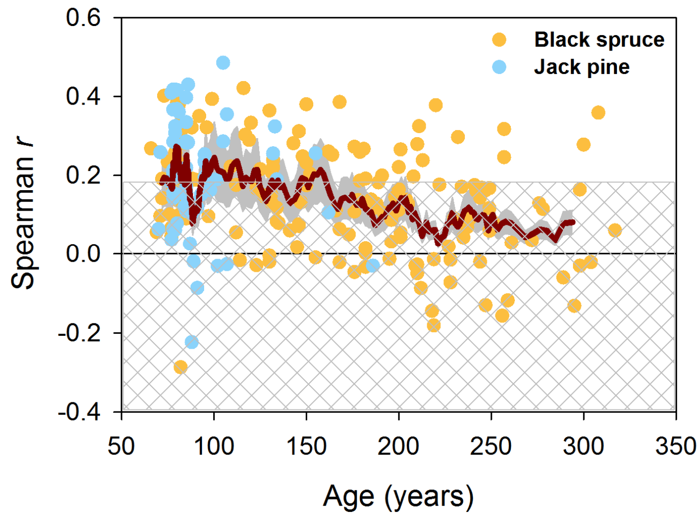

Fig. S4. Spearman correlation coefficients computed between the 252 plot-level tree growth index (TGI) time series and mean April-May daily temperatures. The period of analysis is 1950–2005. The cross-hatched area marks the critical limit at which the null hypothesis of ‘no significant correlation’ is rejected (*P* < 0.10; one-sided test). The thick-solid line shows the mean correlation within a moving window of 11 observations; the shaded area shows 95% confidence interval. Autocorrelation in the TGI data was removed prior to analysis using autoregressive modeling.

Appendix 5

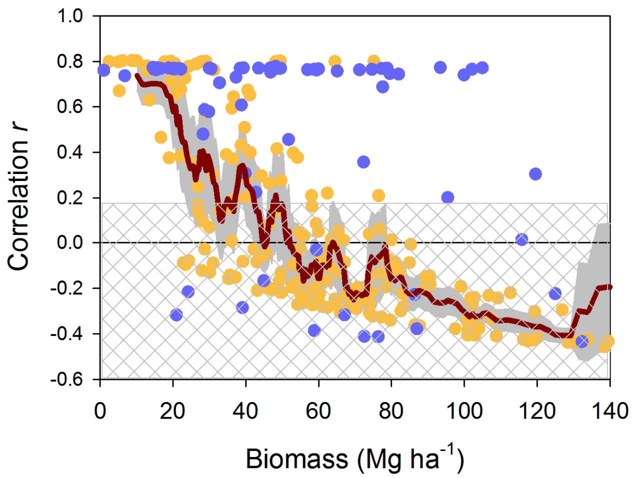

Fig. S5. Pearson correlation coefficients computed between the 284 plot-level simulations of NPP and mean April-May daily temperatures. The period of analysis is 1950–2005. The cross-hatched area marks the critical limit at which the null hypothesis of ‘no significant correlation’ is rejected (*P* < 0.10; one-sided test). The thick-solid line shows the mean correlation in black spruce within a moving window of 11 observations; the shaded area shows 95% confidence interval.

Appendix 6

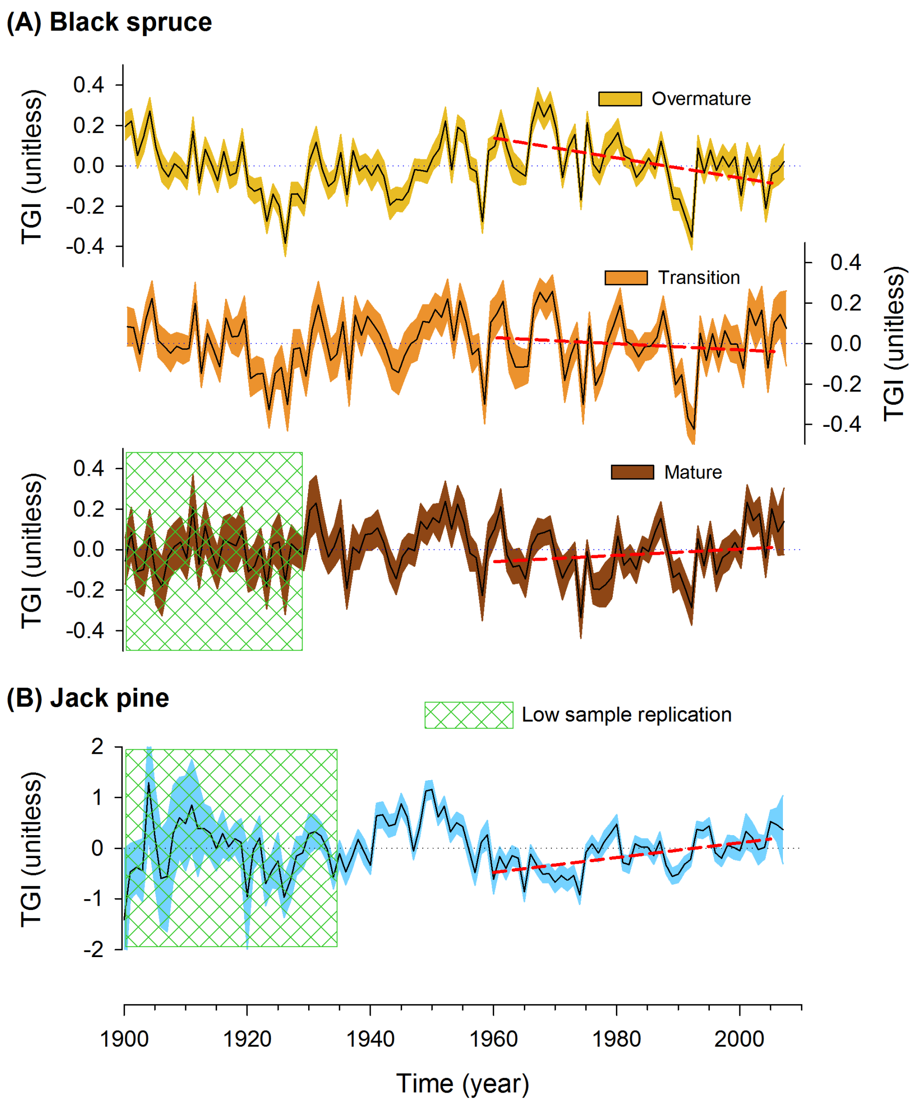

Fig. S6. Means of (a) black spruce and (b) jack pine plot-level TGI time series with 95% confidence intervals. Black spruce TGI time series were pooled according to their position along axis II of the RDA ordination diagram (Fig. 2), with ‘mature’ gathering all plot-level TGI time series with axis II loading ranging from –0.40 to –0.05, ‘transition’ gathering those with loading from –0.05 to 0.05, and ‘overmature’ gathering those between 0.05 and 0.40. The four averaged time series were detrended using a secondorder polynomial curve fitted over 1900–2005 to constrain them to a similar frequency spectrum; the lowest frequency component in all series is thus 106 years. For each series, a trend line is fitted over 1960–2005.

Appendix 7

Computation of the tree growth index (TGI) time series

All ring-width measurement series were rescaled using a power transformation method and detrended using negative exponential modeling in order to eliminate noise caused by site- and biological-related effects such as resulting from competition, self-thinning and aging. The method used for computation of the plot-level TGI time series was derived from methods described by Cook and Peters (1997):

1) the first 10 years of each measurement series was removed to avoid biases induced by the abrupt phase of post-fire growth acceleration at the juvenile stage;

2) the power for each individual tree ring series was estimated and applied using the power transformation method;

3) each individual transformed series was fitted with three growth trend models, that is, linear (*L*), negative exponential (*NE*) and generalized negative exponential (*GNE*):

$$\begin{aligned} &L : Gt = a + bt \\ &NE : Gt = a * \exp(bt) \\ &GNE : Gt = a * \exp(bt) * t^c \end{aligned}$$

where t represents year;

4) the model was selected by comparing the R^2 of the candidate models. The one with higher R^2 between *L* and *NE* was selected; *GNE* was selected if its R^2 was over 5% more than the one selected from above;

5) the TGI time series were calculated using biweight robust means of the differences between the transformed ring series and the selected growth trend model. Analyses were conducted using SAS software.

Application of a more flexible detrending procedure, i.e. cubic smoothing spline functions of wavelength equal to 67% of the ring-width series length with 50% frequency response and calculation of TGI time series as ratios of ring width to predicted growth, yielded similar results (Fig. S7).

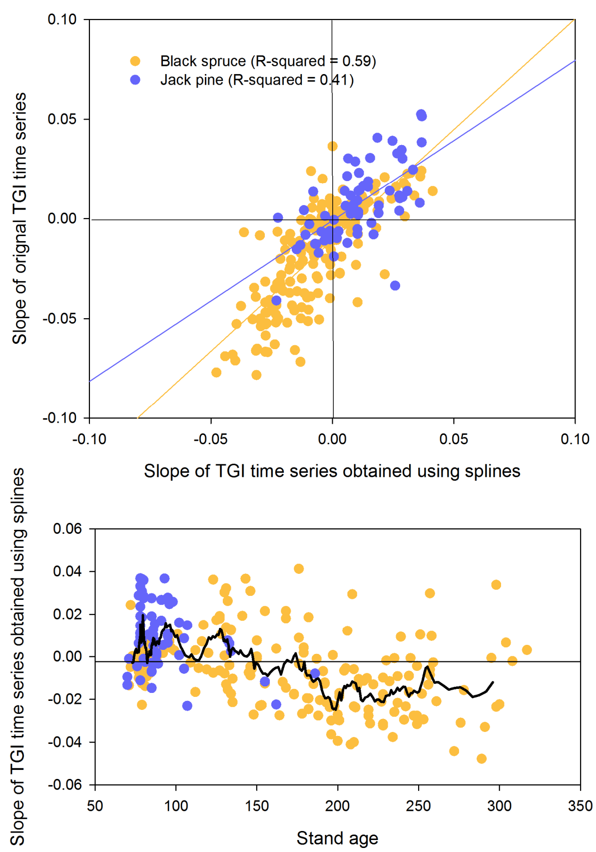

Fig. S7. Top: Comparison of linear fits to the 252 plot-level tree growth indices (TGI) of jack pine and black spruce derived from the application of two different statistical methods of tree-ring measurement detrending, i.e. the generalized negative exponential modeling described in Appendix 7 (original TGI) versus the smoothing spline functions of wavelengths equal 67% of the ring-width series length with 50% frequency response. Bottom: Trends in TGI obtained from spline functions versus stand age. Results are in agreement with those presented in Fig. 1e.

Appendix 8

Table A1. Parameters and allometric coefficients used in the bioclimatic model StandLEAP.

Description	Black spruce	Jack pine
Plot-level partition model parameters		
Allometric coefficient *a* relating foliage biomass to crown biomass; these are the parameters of the equation $y = ax^b$, where x is the crown biomass	0.667	0.825
Allometric coefficient *b* relating foliage biomass to crown biomass; these are the parameters of the equation $y = ax^b$, where x is the crown biomass	0.978	0.931
Allometric coefficient *a* relating stem biomass to aboveground biomass; these are the parameters of the equation $y = ax^b$, where x is the crown biomass	0.359	0.600
Allometric coefficient *b* relating stem biomass to aboveground biomass; these are the parameters of the equation $y = ax^b$, where x is the crown biomass	1.065	1.030
Allometric coefficient *a* relating coarse root biomass to aboveground biomass; these are the parameters of the equation $y = ax^b$, where x is the crown biomass	1.263	1.401
Allometric coefficient *b* relating coarse root biomass to aboveground biomass; these are the parameters of the equation $y = ax^b$, where x is the crown biomass	0.983	0.791
Allometric coefficient *a* relating crown biomass to aboveground biomass; these are the parameters of the equation $y = ax^b$, where x is the crown biomass	2.111	2.007
Allometric coefficient *b* relating crown biomass to aboveground biomass; these are the parameters of the equation $y = ax^b$, where x is the crown biomass	0.811	0.762
Tree-level partition model parameters		
Allometric coefficient *a* relating aboveground biomass and DBH; these are the parameters of the equation $y = ax^b$, where x is the average	0.144	0.068

DBH		
Allometric coefficient *b* relating aboveground biomass and DBH; these are the parameters of the equation $y = ax^b$, where x is the average DBH	2.260	2.488
Allometric coefficient *a* relating stem sapwood biomass and DBH; these are the parameters of the equation $y = ax^b$, where x is the average DBH	0.029	0.012
Allometric coefficient *b* relating stem sapwood biomass and DBH; these are the parameters of the equation $y = ax^b$, where x is the average DBH	2.584	2.686
Fine root foliage ratio	0.750	1.473
Epsilon and water use efficiency model parameters		
Parameter β_l for the epsilon temperature modifier[(1)]	0.456	0.359
Parameter β_q for the epsilon temperature modifier[(1)]	-0.250	-0.194
Parameter $\overline{X}$ for the epsilon temperature modifier[(1)]	13.336	13.332
Parameter β_l for the epsilon VPD modifier[(1)]	0	0
Parameter β_q for the epsilon VPD modifier[(1)]	0	0
Parameter $\overline{X}$ for the epsilon VPD modifier[(1)]	0.653	0.653
Average quantum efficiency (mol C (mol photon)$^{-1}$)	0.011	0.015
Parameter β_l for the epsilon leaf area index modifier[(1)]	0.204	0.347
Parameter β_q for the epsilon leaf area index modifier[(1)]	-0.271	-0.166
Parameter $\overline{X}$ for the epsilon leaf area index modifier[(1)]	5	5
Parameter β_l for the epsilon PAR modifier[(1)]	0	0
Parameter β_q for the epsilon PAR modifier[(1)]	0	0
Parameter $\overline{X}$ for the epsilon PAR modifier[(1)]	1047.307	1036.687
Parameter β_l for the water use efficiency - leaf area index modifier[(1)]	-0.463	0
Parameter β_q for the water use efficiency - leaf area index modifier[(1)]	0.048	0
Parameter β_l for the water use efficiency – VPD modifier[(1)]	0.952	0.782
Parameter β_q for the water use efficiency – VPD modifier[(1)]	-0.087	0
Average water use efficiency (mol CO_2/mol H_2O/kPa)	0.0036	0.0040
Parameter β_l for mortality model climate modifier[(1)]	0.805	1.268
Parameter β_q for mortality model climate modifier[(1)]	-0.895	0

Parameter $\overline{X}$ for mortality model climate modifier[1]	0.534	0.717
Parameter β_l for mean ratio of aboveground mass increment over aboveground mass	-4.897	0
Parameter β_q for mean ratio of aboveground mass increment over aboveground mass	2.681	0
Ingrowth model parameters		
Parameter of the relationship between the extinction coefficient and leaf area index	0.851	0.748
Parameter of the relationship between the extinction coefficient and leaf area index	-0.152	-0.252
Degree days (0°C) to bud break	300.000	116.000
Degree days to end of leaf expansion	800.000	766.664
Lower base temperature for growing degree days sum	0	2.900
Mean foliage retention time (number of growing seasons)	8.621	4.180
Julian day when leaf fall is allowed to start (day)	270.00	270.000
Proportion of GPP partitioned to growth respiration	0.200	0.200
R_{m10} for respiration rate at 10°C	0.0106	0.011
Nitrogen concentration of foliage (gN / gC)	0.007	0.009
Nitrogen concentration of fine roots (gN / gC)	0.009	0.003
Nitrogen concentration of wood (gN / gC)	0.000	0.000
Nitrogen structure roots	0.000	0.000
Q_{10Rm} for temperature sensitivity of R_m, defined as the relative increase in respiration for a 10°C increase in temperature	2.000	2.000
R_{10} for relative increase in heterotrophic respiration for a 10°C increase in temperature (*Lloyd and Taylor*, 1994)	0.800	0.800
Heterotrophic respiration y_0 parameter; these are the parameters of the equation $R_h = y_o + ae^{bT}$, where T is monthly mean temperature	–5.252	–5.252
Heterotrophic respiration a parameter; these are the parameters of the equation $R_h = y_o + ae^{bT}$, where T is monthly mean temperature	18.302	18.302
Heterotrophic respiration b parameter; these are the parameters of the equation $R_h = y_o + ae^{bT}$, where T is monthly mean temperature	0.075	0.075

1. Expressed using the quadratic function $f_x = 1 + \beta_{lx}\left(\frac{x-\bar{x}}{\bar{x}}\right) + \beta_{qx}\left(\frac{x-\bar{x}}{\bar{x}}\right)^2$