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Patterns of soil respiration and its temperature sensitivity in grassland ecosystems across China

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Table S1 Detailed site information across Chinese grasslands. TTS = temperate typical steppe, TMS = temperate meadow steppe, TDS = temperate desert steppe, ALG = alpine grassland, WTG = warm-tropical grassland. MAT = mean annual temperature, MAP = mean annual precipitation, SOC = soil organic carbon, STN = soil total nitrogen, MBC = microbial biomass carbon, AGB = aboveground biomass, BGB = belowground biomass. ST means soil temperature, SM means volumetric soil moisture. Rs = soil respiration, Ra= autotrophic respiration, Rh = heterotrophic respiration, GS = growing season, NGS = non-growing season. “S” represent measurement season for estimating Q_{10} values, 1 = growing season, 2 = non-growing season, 3 = whole year (annual scale). Method represents soil respiration measurement method, DCC = dynamic closed chamber, SCC= static closed chamber, AA = alkali absorption. R^2 for Q_{10} represent the determination coefficient for the relationship between soil temperature and soil respiration rate using van’t Hoff equation (see detailed information in the main body in section 2.1).

No.	Reference source	Grassland type	Longitude (°)	Latitude (°)	Altitude (m)	MAT (℃)	MAP (mm)	Soil pH	SOC (g/kg)	STN (g/kg)	MBC (mg/kg)	AGB (g m^{-2})	BGB (g m^{-2})	ST (℃)	SM (%)	Method	Rs (g C m^{-2} yr^{-1}) Annual	GS	NGS	GS Rs (%)	NGS Rs (%)	Ra (%)	Rh (%)	Q_{10}	S	Depth (cm)	R^2 for Q_{10}
1	Zhang et al., 2014b	TDS	111.89	41.78	1456	2.4	360					44	436	20.7	7.2	DCC								1.52	1	10	0.434
2	Yang et al., 2016	ALG	102.55	32.80	3600	1.4	749		45.6			597		8.5		DCC	1042	915	127	87.8	12.2			5.46	3	5	0.869
3	Yang et al., 2016	ALG	102.55	32.80	3600	1.4	749		53.2			759		5.6		DCC	1070	981	89	91.7	8.3			8.13	3	5	0.935
4	Hu et al., 2012	ALG	102.97	30.88	3600	8.4	927							9.1	44.2	DCC								3.42	1	5	0.660
5	Wang et al., 2014e	TMS	120.05	49.32	628	-2.8	300		43.8	1.46		177			13.7	DCC								2.36	1	5	0.437
6	Zhu et al., 2015a	TTS	112.32	40.00	1348	4.0	450	9.2				389	3702	16.2	18.9	SCC								2.36	1	10	0.913
7	Hu et al., 2011	WTG	114.89	25.82	389	19.4	1461							15.4		AA								2.26	2	5	0.810
8	Tian et al., 2013	ALG	101.27	37.61	3240	-1.7	560							11.7		DCC								2.39	1	5	0.710
9	Zhou et al., 2013	WTG	107.68	35.23	1220	9.4	584	8.3	5.9	0.86				14.9	14.4	DCC	517	345	172	66.8	33.2			1.74	3	5	0.790
10	Wang et al., 2013b	TMS	120.05	49.32	628	-2.8	300							16.8	16.8	DCC								2.49	1	10	0.586
11	Chen et al., 2011	TMS	122.27	43.28	203	6.2	379							7.4		DCC								2.88	1	5	0.787
12	Yu et al., 2016	TMS	123.76	46.00	142	4.2	392									DCC	219	203	15	92.9	7.1			1.49	3	5	0.470
13	Yu et al., 2016	TMS	123.76	46.00	142	4.2	392									DCC								1.35	3	0	0.540
14	Chen et al., 2014	ALG	100.85	36.95	3140	0.8	398	7.7						-0.4	3.5	DCC	490	376	114	76.7	23.3			3.39	3	10	
15	Chen et al., 2014	ALG	100.85	36.95	3140	0.8	398	7.7						-0.9	3.5	DCC	434	333	101	76.8	23.2			3.47	3	10	
16	Wang et al., 2014a	TMS	133.67	47.82	60	1.9	575							16.1	42.9	DCC								2.93	1	5	0.690
17	Wen et al., 2014	ALG	98.08	34.87	4217	-4.0	306					86		8.0	20.7	DCC								1.90	1	5	0.565
18	Wen et al., 2014	ALG	98.32	34.83	4227	-4.0	306					92		8.3	25.1	DCC								1.61	1	5	0.636
19	Wen et al., 2014	ALG	98.28	34.85	4225	-4.0	306					118		9.0	23.1	DCC								1.64	1	5	0.256
20	Zhao et al., 2014	TDS	111.22	41.30	1602	2.5	284		13.3	1.85		168	2266	19.5	5.1	DCC								1.88	1	5	0.408
21	Chen et al., 2003	TTS	116.32	43.92	1200	-0.1	217							21.6		AA								1.52	1	5	0.407
22	Chen et al., 2003	TTS	116.32	43.92	1200	-0.1	217							19.6		AA								1.70	1	10	0.474
23	Chen et al., 2003	TTS	116.32	43.92	1200	-0.1	217									AA								1.90	1	15	0.463
24	Chen et al., 2003	TTS	116.32	43.92	1200	-0.1	217									AA								1.97	1	20	0.426
25	Chen et al., 2003	TTS	116.32	43.92	1200	-0.1	217									AA								1.47	1	0	0.556
26	Wang et al., 2014b	TMS	123.85	45.60	140	4.3	410	10.2	11.5	0.70		307				DCC								1.73	1	0	0.500
27	Wang et al., 2014b	TMS	123.85	45.60	140	4.3	410	10.3	7.4	0.60		191				DCC								2.46	1	0	0.540
28	Wang et al., 2014b	TMS	123.85	45.60	140	4.3	410	8.2	15.8	1.00		549				DCC								1.49	1	0	0.750
29	Wang et al., 2014b	TMS	123.85	45.60	140	4.3	410	9.4	12.8	0.50		419				DCC								1.63	1	0	0.700
30	Wang, 2014	TMS	123.85	45.60	140	4.3	410	10.2	8.7	0.70		419				DCC								2.72	1	20	0.260
31	Wang, 2014	TMS	123.85	45.60	140	4.3	410	9.7	11.9	0.70		307				DCC								5.47	1	20	0.740
32	Wang, 2014	TMS	123.85	45.60	140	4.3	410	9.9	10.2	0.62		191				DCC								2.16	1	20	0.520
33	Wang, 2014	TMS	123.85	45.60	140	4.3	410	9.4	15.2	0.69		419				DCC								2.23	1	20	0.520

34	Wang, 2014	TMS	123.85	45.60	140	4.3	410	8.4	18.9	1.01		549				DCC								2.18	1	20	0.600
35	Kan, 2013	TTS	115.68	41.77	1380	1.0	430	8.9	23.0	2.70				11.4	14.1	DCC								3.10	1	10	0.691
36	Chen, 2009	TTS	106.84	37.14	1650	7.1	359					133	460	17.7	5.4	DCC								2.28	1	5	0.832
37	Zhang, 2010	WTG	111.52	37.65	2708	3.5	700		60.5							DCC								2.95	1	5	0.924
38	Zhang, 2010	WTG	111.52	37.65	2708	3.5	700		60.5					11.4	41.3	DCC								4.22	1	10	0.986
39	Zhang, 2010	WTG	111.52	37.65	2708	3.5	700		60.5							DCC								4.16	1	15	0.864
40	Zhang et al., 2013	TTS	116.48	44.16	1102	2.6	271	8.6						17.6	16.8	DCC								2.64	1	10	0.325
41	Li et al., 2015	ALG	102.44	37.22	2960	0.8	425		98.7	5.44		1183		8.3	33.2	DCC								1.88	1	5	0.793
42	Cui and Zhang, 2016	TDS	106.98	37.92	1427	7.7	288	8.5	2.8	0.63		213	5798	21.0	3.6	DCC								2.34	1	5	0.310
43	Cui and Zhang, 2016	TDS	106.98	37.92	1427	7.7	288	8.5	2.8	0.63		213	5798			DCC								2.72	1	10	0.311
44	Cui and Zhang, 2016	TDS	106.98	37.92	1427	7.7	288	8.5	2.8	0.63		213	5798			DCC								3.06	1	15	0.319
45	Cui and Zhang, 2016	TDS	106.98	37.92	1427	7.7	288	8.5	2.8	0.63		213	5798			DCC								3.49	1	20	0.345
46	Cui and Zhang, 2016	TDS	106.98	37.92	1427	7.7	288	8.5	2.8	0.63		213	5798			DCC								2.03	1	0	0.413
47	Cui and Zhang, 2016	TDS	107.00	37.95	1427	7.7	288	8.5	2.5	0.58		165	4243	21.1	3.4	DCC								2.18	1	5	0.335
48	Cui and Zhang, 2016	TDS	107.00	37.95	1427	7.7	288	8.5	2.5	0.58		165	4243			DCC								2.36	1	10	0.357
49	Cui and Zhang, 2016	TDS	107.00	37.95	1427	7.7	288	8.5	2.5	0.58		165	4243			DCC								2.66	1	15	0.367
50	Cui and Zhang, 2016	TDS	107.00	37.95	1427	7.7	288	8.5	2.5	0.58		165	4243			DCC								3.16	1	20	0.394
51	Cui and Zhang, 2016	TDS	107.00	37.95	1427	7.7	288	8.5	2.5	0.58		165	4243			DCC								1.82	1	0	0.425
52	Chang et al., 2005	ALG	100.28	38.40	2730	0.5	435									DCC								2.16	1	15	0.760
53	Wu et al., 2005	ALG	101.29	37.62	3200	-1.7	618	8.0	72.7	5.32				9.7		SCC								2.11	3	5	0.819
54	Cui et al., 2010	TTS	124.03	45.75	1130	-0.4	321					282			13.9	AA	203	171	32	84.2	15.8						
55	Zhang et al., 2014a	TMS	120.10	49.35	695	-2.4	350							0.6	21.0	DCC								2.70	3	5	0.570
56	Zhang et al., 2014a	TMS	120.10	49.35	695	-2.4	350							0.6	21.6	DCC								2.81	3	10	0.590
57	Zhang et al., 2014a	TMS	120.10	49.35	695	-2.4	350									DCC								2.87	3	15	0.590
58	Zhang et al., 2014a	TMS	120.10	49.35	695	-2.4	350									DCC								2.83	3	20	0.570
59	Guo et al., 2014	WTG	107.67	35.20	1200	9.3	644	8.4	10.5	0.62	204			15.0	56.1	DCC								1.85	1	5	0.900
60	Chang et al., 2007	TDS	100.28	38.40	2730	0.5	435							8.9	12.9	DCC								3.69	1	10	0.806
61	Zhang et al., 2003	TTS	116.02	43.63	1187	0.8	350	7.7								AA								1.55	1	5	0.411
62	Zhang et al., 2003	TTS	116.02	43.63	1187	0.8	350	7.7							18.5	AA								1.66	1	10	0.432
63	Zhang et al., 2003	TTS	116.02	43.63	1187	0.8	350	7.7								AA								1.75	1	15	0.462
64	Zhang et al., 2003	TTS	116.02	43.63	1187	0.8	350	7.7								AA								1.83	1	20	0.481
65	Zhang et al., 2003	TTS	116.02	43.63	1187	0.8	350	7.7								AA								1.38	1	0	0.362
66	Lin et al., 2016	TMS	122.35	42.97	260	6.0	450	7.2	7.4	0.29				16.6	7.1	DCC								3.61	1	10	0.686
67	Xiao et al., 2015	WTG	115.71	29.29	60	16.7	1469	5.8	9.5	0.72	177			19.4	31.3	DCC	1145	936	209	81.8	18.2	25.0	75.0	2.20	3	5	0.859
68	Liu, 2013	ALG	100.28	38.40	2750	0.7	434							12.0		DCC								2.73	1	10	0.427
69	Liu, 2013	ALG	100.28	38.40	1800	0.7	434							11.2		DCC								2.75	1	10	0.143
70	Bai et al., 2011	ALG	92.90	34.73	4754	-5.3	270		10.0	0.96		305		9.8	36.4	DCC								2.74	1	5	0.878
71	Wang et al., 2014d	TTS	110.37	38.81	1184	8.4	437		3.6	0.47		586		20.2	16.0	DCC								1.39	1	5	0.281
72	Wang et al., 2011	TTS	110.37	38.81	1184	8.4	437		3.4	0.38		467		17.7		DCC								1.89	1	10	0.640
73	Wang et al., 2011	TTS	110.37	38.81	1184	8.4	437		2.7	0.27		238		18.5		DCC								1.95	1	10	0.570
74	Wang et al., 2011	TTS	110.37	38.81	1184	8.4	437		4.4	0.48		243		18.9		DCC								1.90	1	10	0.716
75	Qi et al., 2008	TTS	110.37	38.81	1178	8.4	437	8.5	3.4	0.40				17.9	11.9	DCC								1.86	1	10	0.570

76	Qi et al., 2008	TTS	110.37	38.81	1178	8.4	437	8.5	3.4	0.34				22.2	12.4	DCC								2.01	1	10	0.508
77	Shi et al., 2008	WTG	117.65	27.74	2100	16.5	2000	4.3	129.4	10.06	4071			12.3	55.9	DCC	844	695	149	82.3	17.7			3.85	3	5	
78	Shi et al., 2008	WTG	117.65	27.74	2100	16.5	2000	4.3	129.4	10.06	4071			11.8		DCC								4.16	3	10	
79	Shi et al., 2008	WTG	117.65	27.74	2100	16.5	2000	4.3	129.4	10.06	4071					DCC								4.64	3	15	
80	Chang et al., 2011	WTG	113.08	28.18	197	17.2	1362							17.0	14.0	AA								3.16	3	5	0.735
81	Yan et al., 2008	WTG	112.59	37.80	785	10.0	425		18.5					15.6	20.0	DCC								2.28	3	10	0.466
82	Ma et al., 2015	TTS	99.86	38.42	2715	1.0	450		43.9					13.3	66.0	DCC								2.23	1	10	0.310
83	Ma et al., 2015	TTS	99.86	38.42	2715	1.0	450		43.9							DCC								1.82	1	0	0.950
84	Ma et al., 2015	ALG	99.86	38.42	3068	1.0	450		43.9					11.0	71.2	DCC								3.00	1	10	0.460
85	Ma et al., 2015	ALG	99.86	38.42	3068	1.0	450		43.9							DCC								1.65	1	0	0.820
86	Ma, 2015	ALG	99.93	38.42	3050	0.2	500		43.9					1.8		DCC	939	832	107	88.6	11.4						
87	Shen et al., 2014b	TTS	104.15	35.95	1966	6.7	382	8.2	9.5	0.88		163	377	14.2	9.1	DCC	171	162	10	94.4	5.6						
88	Yang, 2015	TMS	120.12	49.35	302	-0.3	350		44.9			357		15.1	22.2	DCC								2.83	1	5	0.762
89	Ma et al., 2016	TMS	125.16	46.62	428	4.3	428	8.3		1.60		790	1340	19.8		DCC								2.48	1	10	0.775
90	Zhang, 2015	TTS	106.43	36.27	1974	5.0	477		32.5	3.43		488		14.8	15.5	DCC								2.56	3	10	0.830
91	Zhang, 2015	TTS	106.43	36.27	1974	5.0	477		32.5	3.43		488				DCC								2.90	3	20	0.778
92	Wang et al., 2014c	TMS	123.84	45.60	182	4.0	414	9.4	15.2	0.69				17.6	31.7	DCC								1.82	1	10	0.667
93	Gong et al., 2015	TTS	116.03	44.80	1160	-0.4	300		12.5	0.81	72	103		20.7	10.0	DCC								1.03	1	10	
94	Gong et al., 2015	TTS	116.03	44.80	1160	-0.4	300		12.5	0.76	86	154		19.3	9.4	DCC								1.77	1	10	
95	Gong et al., 2015	TTS	116.03	44.80	1160	-0.4	300		12.5	0.69	41	209		20.4	14.7	DCC								2.34	1	10	
96	Peng et al., 2014b	ALG	92.93	34.82	4635	-3.8	291	8.3	9.0	0.51		246	3100	2.9	12.2	DCC	371	334	37	90.1	9.9	29.0	71.0	3.32	3	5	0.830
97	Cui et al., 2014	ALG	101.20	37.62	3200	-1.7	580		76.0	5.50		503	3257	10.2	30.6	SCC								2.16	1	5	0.412
98	Liu et al., 2016a	TDS	110.33	41.64	1409	4.6	255	7.4	10.0			175		3.3	5.1	DCC								1.76	2	5	0.740
99	Peng et al., 2014a	ALG	92.93	34.82	4635	-3.8	420	7.2	15.0			424		0.7	9.3	DCC								5.00	1	5	0.665
100	Wang and Guo, 2006	TMS	123.75	44.75	160	4.9	470	10.4	10.0					21.9	15.1	AA								2.46	1	10	0.830
101	Wang et al., 2016	ALG	100.22	34.46	3947	-0.4	544					646	1812	-1.3	4.9	DCC	473	410	63	86.6	13.4						
102	Zhang et al., 2005	ALG	90.02	31.38	4800	-1.2	380	8.2	5.5	0.67		102		9.3		SCC								2.44	3	5	0.612
103	Zhang et al., 2005	ALG	90.02	31.38	4800	-1.2	380	8.2	5.5	0.67		102				SCC								1.61	3	0	0.695
104	Li et al., 2013	TTS	104.15	35.95	1966	6.7	382	8.4	8.7		559	71			13.5	DCC	258	216	42	83.8	16.2	35.6	64.4				
105	Chen et al., 2016	ALG	100.85	36.95	3140	0.8	398				277	226	1360	5.9	10.0	DCC	434	336	98	77.4	22.6			2.89	3	10	
106	Chang et al., 2013	ALG	100.00	38.24	2500	0.8	435		35.5					-6.9	11.4	DCC								1.99	2	5	0.663
107	Chang et al., 2013	ALG	100.01	38.24	2600	0.8	435		37.4					-6.1	12.8	DCC								2.10	2	5	0.675
108	Chang et al., 2013	ALG	100.01	38.23	2700	0.5	435		37.7					-7.0	13.3	DCC								2.27	2	5	0.672
109	Chang et al., 2013	ALG	100.02	38.23	2800	0.3	435		38.6					-7.4	13.9	DCC								2.59	2	5	0.796
110	Chang et al., 2013	ALG	100.03	38.23	2900	-0.2	435		39.2					-8.2	14.6	DCC								2.93	2	5	0.667
111	Chang et al., 2013	ALG	100.03	38.22	3000	-0.4	435		39.2					-8.7	15.8	DCC								3.15	2	5	0.753
112	Zhang et al., 2015a	ALG	92.94	34.73	4700	-5.3	270		11.6	0.93		300		2.6	26.2	DCC	246	184	62	74.8	25.2			4.00	3	5	0.850
113	Zhang et al., 2015a	ALG	92.94	34.73	4700	-5.3	270		62.7	3.88		500		2.7	22.1	DCC	371	273	98	73.7	26.3			5.05	3	5	0.760
114	Wang et al., 2014f	ALG	101.20	37.50	3200	-0.8	351	6.4	63.0					8.1		DCC	696	610	87	87.6	12.4			3.78	1	5	
115	Lin et al., 2011	ALG	101.28	37.62	3200	-1.7	580					295	3250			SCC								1.43	1	5	0.188
116	Jia et al., 2014	TTS	110.38	38.82	1235	8.4	400					402		18.2	9.3	DCC								1.54	1	10	0.370
117	Jia et al., 2014	TTS	110.38	38.82	1235	8.4	400					278		18.9	10.5	DCC								1.99	1	10	0.600

118	Jia et al., 2014	TTS	110.38	38.82	1235	8.4	400				307		18.9	10.3	DCC								2.07	1	10	0.630
119	Fang et al., 2012	ALG	101.32	37.62	3220	-1.7	580				581		9.4	34.7	SCC								4.48	1	5	0.881
120	Jia et al., 2012	TTS	110.38	38.82	1235	8.4	405				141	476	18.4	10.8	DCC								1.92	1	5	0.683
121	Wang et al., 2013a	TMS	117.35	42.50	1400	-1.4	450	6.3	8.0	0.74			3.8	8.4	DCC	450	387	63	86.0	14.0	4.7	95.3	2.80	3	5	0.850
122	Wang et al., 2015a	TMS	123.85	45.60	140	4.0	414	10.2	8.7	0.70	76		18.7	19.7	DCC								3.46	1	10	0.730
123	Wang et al., 2015a	TMS	123.85	45.60	140	4.0	414	9.7	11.9	0.70	307		17.9	22.4	DCC								6.69	1	10	0.820
124	Wang et al., 2015a	TMS	123.85	45.60	140	4.0	414	9.9	10.2	0.61	191		18.3	23.9	DCC								2.01	1	10	0.540
125	Wang et al., 2015a	TMS	123.85	45.60	140	4.0	414	9.4	15.2	0.69	419		17.8	22.4	DCC								2.01	1	10	0.600
126	Wang et al., 2015a	TMS	123.85	45.60	140	4.0	414	8.4	18.9	1.01	549		16.5	27.7	DCC								2.23	1	10	0.530
127	Qi et al., 2010	TMS	116.83	43.51	1343	-1.4	347		24.3	2.20				10.5	SCC	254	197	57	77.4	22.6			1.98	3	5	0.577
128	Qi et al., 2010	TMS	116.83	43.51	1343	-1.4	347		24.3	2.20					SCC								2.16	3	10	0.635
129	Qi et al., 2010	TMS	116.83	43.51	1343	-1.4	347		24.3	2.20					SCC								1.71	3	0	0.445
130	Qi et al., 2010	TTS	116.55	43.54	1130	-0.1	339		20.3	2.00				14.5	SCC	185	166	19	89.6	10.4			2.98	3	5	0.730
131	Qi et al., 2010	TTS	116.55	43.54	1130	-0.1	339		20.3	2.00					SCC								3.14	3	10	0.670
132	Qi et al., 2010	TTS	116.55	43.54	1130	-0.1	339		20.3	2.00					SCC								2.53	3	0	0.611
133	Qi et al., 2010	TTS	115.90	44.09	970	-0.5	288		11.3	1.25				25.7	SCC	123	97	26	78.9	21.1			2.09	3	5	0.622
134	Qi et al., 2010	TTS	115.90	44.09	970	-0.5	288		11.3	1.25					SCC								2.40	3	10	0.732
135	Qi et al., 2010	TTS	115.90	44.09	970	-0.5	288		11.3	1.25					SCC								1.79	3	0	0.490
136	Wang et al., 2010	TMS	117.35	42.50	1400	-1.4	450						12.0		DCC	425	367	58	86.3	13.7			3.10	3	5	0.910
137	Wang et al., 2010	TMS	117.35	42.50	1400	-1.4	450						6.8		DCC	785	717	68	91.3	8.7			4.69	3	5	0.910
138	Wang et al., 2007	TTS	123.75	44.75	160	4.9	470	9.6	31.1		203		22.1	13.9	AA								2.16	1	10	0.690
139	Wang et al., 2007	TTS	123.75	44.75	160	4.9	470	10.4	22.2		131		22.0	15.0	AA								2.36	1	10	0.830
140	Chang et al., 2009	ALG	100.00	38.24	2500	0.8	435		35.5				0.8	17.5	DCC	476	288	188	60.5	39.5						
141	Chang et al., 2009	ALG	100.01	38.24	2600	0.8	435		37.4				0.8	18.0	DCC	452	291	161	64.4	35.6						
142	Chang et al., 2009	ALG	100.01	38.23	2700	0.5	435		37.7				0.5	18.3	DCC	423	272	151	64.3	35.7						
143	Chang et al., 2009	ALG	100.02	38.23	2800	0.3	435		38.6				0.3	18.7	DCC	384	246	137	64.2	35.8						
144	Chang et al., 2009	ALG	100.03	38.23	2900	-0.2	435		39.2				-0.2	19.8	DCC	365	236	130	64.5	35.5			3.44	1	10	0.808
145	Chang et al., 2009	ALG	100.03	38.22	3000	-0.4	435		39.2				-0.4	21.3	DCC	310	202	108	65.1	34.9						
146	Peng et al., 2015b	ALG	92.93	34.82	4635	-3.8	291	8.3	9.0	0.51	246	3372			DCC											
147	Peng et al., 2011	TTS	116.67	43.55	1265	-0.4	400		20.0	1.88			8.4	12.1	SCC	127	98	29	77.4	22.6			1.70	3	10	0.501
148	Yan et al., 2013	WTG	112.37	37.73	1350	10.0	320		3.1						DCC								2.75	3	5	0.710
149	Yan et al., 2013	WTG	112.37	37.73	1350	10.0	371		3.1				14.1	25.6	DCC								2.96	3	10	0.670
150	Yan et al., 2013	WTG	112.37	37.73	1350	10.0	509		3.1						DCC								3.07	3	15	0.680
151	Wei et al., 2016b	TTS	106.43	36.27	1974	6.9	425		32.5	3.43	488		12.7	16.5	DCC	581	507	73	87.3	12.7			1.92	3	10	0.586
152	Zhang et al., 2016	WTG	118.05	32.00	6	25.0	980						15.7	52.3	SCC	870	708	162	81.4	18.6						
153	Zhang et al., 2016	WTG	118.05	32.00	6	25.0	980						15.7	44.4	SCC	1435	1235	200	86.0	14.0			1.22	3	15	0.084
154	Zhang et al., 2016	WTG	118.05	32.00	6	25.0	980						15.9	35.6	SCC	1180	965	215	81.8	18.2			1.49	3	15	0.325
155	Wang et al., 2015b	TMS	120.05	49.32	628	-2.8	300		43.8	1.46	177				DCC	519							3.64	3	5	0.911
156	Qi et al., 2006	TTS	116.68	43.57	1225	-0.1	339		22.2	1.73					SCC	375	266	109	71.1	28.9						
157	Qi et al., 2006	TTS	116.91	44.09	923	-0.4	250		12.0	1.03					SCC	128	85	43	66.3	33.7						
158	Dong et al., 2006	TTS	116.55	43.54	1130	-0.1	339	7.9	17.8	1.80					SCC	136										
159	Zhu et al., 2015b	TTS	115.77	41.73	1380	1.0	400	8.8		0.41			14.1	23.9	DCC								2.66	1	10	0.732

160	Zhang et al., 2015b	WTG	107.67	35.22	1095	9.4	560	8.3	5.9					16.7	34.9	DCC	583	398	185	68.2	31.8			2.11	3	5	0.800
161	Lai et al., 2012	TDS	87.83	44.17	933	6.6	160	9.4	2.5							DCC								1.36	1	0	0.809
162	Rong et al., 2015	TTS	115.68	41.77	1380	1.0	400					501		14.1	21.8	DCC	1670	1580	90	94.6	5.4			2.26	3	5	0.540
163	Shen et al., 2014a	WTG	114.25	37.90	374	13.0	560	8.5	15.0					13.6	14.7	DCC	603	456	146	75.7	24.3			3.86	3	10	0.738
164	Li and Sun, 2011	ALG	102.55	32.80	3494	1.4	749							7.8		DCC								6.36	3	5	0.833
165	Peng et al., 2015a	ALG	92.93	34.82	4635	-3.8	291	8.8	4.9	0.44		383	14733	0.3	5.8	DCC								3.55	1	5	0.430
166	Peng et al., 2015a	ALG	92.93	34.82	4635	-3.8	291	8.3	10.5	0.88		387	12072	-0.1	12.5	DCC								4.67	1	5	0.140
167	Chen et al., 2013	TTS	116.55	43.53	1180	0.7	330	6.6	31.0	3.15		255		-2.4	8.2	DCC								2.70	2	5	0.660
168	Chen et al., 2013	TTS	116.67	43.55	1268	0.7	330	6.8	25.5	2.65		519		-3.0	12.6	DCC								2.50	2	5	0.310
169	Huang et al., 2016	ALG	100.09	37.74	3246	-3.3	420							7.3	34.3	DCC								2.84	1	5	0.672
170	Luo et al. 2016	TTS	116.27	44.81	1160	0.7	321	8.6	12.5	1.10	268	210	451			DCC	252	184	68	73.0	27.0			2.05	3	10	0.561
171	Wei et al., 2016a	TTS	106.40	36.23	1900	7.0	425		23.6	2.47	330	381	1997	15.3	18.2	DCC								1.52	1	10	0.232
172	Han et al., 2017	TDS	122.62	43.33	192	6.6	389	9.3	3.1					19.1	35.9	DCC								2.83	1	10	0.458
173	Fang et al., 2017	TTS	104.42	36.03	2400	6.5	305	8.5	7.8	0.93				9.9	1.9	DCC	553	484	69	87.5	12.5			2.79	3	5	0.790
174	Liu et al., 2016b	WTG	114.26	37.88	500	13.0	560		39.2					13.4	14.6	DCC								3.35	3	10	0.586
175	Zhai et al., 2017	WTG	121.52	31.65	4	15.2	1025							14.5	43.8	DCC	2407	1403	1004	58.3	41.7			2.02	3	5	0.860
176	Ren et al., 2016	ALG	101.32	37.62	3220	-1.7	580	7.5	72.4	8.70		407	1263	5.2	30.7	DCC	664	581	83	87.5	12.5	31.7	68.3				
177	Li et al., 2017b	WTG	117.32	36.28	730	12.1	950	5.9	17.4					12.7	14.8	SCC	429	333	96	77.7	22.3						
178	Sun et al., 2017	WTG	110.30	37.25	979	8.6	505		5.1	0.30				15.1	6.7	SCC								1.82	1	10	0.580
179	Wang et al., 2008a	ALG	102.53	32.78	3470	2.6	700	7.0	50.0					9.1		SCC								1.81	1	5	0.303
180	Du et al., 2005	TTS	116.68	43.55	1200	-0.1	339	6.9	18.5	1.88						SCC	278										
181	Wang et al., 2017	ALG	101.30	37.60	3198	-1.1	486	7.8	63.0					7.9	19.5	DCC	829					42.0	58.0				
182	Pan et al., 2017	TTS	115.68	41.77	1380	1.0	400									DCC								1.65	2	0	0.540
183	Zeng et al., 2017	WTG	114.24	37.91	350	13.2	570	8.5	11.2	1.04				13.0	12.9	DCC	710	555	155	78.2	21.8			2.61	3	10	0.530
184	Zhao et al., 2017	TTS	104.42	36.03	2400	6.2	375		5.0	1.15		98		7.1	2.6	DCC	501	322	179	64.2	35.8			2.21	3	5	0.600
185	Fang et al., 2018	TTS	104.42	36.03	2400	6.5	305					99		11.1	3.3	DCC	401	250	151	62.3	37.7	22.0	78.0	1.78	3	5	
186	Guo et al., 2017	ALG	102.79	37.20	2960	-0.1	416							4.7		SCC								3.25	3	5	0.903
187	Xue and Tang, 2017	TTS	116.29	42.04	1239	2.3	382		18.0			178	1141	18.7	15.3	DCC								2.10	1	5	0.500
188	Xue and Tang, 2017	TTS	116.28	42.04	1239	2.3	382		14.7			143	873	18.8	14.4	DCC								2.01	1	5	0.490
189	Li et al., 2017a	ALG	102.55	32.80	3500	0.9	749		210.4					13.5	45.0	DCC	1161	1013	148	87.3	12.7			5.07	3	5	0.930
190	Wang et al., 2008b	WTG	105.47	31.27	500	17.3	826	8.2	18.5	0.95				15.6	38.9	DCC	480							2.34	3	5	0.330

Table S2 The abiotic and biotic factors among different grassland types. Values are mean ± SE (standard error). MAT = mean annual temperature, MAP = mean annual precipitation, ST_5 = soil temperature at the depth of 5 cm, SM_5 = soil moisture at the depth of 5 cm, ST_{10} = soil temperature at the depth of 10 cm, SM_{10} = soil moisture at the depth of 10 cm, SOC = soil organic carbon, STN = soil total nitrogen, MBC = microbial biomass carbon, AGB= aboveground biomass, BGB = belowground biomass. NA means no data. TTS = temperate typical steppe, TMS = temperate meadow steppe, TDS = temperate desert steppe, ALG = alpine grassland, WTG = warm-tropical grassland. NA = no data. The numbers in parentheses represent sample sizes.

Factors	TTS	TMS	TDS	ALG	WTG
MAT (℃)	2.9 ± 0.4 (60)	1.9 ± 0.5 (36)	6.3 ± 0.6 (16)	-0.7 ± 0.3 (52)	13.4 ± 1.2 (26)
MAP (mm)	361 ± 9 (60)	397 ± 9 (36)	298 ± 15 (16)	461 ± 20 (52)	913 ± 99 (26)
ST_5 (℃)	12.7 ± 2.4 (12)	8.8 ± 2.2 (7)	16.2 ± 4.3(4)	4.3 ± 1.2(31)	15.7 ± 0.7(9)
SM_5 (%, v/v)	11.7 ± 2.0 (13)	19.8 ± 5.2 (6)	4.3 ± 0.5 (4)	22.6 ± 2.5(22)	36.2 ± 5.7 (8)
ST_{10} (℃)	17.3 ± 0.7 (23)	16.6 ± 1.7 (11)	16.2 ± 3.7 (3)	5.5 ± 2.3 (7)	13.5 ± 0.5 (8)
SM_{10} (%, v/v)	16.9 ± 2.7 (20)	20.8 ± 2.2 (10)	18.7 ± 8.8 (3)	21.6 ± 12.8 (5)	19.4 ± 4.3 (7)
SOC (g kg^{-1})	17.4 ± 1.8 (38)	17.6 ± 2.3 (24)	3.9 ± 0.9 (14)	43.9 ± 6.2 (35)	36.8 ± 9.9 (20)
STN (g kg^{-1})	1.5 ± 0.2 (32)	1.0 ± 0.1 (23)	0.7 ± 0.1 (11)	2.6 ± 0.8 (13)	3.9 ± 1.6 (9)
Soil pH	8.2 ± 0.2 (21)	9.2 ± 0.3 (19)	8.6 ± 0.1 (13)	7.8 ± 0.2 (14)	6.8 ± 0.6 (11)
MBC (mg kg^{-1})	226 ± 82 (6)	NA	NA	277 ± NA (1)	2519 ± 951 (5)
AGB (g m^{-2})	278 ± 28 (30)	355 ± 42 (18)	175 ± 13 (13)	386 ± 56 (22)	NA
BGB (g m^{-2})	1185 ± 408 (8)	1340 ± NA (1)	4409 ± 478 (12)	4913 ± 1643 (9)	372 ± NA (1)

Table S3 Pearson correlation (r) among abiotic factors. MAT = mean annual temperature, MAP = mean annual precipitation, ST_5 = soil temperature at the depth of 5 cm, SM_5 = soil moisture at the depth of 5 cm, ST_{10} = soil temperature at the depth of 10 cm, SM_{10} = soil moisture at the depth of 10 cm, SOC = soil organic carbon, STN = soil total nitrogen, MBC = microbial biomass carbon, AGB= aboveground biomass, BGB = belowground biomass. ND = not detected. The numbers in left bottom represent Pearson's correlation coefficients, and the numbers in upper right represent sample sizes. * P < 0.05, ** P < 0.01

	Latitude	Altitude	MAT	MAP	ST_5	SM_5	ST_{10}	SM_{10}	SOC	STN	Soil pH	MBC	AGB	BGB
Latitude		190	190	190	66	53	52	45	131	88	78	12	83	31
Altitude	-0.548**		197	197	66	53	52	45	131	88	78	12	90	38
MAT	-0.424**	-0.482**		197	66	53	52	45	131	88	78	12	90	38
MAP	-0.593**	-0.039	0.602**		66	53	51	45	131	88	78	12	90	38
ST_5	-0.027	-0.471**	0.462**	0.212		49	ND	ND	41	24	21	3	31	11
SM_5	-0.322	-0.011	0.220	0.572**	0.225		ND	ND	39	26	17	3	29	11
ST_{10}	0.345	-0.650*	0.279*	-0.115	ND	ND			35	25	23	6	23	5
SM_{10}	0.017	0.170	-0.138	0.192	ND	ND	-0.014		31	20	22	5	19	4
SOC	-0.351**	0.344**	-0.053	0.602**	-0.046	0.521**	-0.450**	0.521**		86	67	11	65	23
STN	-0.395**	0.247*	0.154	0.713**	-0.109	0.473*	-0.520**	-0.020	0.995**		55	10	56	21
Soil pH	0.600**	-0.340**	-0.220	-0.659**	0.134	0.157	0.497*	0.463*	-0.662**	-0.723**		7	42	20
MBC	-0.749**	0.420	0.746**	0.899**	-0.796	0.667	-0.368	0.426	0.994**	0.996**	-0.878**		7	3
AGB	-0.031	0.069	-0.085	0.517**	-0.229	0.511**	-0.273	0.446	0.635**	0.485**	-0.175	-0.020		37
BGB	-0.404*	0.425*	-0.223	-0.400*	-0.728*	-0.174	-0.128	0.878	-0.298	-0.323	0.405	0.878	0.116	

Table S4 Multiple linear regression of Q_{10} derived by soil temperature at the depth of 5 cm with environmental factors, including mean annual temperature (MAT) and mean annual precipitation (MAP), soil temperature (SM) and soil moisture (ST).

Equation	N	R^2	P-value
$Q_{10} = -0.12 \times \mathrm{MAT} + 0.0022 \times \mathrm{MAP} + 2.0$	73	0.221	< 0.001
$Q_{10} = -0.036 \times \mathrm{ST} + 0.017 \times \mathrm{SM} + 2.6$	49	0.139	0.032

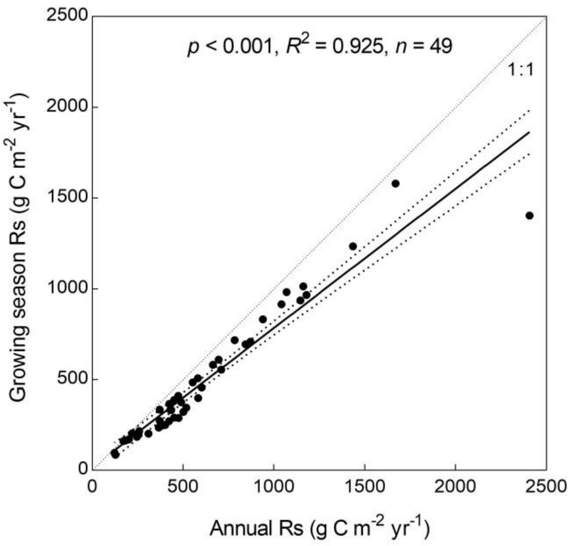

Figure S1. The linear relationship between growing season soil respiration (Rs) and annual Rs. The dash lines represent the 95% confidence intervals.

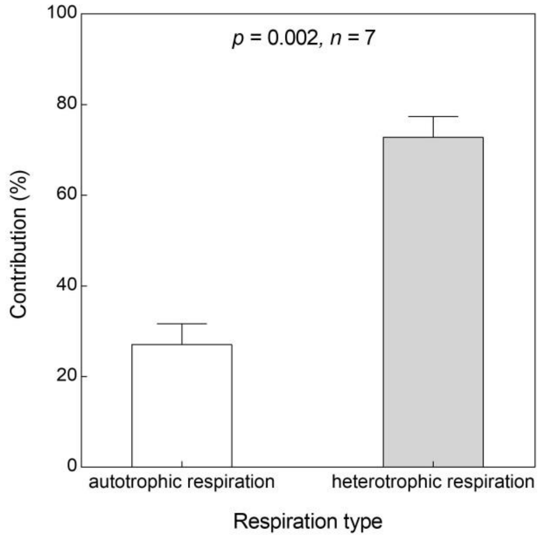

Figure S2. The mean contribution (mean ± SE) of autotrophic and heterotrophic respiration to annual soil carbon emission.

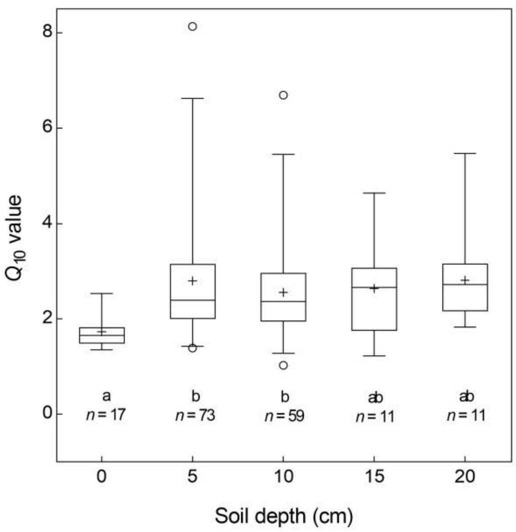

Figure S3. Comparisons of Q_{10} values among soil temperature at the depths of 0, 5, 10, 15, and 20 cm, respectively. In the box plot, the "+" represent mean values, horizontal lines inside box represent medians, box ends represent the 25th and the 75th quartiles, vertical lines represent 2.5th and 97.5th percentiles, hollow circles represent outliers, and n represents the number of samples. The different lowercase letters indicate the significant difference among soil depths at $p = 0.05$.

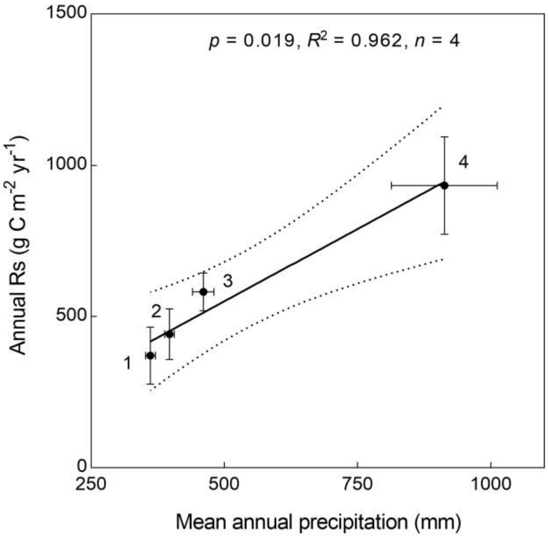

Figure S4. The linear relationship between annual soil respiration (Rs) and mean annual precipitation. The dash lines represent the 95% confidence intervals. 1 = temperate typical steppe, 2 = temperate meadow steppe, 3 = alpine grassland, 4 = warm-tropical grassland. Data are means with standard errors.

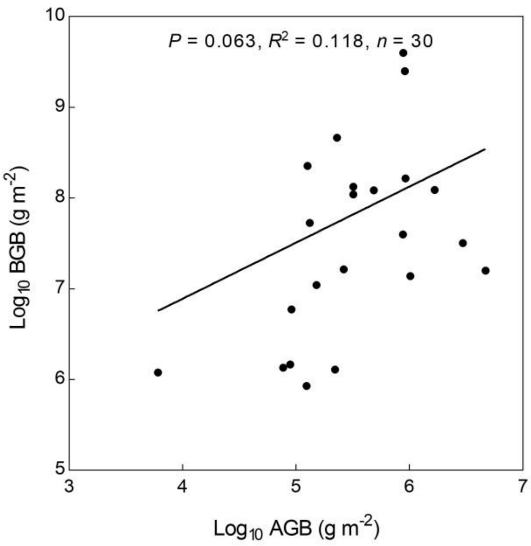

Figure S5. The relationships between aboveground biomass (AGB) and belowground biomass (BGB). The equation used is $Y = a \times X + b$.

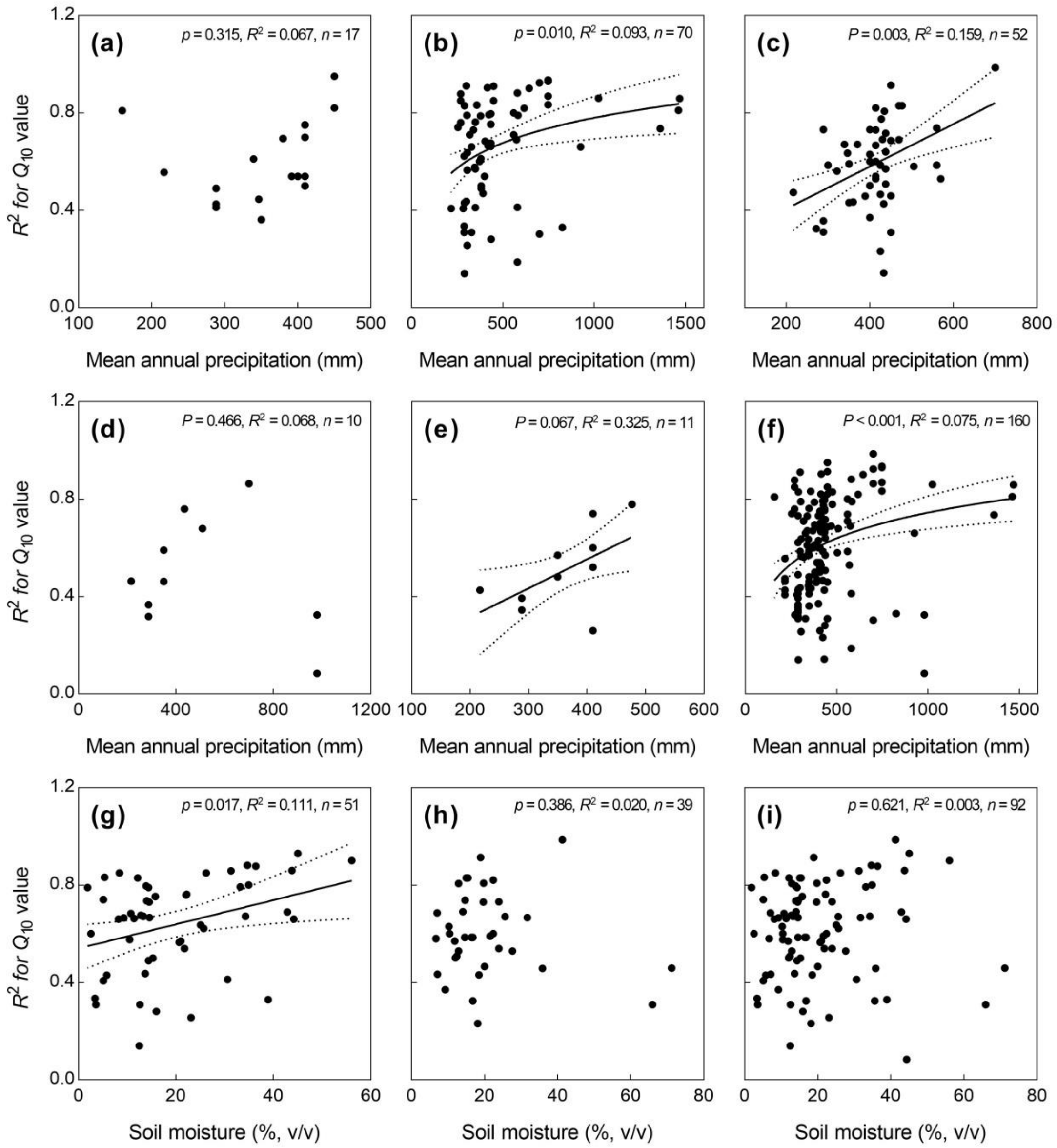

Figure S6. The relationships of coefficient of determination (R^2) for temperature sensitivity of soil respiration (Q_{10}) with mean annual precipitation (a-f) and soil moisture (g-i). (a) Q_{10} derived by soil surface temperature, (b, g) Q_{10} derived by soil temperature at 5 cm, (c, h) Q_{10} derived by soil temperature at 10 cm, (d) Q_{10} derived by soil temperature at 15 cm, (e) Q_{10} derived by soil temperature at 20 cm, (f, i) Q_{10} derived by all soil temperatures. For Q_{10} derived by soil temperature at 10 and 20 cm, there were not enough sample sizes to conduct regression analysis between Q_{10} and soil moisture, and not presented here. The equation used in (b) and (f) is $Y = a \times \text{Ln}(X) + b$, and in (c), (e) and (g) is $Y = a \times X + b$.

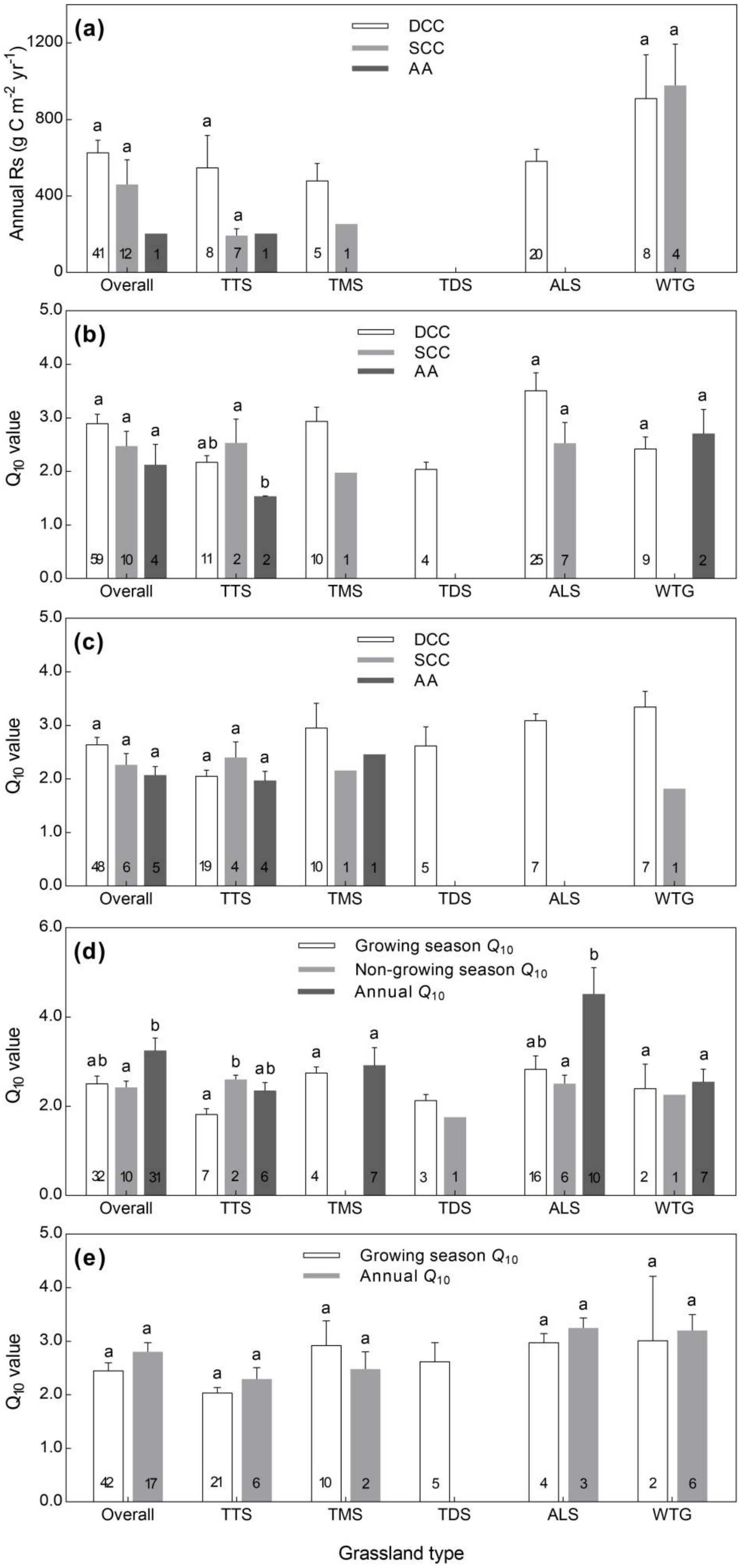
(a)
DCC
SCC
AA
Annual Rs (g C m-2 yr-1)
(b)
Q10 value
(c)
(d)
Growing season Q10
Non-growing season Q10
Annual Q10
(e)
Overall
TTS
TMS
TDS
ALS
WTG
Grassland type

Figure S7. Comparisons of annual soil respiration (Rs) and temperature sensitivity (Q_{10}) among measurement methods or measurement period. (a) Annual Rs, (b, d) Q_{10} derived by soil temperature at the depth of 5 cm, (c, e) Q_{10} derived by soil temperature at the depth of 10 cm. Overall represent data from all grassland types. TTS = temperate typical steppe, TMS = temperate meadow steppe, TDS = temperate desert steppe, ALG = alpine grassland, and WTG = warm-tropical grassland. DCC = dynamic closed chamber, SCC = static closed chamber, and AA = alkali absorption. The numbers in figure represent sample sizes, error bar represent standard error (SE). Within each grassland type, the differences among groups were analyzed by one-way ANOVA. Different lowercase letters within each category indicate significant difference at $p = 0.05$. Among measurement methods, AA was less used. Including the data measured by the AA method in our synthesis does not meaningfully change the results of Rs and Q_{10}.

References list

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