Supplementary materials

Supplementary Figures and Tables

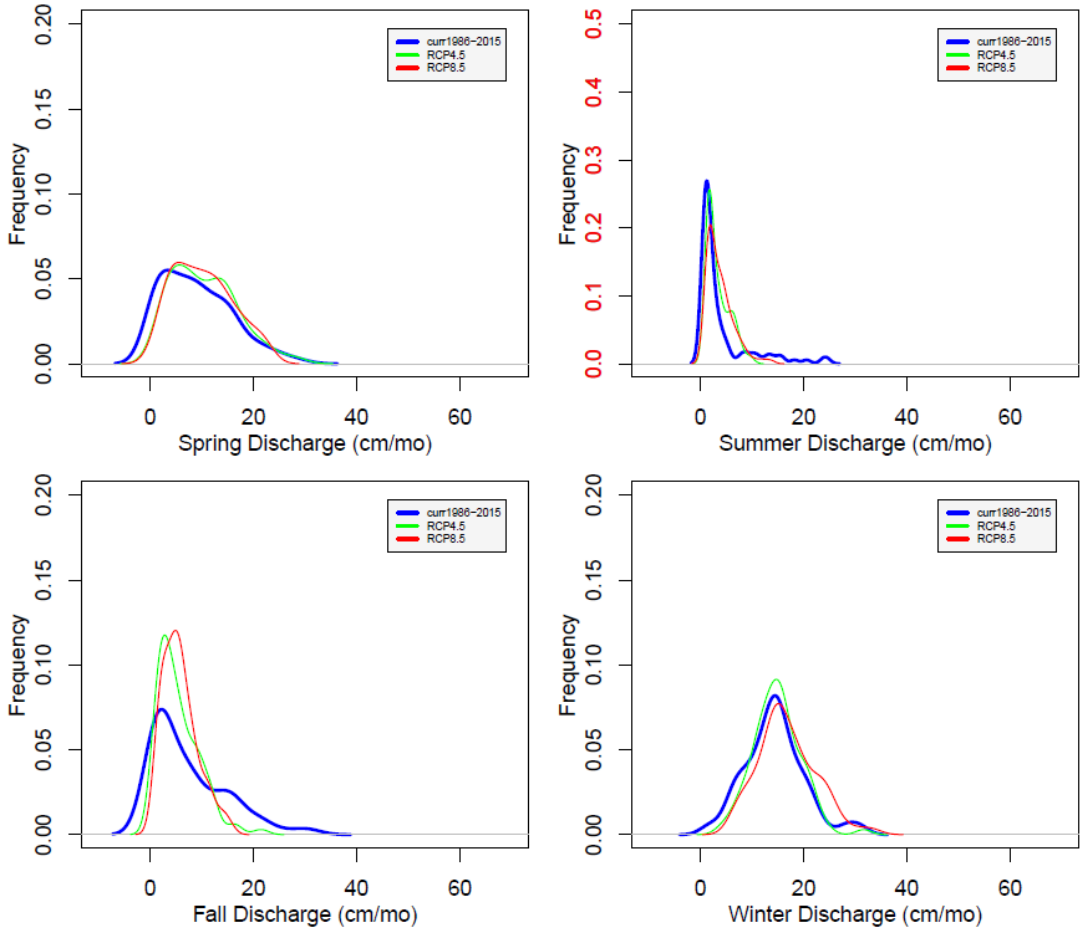


Fig. S1a Comparison of simulated discharge between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models) at WS18.

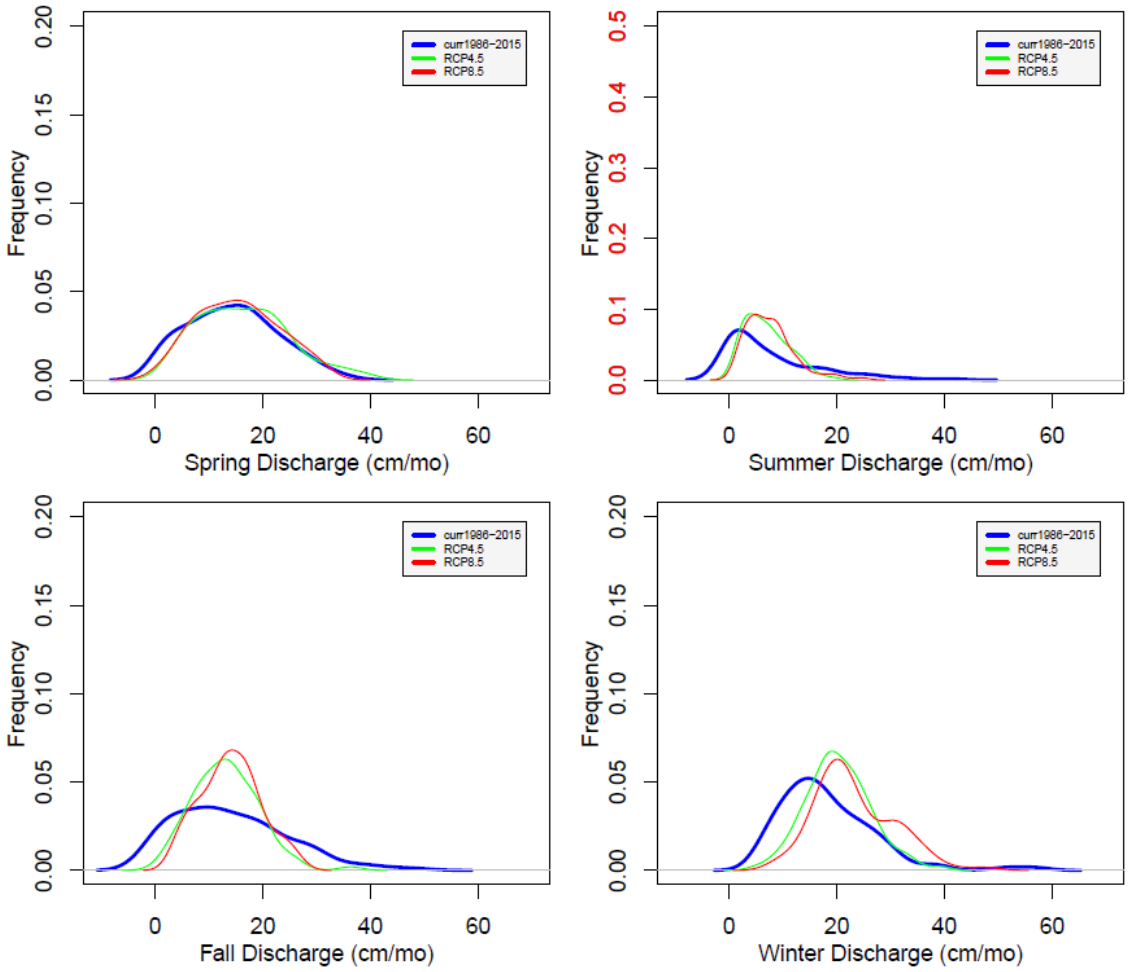


Fig. S1b Comparison of simulated discharge between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models) at WS27.

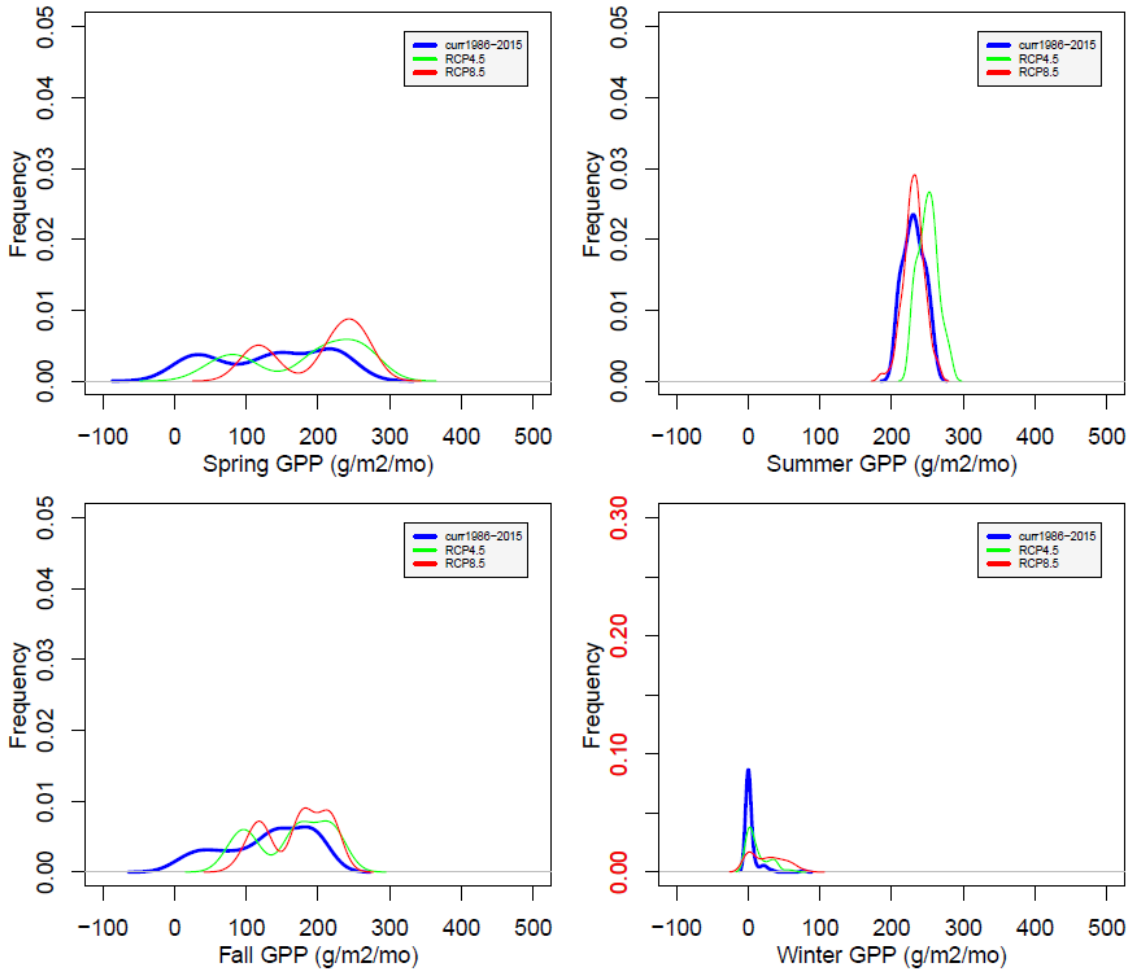


Fig. S2a Comparison of simulated Gross Primary Productivity (GPP) between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models) at WS18.

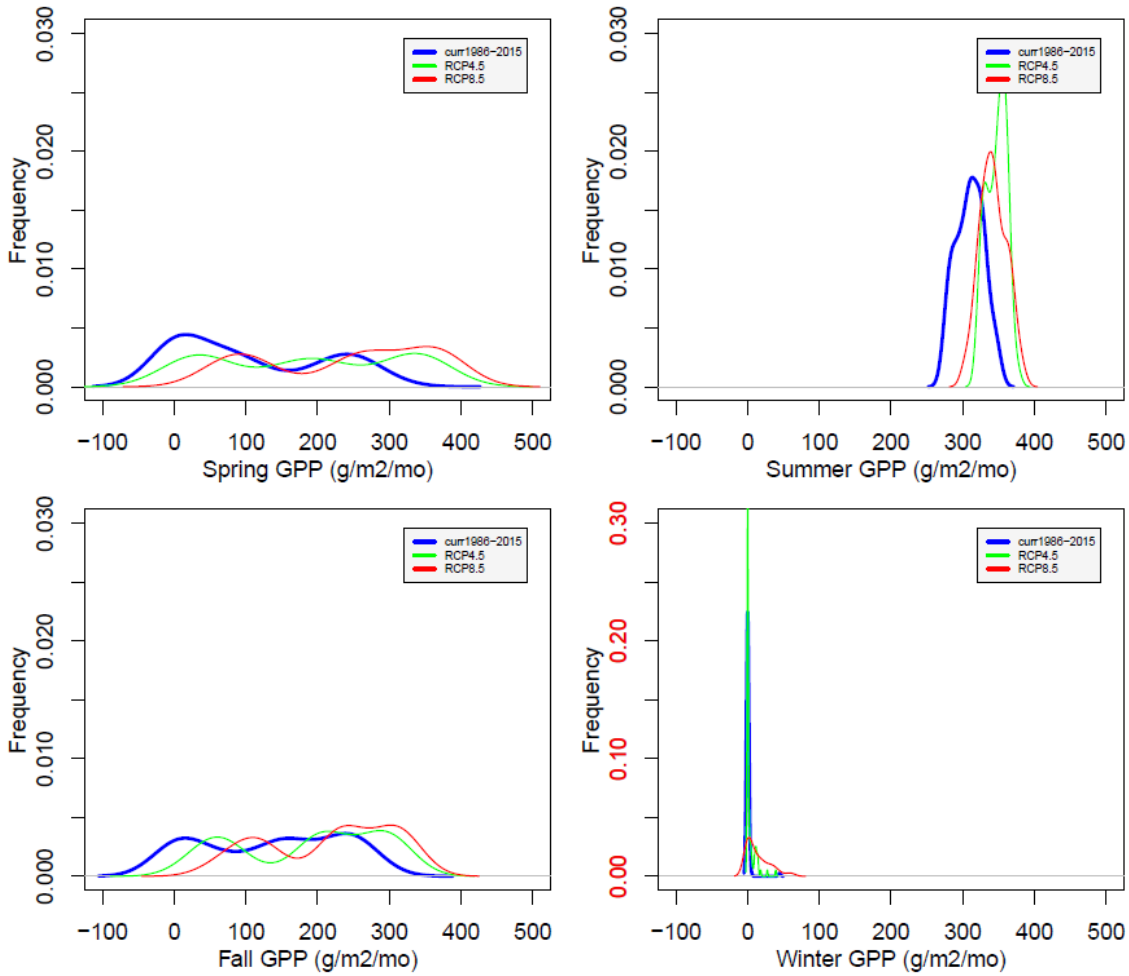


Fig. S2b Comparison of simulated Gross Primary Productivity (GPP) between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models) at WS27.

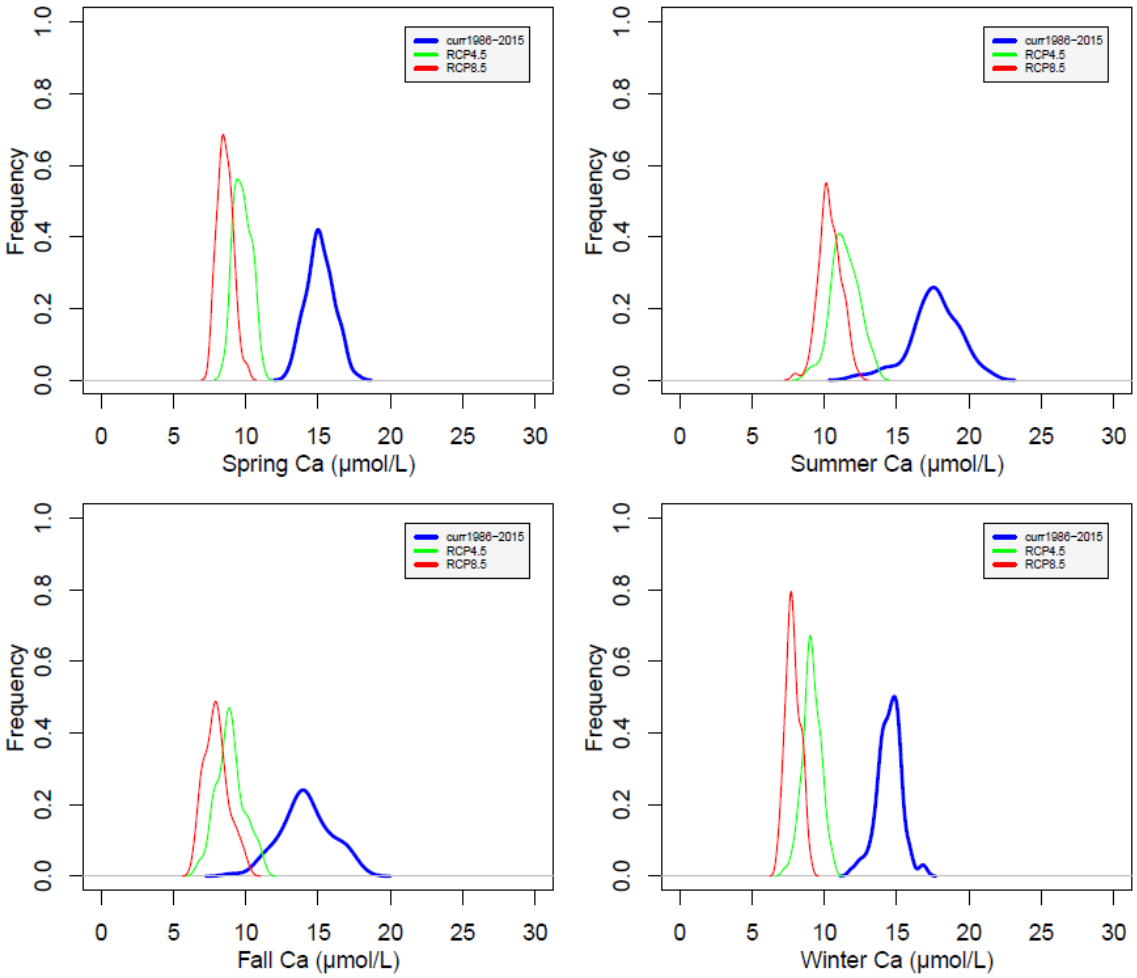


Fig. S3a Comparison of simulated stream Ca^{2+} between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models) at WS18.

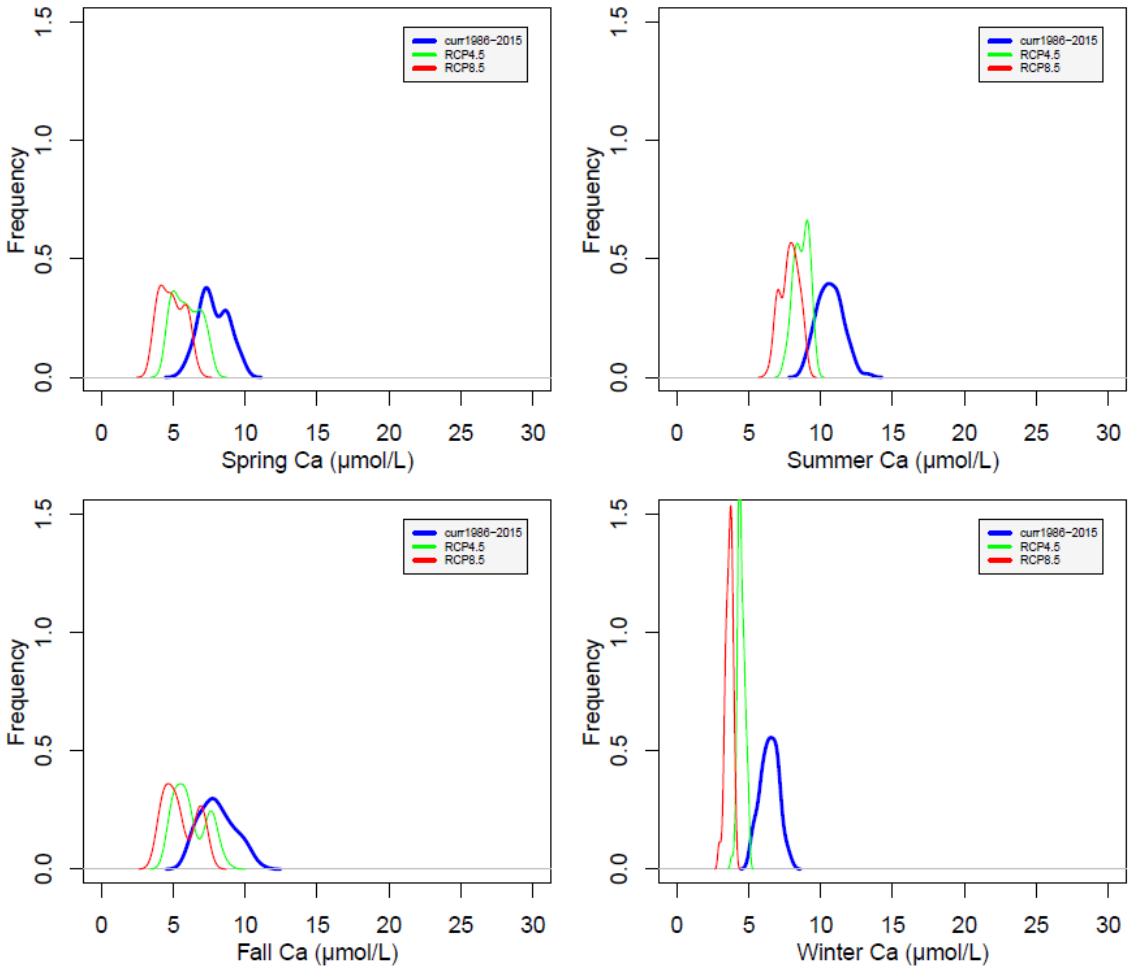


Fig. S3b Comparison of simulated stream Ca^{2+} between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models) at WS27.

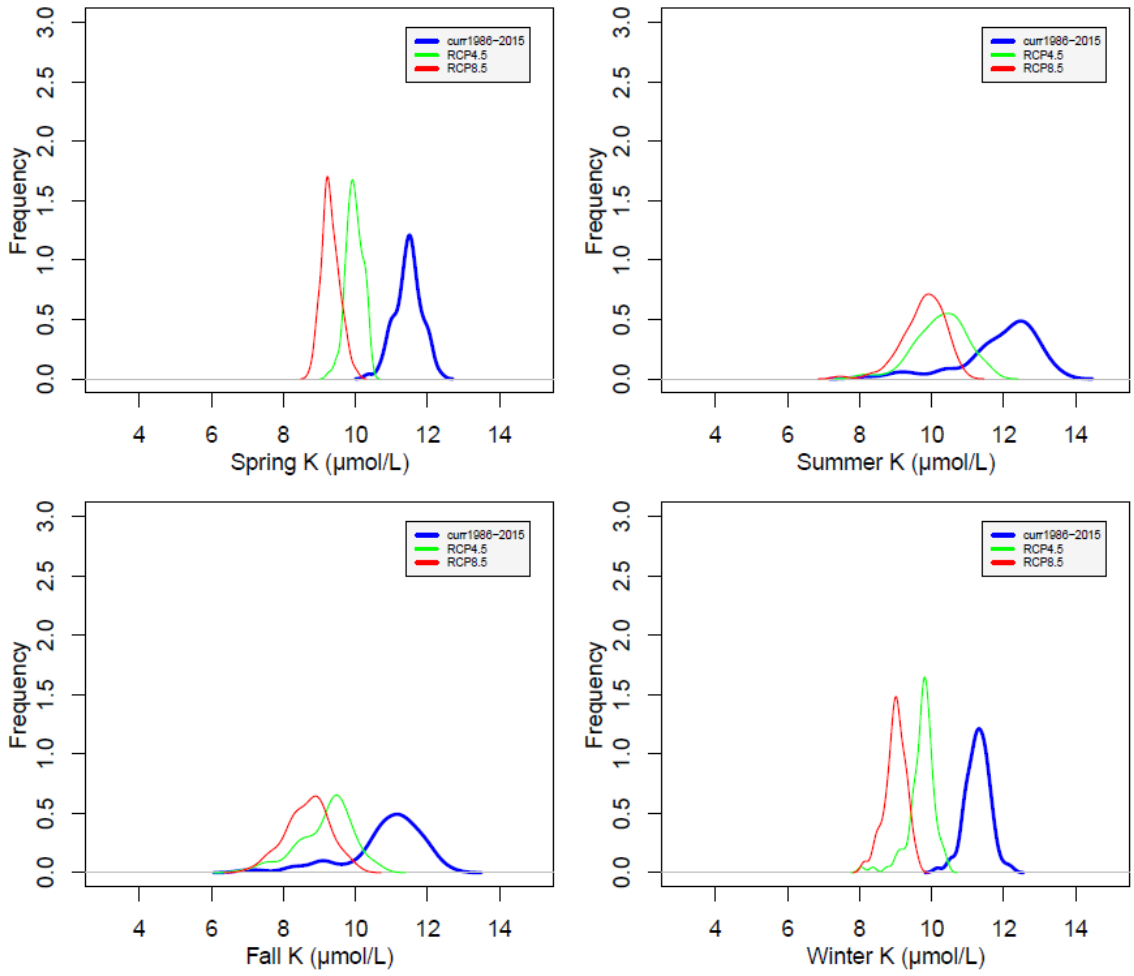


Fig. S4a Comparison of simulated stream K^+ between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models) at WS18.

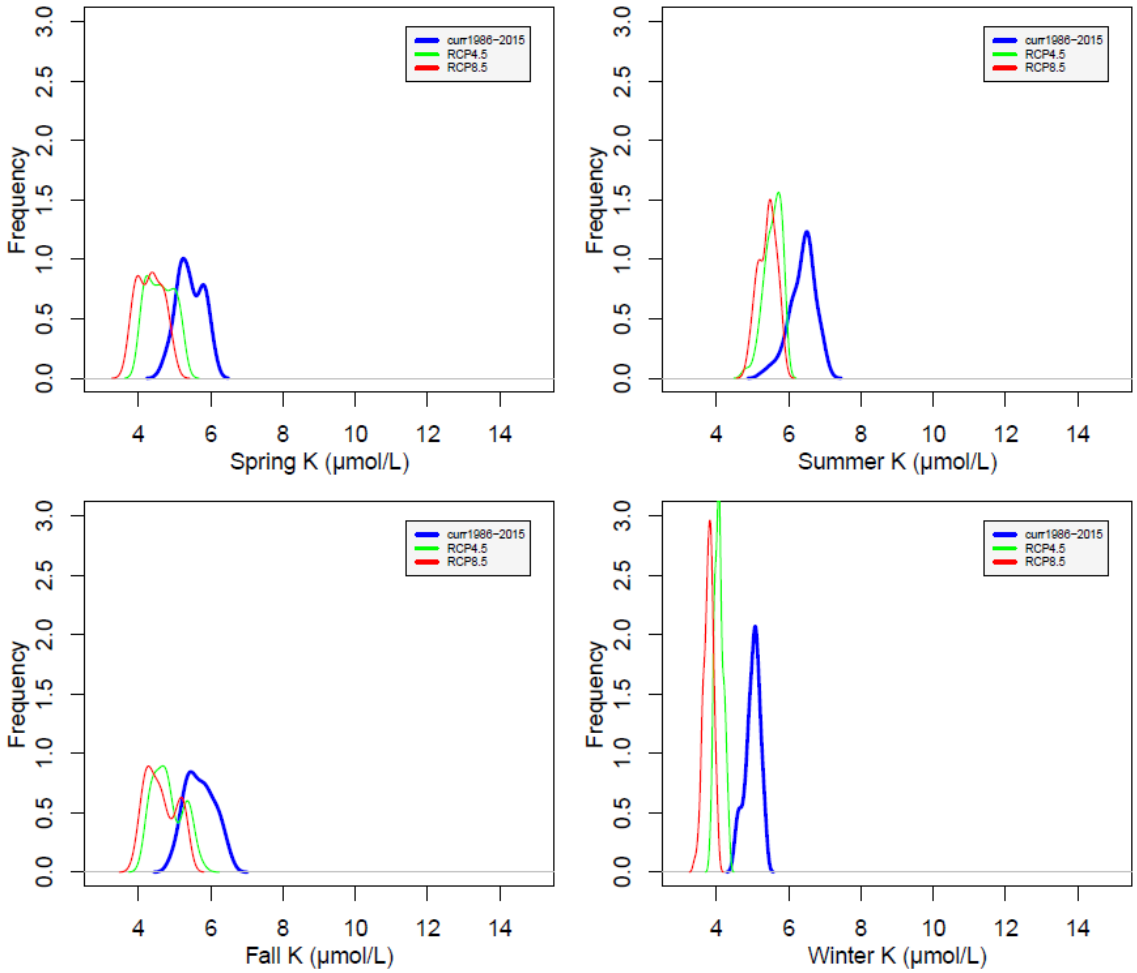


Fig. S4b Comparison of simulated stream K^+ between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models) at WS27.

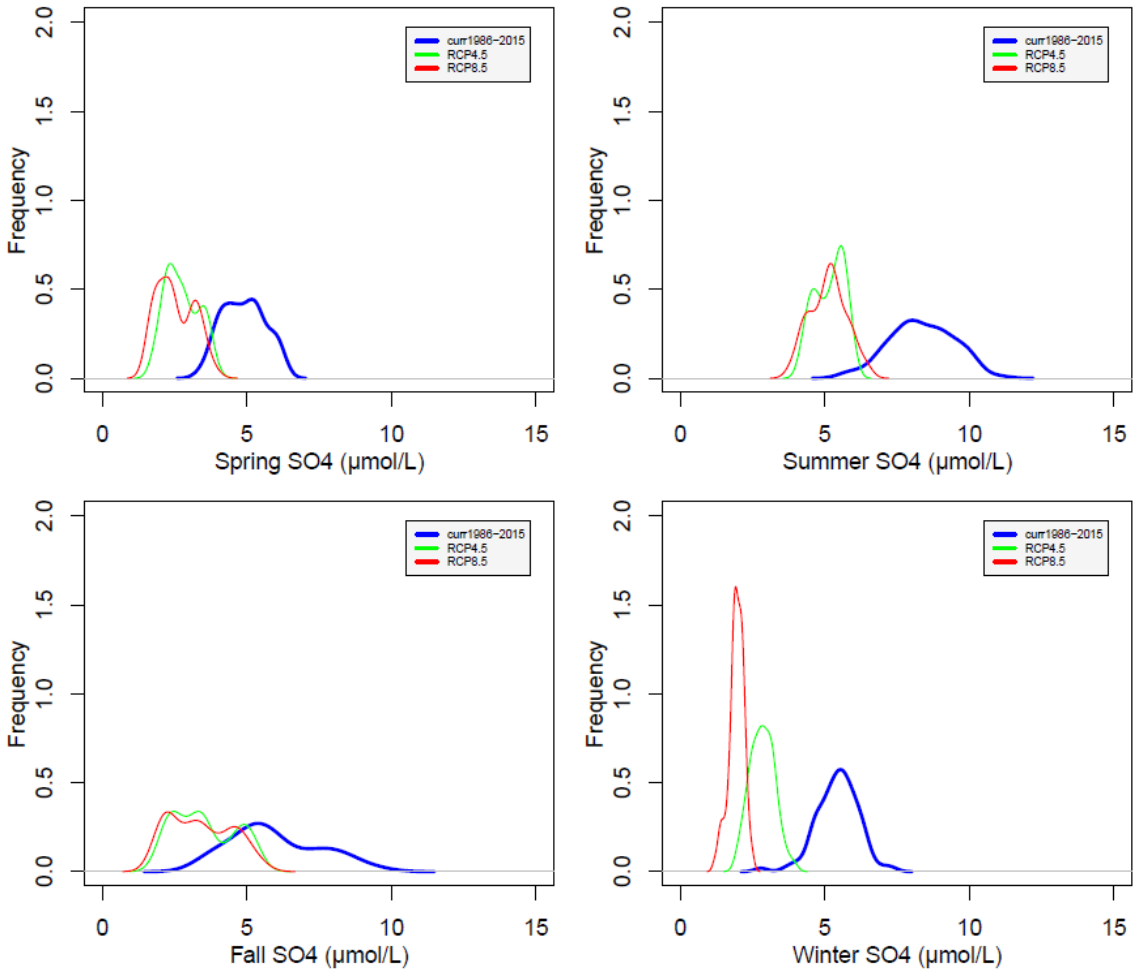


Fig. S5a Comparison of simulated stream SO_4^{2-} between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models at WS18.

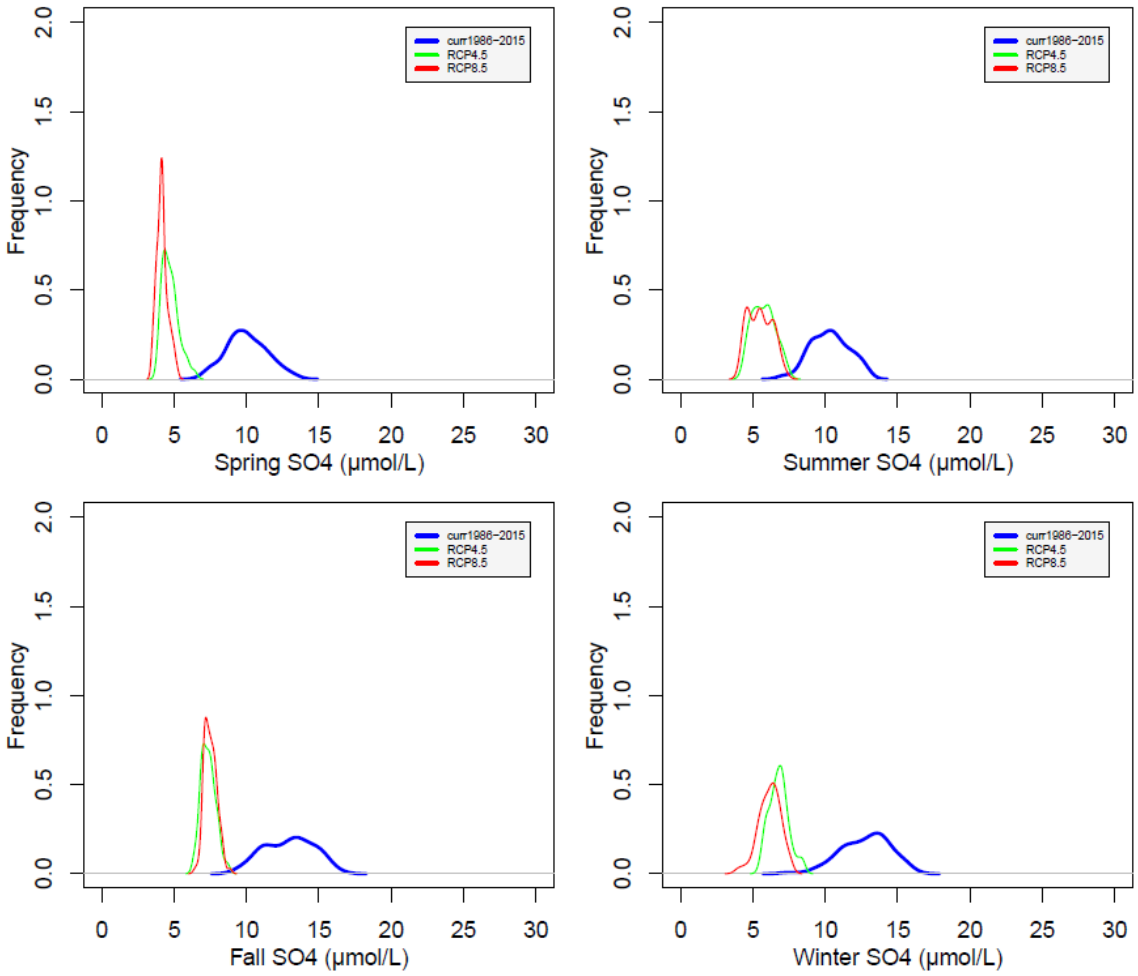


Fig. S5b Comparison of simulated stream SO_4^{2-} between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models at WS27.

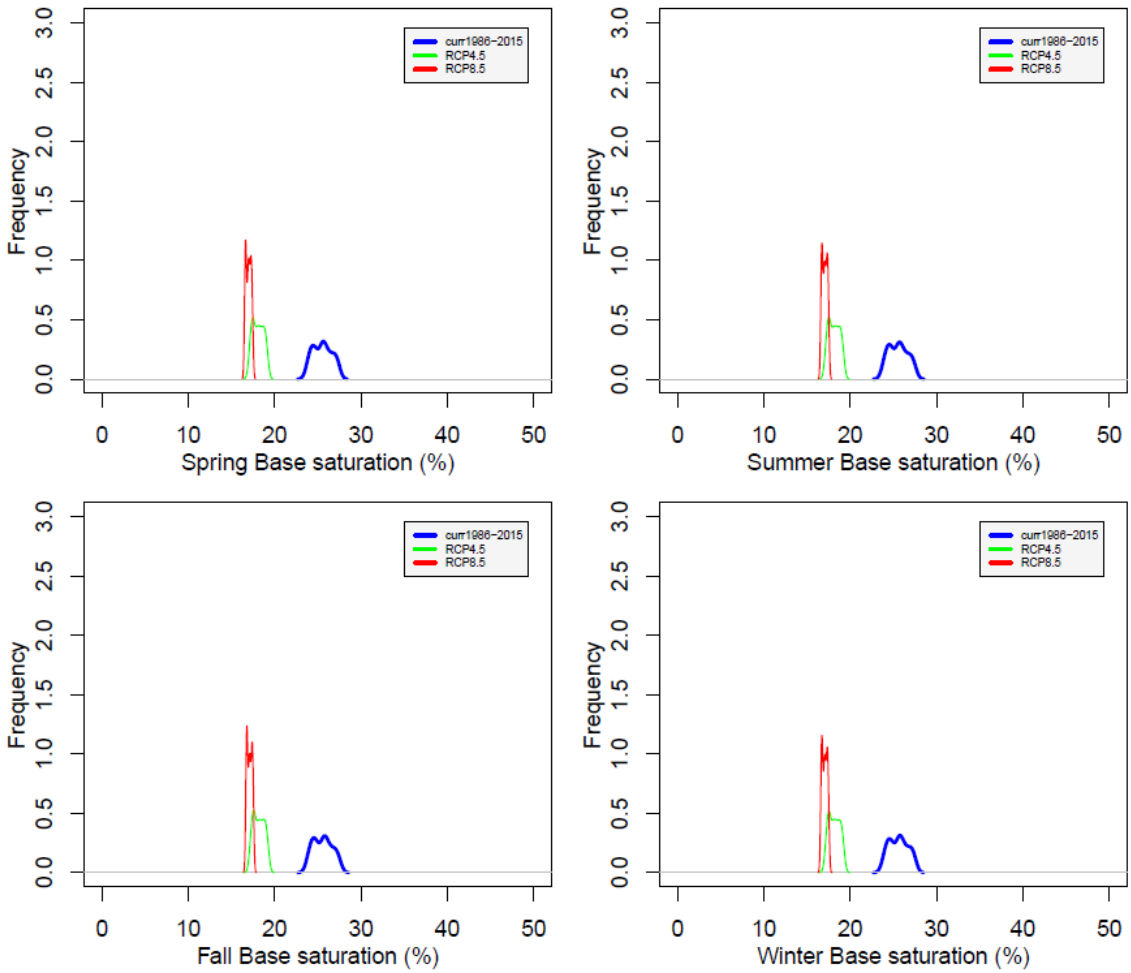


Fig. S6a Comparison of simulated base saturation between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models at WS18.

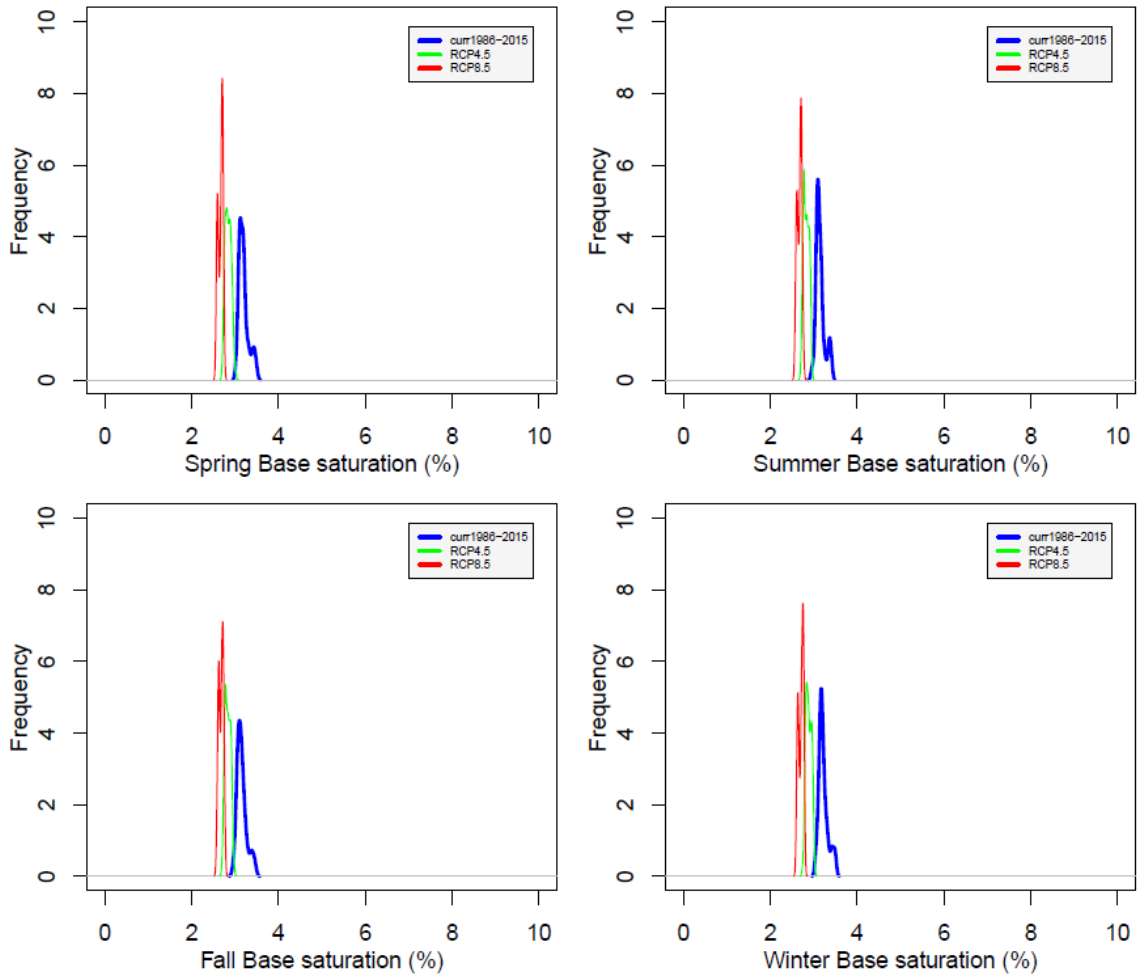


Fig. S6b Comparison of simulated base saturation between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models at WS27.

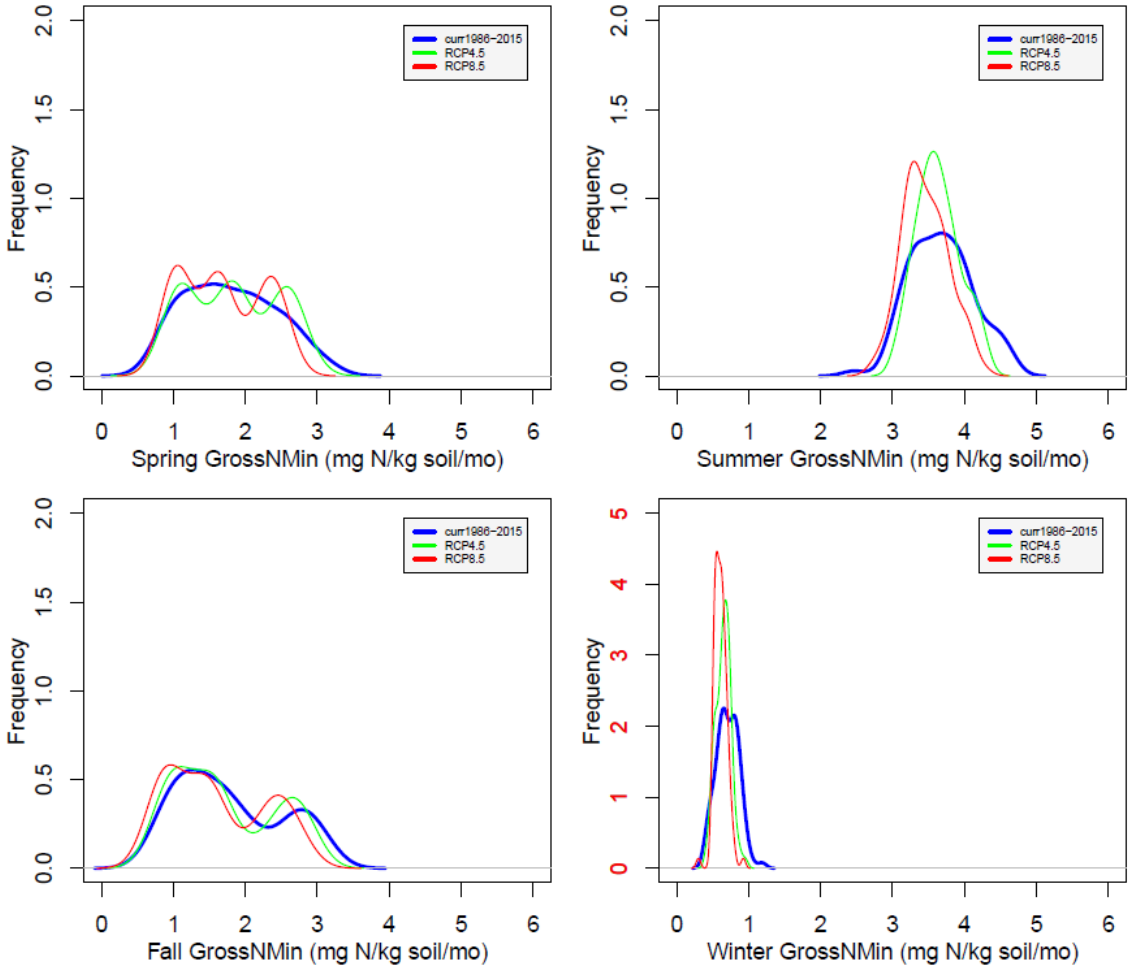


Fig. S7a Comparison of simulated gross nitrogen mineralization between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models at WS18.

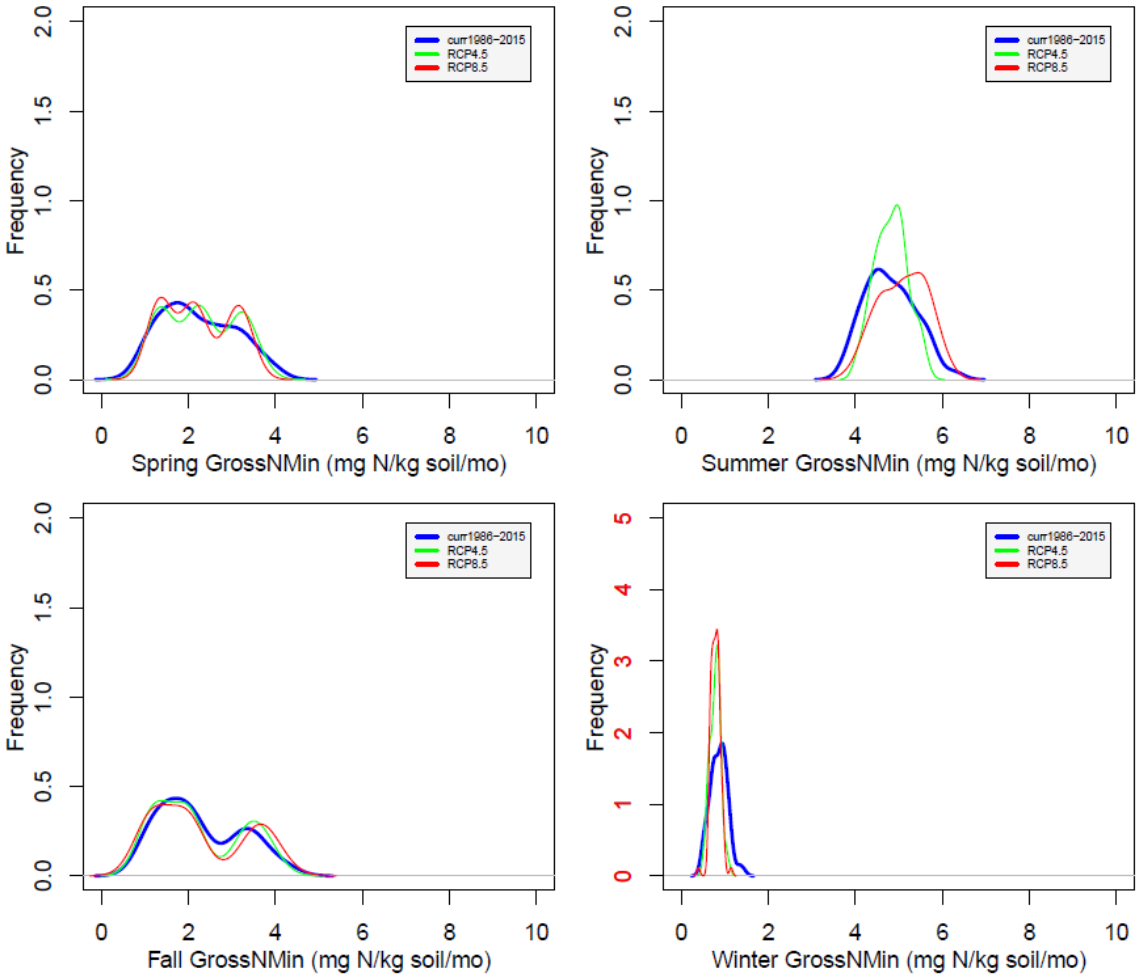
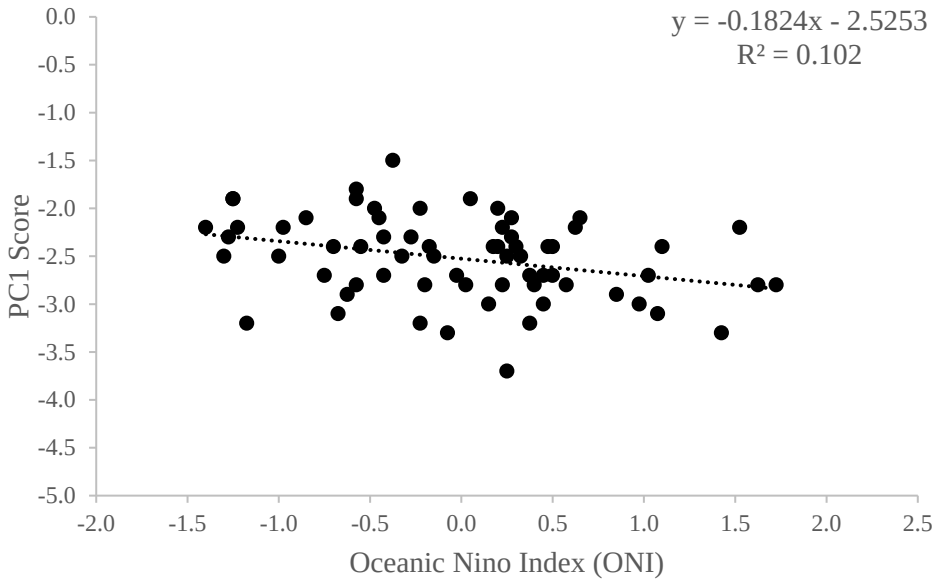
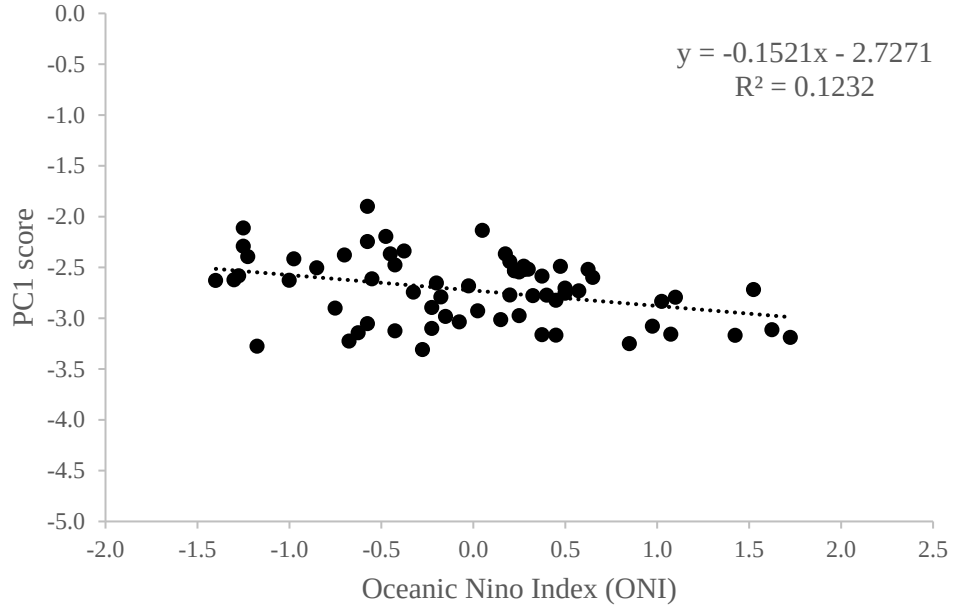


Fig. S7b Comparison of simulated gross nitrogen mineralization between current (1986-2015) and future climate scenarios (2071-2100, RCP4.5 and 8.5 – average of four climate models at WS27.



(A)



(B)

Fig. S8 The scores of the first principle component of the simulated biogeochemical variables in January to April from 1950 to 2015 (PC1 scores) vs. Oceanic Niño Index (ONI) at (A) WS18 and (B) WS27.

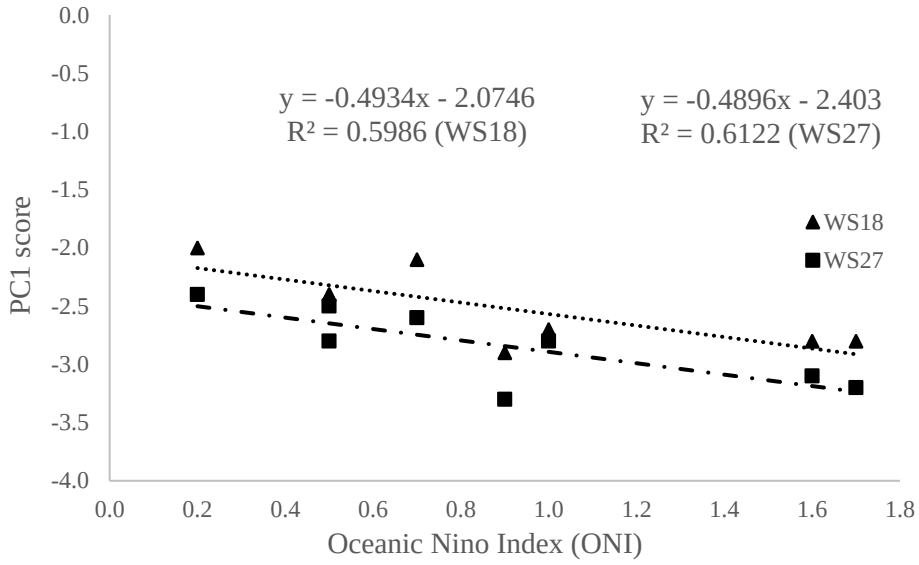


Fig. S9 The scores of the first principle component of the simulated biogeochemical variables at El Ni*ño* years vs. Oceanic Ni*ño* Index (ONI) at (A) WS18 and (B) WS27.

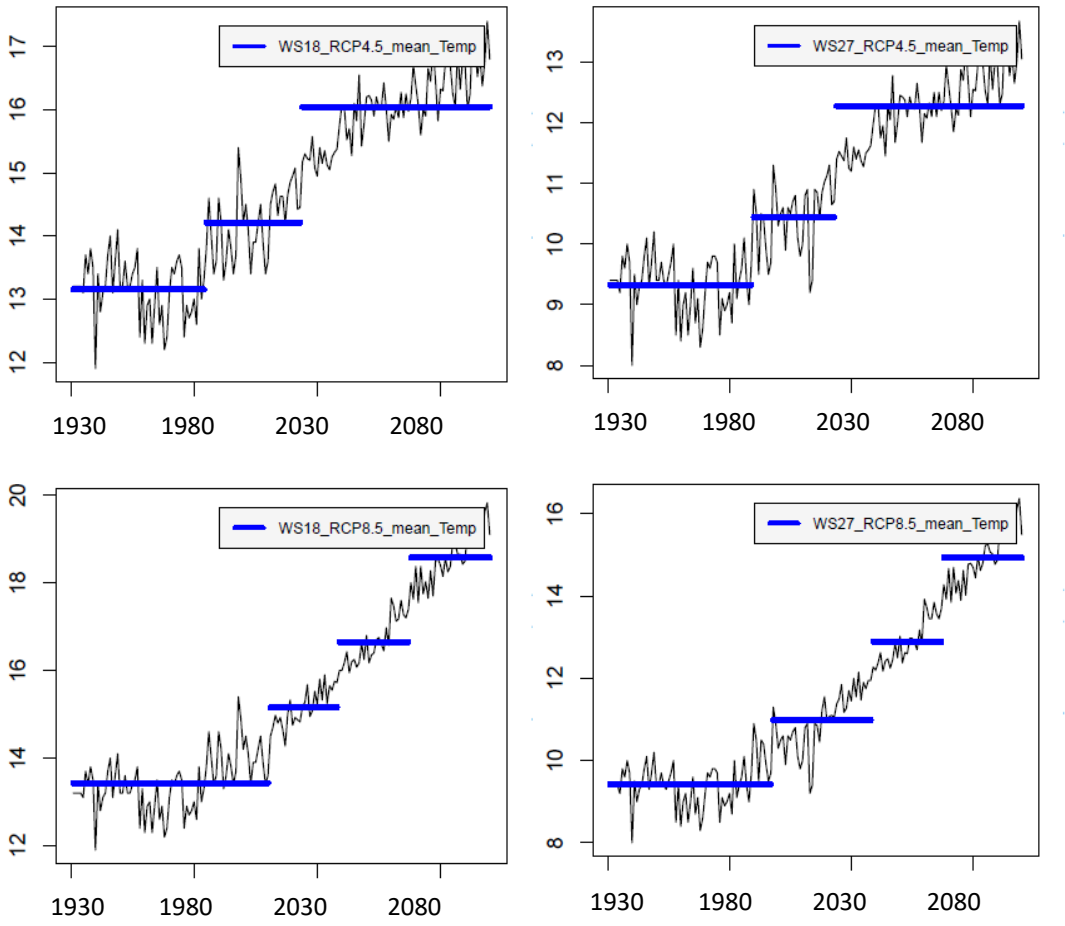


Fig. S10a Change points of temperature from 1931 to 2100 (top right – WS18 RCP4.5, bottom right – WS18 RCP8.5, top left – WS27 RCP4.5, and bottom left – WS27 RCP8.5).

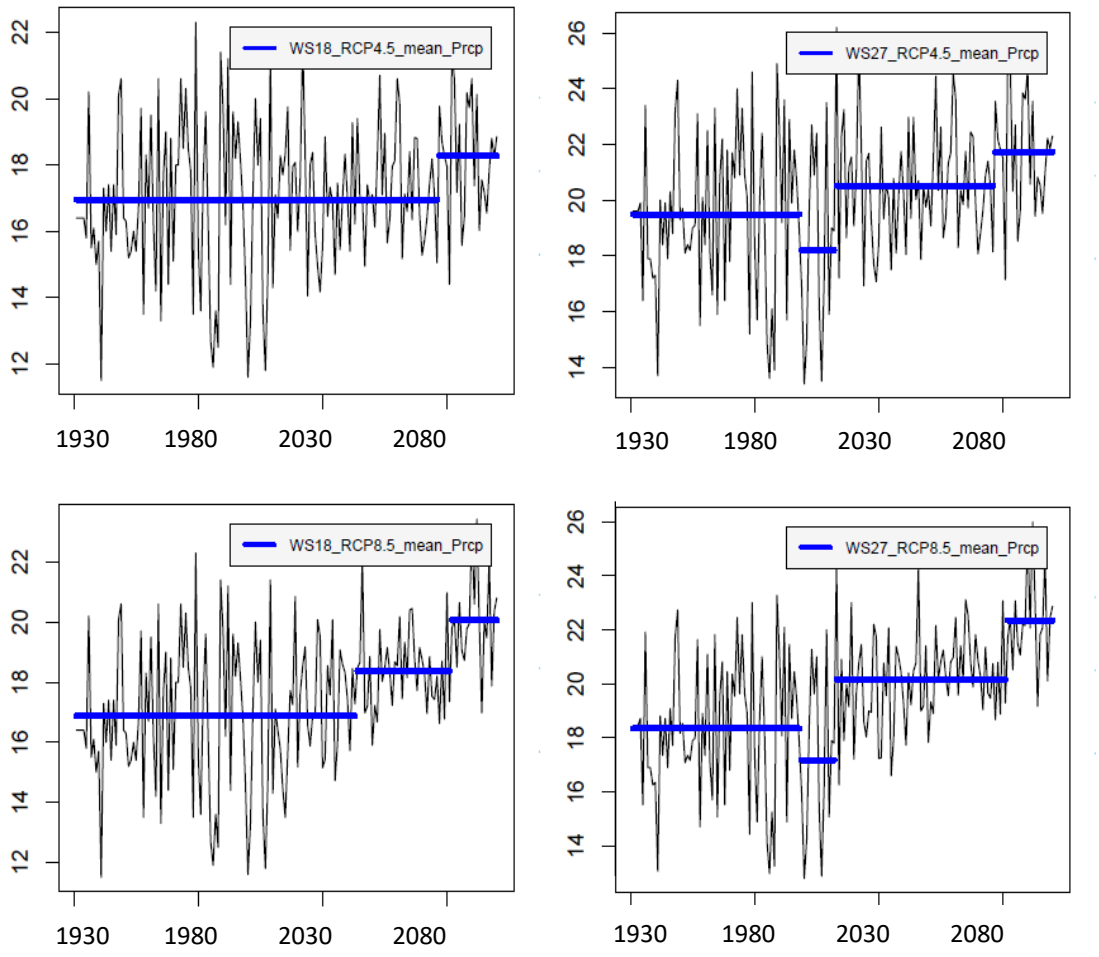


Fig. S10b Change points of precipitation from 1931 to 2100 (top right – WS18 RCP4.5, bottom right – WS18 RCP8.5, top left – WS27 RCP4.5, and bottom left – WS27 RCP8.5).

Table S1 Climate data and data (monthly) for model calibration at Coweeta WS18 and WS27

			Observation data	Source
WS18	Climate	Tmax	1985.01 - 2015.12 (1935.04 - 1984.12 using WS01 and WS18 regression between 1985.01 and 2015.12)	USDA FS
		Tmin	1985.01 - 2015.12 (1935.04 - 1984.12 using WS01 and WS18 regression between 1985.01 and 2015.12)	USDA FS
		Rain	1936.08 - 2015.12 (1934.08 - 1936.07 using WS01 and WS18 regression between 1936.08 and 2015.12)	USDA FS
		Solar	2010.05 - 2011.12 (1980.01 - 2010.04 using DayMET)	USDA FS
	Deposition	wet	1978.01 - 2015.12 (1930.01 - 1977.12 using SO_2 emission for SO_4^{2-})	NADP
		dry	1987.11 - 2015.12 (1978.01-1987.10 using monthly dry/wet deposition ratio derived with 1987.11-2015.12 data)	CASTNET
WS27	Climate	Tmax	1992.05 - 2015.12 (1935.04 - 1992.04using WS01 regression)	USDA FS
		Tmin	1992.05 - 2015.12 (1935.04 - 1992.04 using WS01 regression)	USDA FS
		Rain	1958.04 - 2011.12 (1934.08 - 1958.03 and 2012.01-2015.12 using WS01 regression)	USDA FS
		Solar	2010.05 - 2011.12 (1980 - 2010 using DayMET)	USDA FS
	Deposition	wet	1978.01 - 2015.12 (1930.01 - 1977.12 using SO_2 emission for SO_4^{2-})	NADP
		dry	1987.11 – 2015.12 (1978.01-1987.10 using monthly dry/wet deposition ratio derived with 1987.11-2015.12 data)	CASTNET
Vegetation			SHWDS - southern hardwoods	
Soil chemistry			varied soil chemistry from publications	
Soil properties			STATSGO	
Discharge			1936.07 - 2015.12 for WS18 and 1946.11 - 2015.12 for WS27	USDA FS
Water chemistry			1971.09-2014.12 for WS18 and 1971.09-2014.12 for WS27	USDA FS

Table S2 Summary of past, current, and future (RCP4.5 and RCP8.5) seasonal climate at WS18 and WS27

		Spr	Sum	Aut	Win	Mean	Differ.②	Var.③
	*Climate*①				Temperature (°C)			
WS18	Past	12.9	21.6	13.6	4.8	13.2		
	Current	13.9	22.5	14.6	5.2	14.1	0.8*	
	RCP4.5	16.7	25.2	17.1	7.0	16.5	2.45^	0.5
	RCP8.5	18.6	27.5	19.2	9.2	18.6	4.58^	0.4
WS27	Past	9.0	17.9	9.8	0.8	9.4		
	Current	10.2	18.9	10.4	1.4	10.2	0.9	
	RCP4.5	13.1	21.7	13.0	3.1	12.7	2.50	0.5
	RCP8.5	15.0	24.4	15.2	5.4	15.0	4.78	0.6
					Precipitation (cm/mo)			
WS18	Past	16.9	15.6	12.7	19.6	16.2		
	Current	14.7	13.8	15.3	17.2	15.3	-1.0	
	RCP4.5	19.8	15.7	15.8	20.2	17.9	2.63	1.9
	RCP8.5	20.2	17.1	16.8	22.8	19.2	3.98	2.0
WS27	Past	20.0	18.4	15.3	23.0	19.2		
	Current	18.4	17.7	19.4	20.8	19.1	-0.1	
	RCP4.5	23.3	18.8	19.7	23.4	21.3	2.23	2.0
	RCP8.5	22.5	19.0	20.8	24.9	21.8	2.73	1.6

In this table, seasonal average climate in: ① – past climate between 1936 and 1965, – current climate between 1986 and 2015, and – future climate between 2071 and 2100 from four GCMs under either RCP4.5 or RCP8.5 scenario; ②– current climate minus past climate (*) or future climate minus current climate (^); ③: seasonal variability – future climate minus current climate. For seasons: Spr – March to May, Sum – June to August, Aut – September to November, and Win – December to February.

Table S3 Comparison of PnET-BGC simulations vs published data

	Simulations-WS18	Simulations-WS27	Measured	Sources
NPP (kg/ha/yr) Aboveground (wood and foliage)	8,882 (1971-1980 average)	7,230 (1971-1980 average)	7,965	Day and Monk, 1977 at WS18, Coweeta Basin, NC
Base saturation (BS, %)	24.9 (2001 - 2010 average)	4.0 (2001 - 2010 average)	9.2 – 19.7 (top soil: <10 cm, soil: 10-30 cm, and bottom soil: 30-90 cm)	USDA FS 2008 soil survey provided by USDA FS Southern Research Station at Coweeta, NC
Net nitrogen mineralization (mg N/kg soil/mo)	2.5	3.1	<1.2 mg N /kg soil/ 28 days at lower elevation oak-pine; 3.8 mg N/kg soil/28 days @ cove hardwood; 13 mg N/kg soil/28 days @ higher elevation northern hardwoods	Knoepp and Swank, 1998 at WS18 and WS27, Coweeta Basin, NC

In above table, all the simulations results listed were ten years range covering the published work date, such as NPP, Day and Monk's work published in 1977 and then the NPP simulation results used was from 1971 to 1980.

Table S4 Results of PCA analysis - Eigenvectors of the first three principal components at WS18 and WS27 under different climate change scenarios. (The high loading values are highlighted)

	WS18			WS27		
RCP4.5	Comp 1	Comp 2	Comp 3	Comp 1	Comp 2	Comp 3
GPP	0.98	-0.07	0.02	0.94	-0.18	0.15
NPP	0.96	-0.10	0.04	0.93	-0.18	0.13
TotLitterMass	-0.49	0.26	-0.26	0.48	0.04	0.18
Streamflow	-0.21	-0.29	0.67	-0.02	-0.36	0.01
Transpiration	0.93	0.10	-0.06	0.87	-0.14	0.25
Base Saturation	-0.97	0.05	0.06	-0.93	0.03	0.35
Al/Ca	0.97	-0.02	0.04	0.93	0.01	-0.34
NetNMin	0.75	-0.62	0.03	0.27	0.80	0.48
GrossNMin	-0.01	-0.97	-0.02	0.56	0.74	0.34
GrossNImmob	-0.83	-0.46	-0.06	0.76	0.57	0.14
N_uptake	0.79	-0.57	0.05	0.68	0.60	0.36
ANC	-0.92	-0.21	0.28	-0.74	-0.16	0.60
NO_3^-	-0.75	0.07	-0.16	-0.80	-0.04	0.43
SO_4^{2-}	-0.07	-0.44	-0.75	0.11	0.55	-0.81
Ca^{2+}	-0.96	-0.19	-0.13	-0.88	0.45	0.01
Mg^{2+}	-0.89	-0.10	0.11	-0.63	0.68	-0.10
K^+	-0.94	-0.30	0.02	-0.60	0.66	-0.38
Cumulative Variance (%)	63.2	77.4	84.6	50.6	71.3	84.3

	WS18			WS27		
RCP8.5	Comp 1	Comp 2	Comp 3	Comp 1	Comp 2	Comp 3
GPP	0.96	-0.15	0.02	0.97	-0.15	0.03
NPP	0.91	-0.22	0.02	0.94	-0.10	0.00
TotLitterMass	-0.74	-0.00	0.21	-0.05	0.45	0.21
Streamflow	-0.02	-0.02	-0.91	0.19	-0.42	-0.14
Transpiration	0.95	0.07	0.14	0.91	-0.15	0.17
Base Saturation	-0.97	0.10	-0.04	-0.93	-0.12	0.33
Al/Ca	0.98	0.01	-0.00	0.94	0.07	-0.27
NetNMin	0.82	-0.50	-0.12	0.71	0.28	0.57

GrossNMin	-0.28	-0.92	-0.09	0.68	0.53	0.46
GrossNImmob	-0.88	-0.40	0.02	0.51	0.72	0.25
N_uptake	0.86	-0.44	-0.13	0.89	0.17	0.36
ANC	-0.94	-0.06	-0.27	-0.78	-0.32	0.49
NO_3^-	-0.78	0.13	0.07	-0.77	-0.26	0.43
SO_4^{2-}	-0.35	-0.58	0.43	-0.10	0.75	-0.61
Ca^{2+}	-0.98	-0.18	0.02	-0.93	0.33	0.12
Mg^{2+}	-0.92	0.02	-0.01	-0.77	0.51	0.11
K^+	-0.96	-0.23	-0.09	-0.77	0.58	-0.14
Cumulative Variance (%)	68.8	80.4	87.5	57.1	73.7	84.5

Table S5 Results of PCA analysis – eigenvalues (EV) of 17 watershed processes variables (data from 1931 to 2100) at WS18 and WS27 under different climate change scenarios

WS18	RCP4.5 EV	% of Variance	Cumulative % of variance	RCP8.5 EV	% of Variance	Cumulative % of variance
comp 1	10.7	63.2	63.2	11.7	68.8	68.8
comp 2	2.4	14.3	77.4	2.0	11.6	80.4
comp 3	1.2	7.2	84.6	1.2	7.1	87.5
comp 4	0.9	5.3	89.9	0.7	4.3	91.8
comp 5	0.7	4.3	94.2	0.5	2.9	94.7
comp 6	0.5	2.7	96.9	0.3	2.0	96.8
comp 7	0.2	1.2	98.1	0.3	1.7	98.5
comp 8	0.1	0.8	98.9	0.1	0.7	99.1
comp 9	0.1	0.5	99.4	0.1	0.5	99.6
comp 10	0.1	0.4	99.8	0.0	0.2	99.8
comp 11	0.03	0.17	99.9	0.0	0.1	99.9
comp 12	0.01	0.03	100	0.00	0.02	100
comp 13	0.00	0.02	100	0.00	0.01	100
comp 14	0.00	0.02	100	0.00	0.01	100
comp 15	0.00	0.01	100	0.00	0.01	100
comp 16	0.00	0.00	100	0.00	0.00	100
comp 17	0.00	0.00	100	0.00	0.00	100

WS27	RCP4.5 EV	% of Variance	Cumulative % of variance	RCP8.5 EV	% of Variance	Cumulative % of variance
comp 1	8.6	50.6	50.6	9.7	57.1	57.1
comp 2	3.5	20.6	71.3	2.8	16.6	73.7
comp 3	2.2	13.1	84.3	1.8	10.9	84.5
comp 4	1.2	7.2	91.5	1.0	5.8	90.3
comp 5	0.7	4.2	95.7	0.9	5.0	95.4
comp 6	0.3	1.5	97.2	0.3	1.8	97.2

comp 7	0.2	0.9	98.1	0.2	1.3	98.4
comp 8	0.1	0.7	98.8	0.1	0.7	99.1
comp 9	0.1	0.5	99.3	0.1	0.4	99.5
comp 10	0.0	0.2	99.6	0.0	0.2	99.7
comp 11	0.0	0.2	99.8	0.0	0.2	99.9
comp 12	0.02	0.14	99.9	0.01	0.08	99.9
comp 13	0.01	0.05	100	0.00	0.03	100
comp 14	0.01	0.03	100	0.00	0.02	100
comp 15	0.00	0.01	100	0.00	0.01	100
comp 16	0.00	0.00	100	0.00	0.01	100
comp 17	0.00	0.00	100	0.00	0.00	100