Supplemental Information

Climate change and landscape-use patterns influence recent past distribution of giant pandas

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1. Supplementary Tables

Table S1. Definition and description of variables in our datasets.

Category	Variables	Variable description and description	Units
Climate	**BIO1***	Mean annual temperature in each grid cell	℃
	BIO2	Mean diurnal range (mean of maximal temperature - minimal temperature) in each grid cell	℃
	BIO3	Isothermality (Bio2/Bio7) (* 100) in each grid cell	
	BIO4*	Temperature seasonality (standard deviation *100) in each grid cell	℃
	BIO5	Maximal temperature of the warmest month in each grid cell	℃
	BIO6	Minimal temperature of coldest month in each grid cell	℃
	BIO7	Temperature annual range (Bio5-Bio6) in each grid cell	℃
	BIO8	Mean temperature of the wettest quarter in each grid cell	℃
	BIO9	Mean temperature of the driest quarter in each grid cell	℃
	BIO10	Mean temperature of the warmest quarter in each grid cell	℃
	BIO11	Mean temperature of the coldest quarter in each grid cell	℃
	BIO12	Total annual precipitation in each grid cell	mm
	BIO13	Precipitation of the wettest month in each grid cell	mm
	BIO14*	Precipitation of the driest month in each grid cell	mm
	BIO15*	Precipitation seasonality (coefficient of variation) in each grid cell	
	BIO16	Precipitation of the wettest quarter in each grid cell	mm
	BIO17	Precipitation of the driest quarter in each grid cell	mm
	BIO18	Precipitation of the warmest quarter in each grid cell	mm
	BIO19	Precipitation of the coldest quarter in each grid cell	mm
Land-use	**FAL***	The proportion of farmland area in each grid cell	%
	FOL*	The proportion of forest land area in each grid cell	%
	GL	The proportion of grassland area in each grid cell	%
	Waters	The proportion of water area in each grid cell	%
	RL*	The proportion of residential land area in each grid cell	%
	OL*	The proportion of other land area in each grid cell	%
Topography	ME	Mean elevation in each grid cell	m
	MA*	Mean aspect in each grid cell	◦
	MS	Mean slope in each grid cell	◦
	RE*	Mean range of elevation in each grid cell	m

*****: Variables used in models according to Pearson's correlation coefficients (< 0.7)

Table S2. The maximum values (right-upper triangle) and corresponding significance (left-lower triangle) of Pearson correlation coefficients between the ten selected variables, examined at three grid sizes and three time periods.

	BIO1	BIO4	BIO14	BIO15	FAL	FOL	RL	OL	MA	RE
BIO1		0.205	0.597	0.624	0.593	0.349	0.283	-0.377	-0.085	0.146
BIO4	***		-0.181	0.486	0.336	-0.119	0.225	0.120	-0.031	-0.389
BIO14	***	***		0.364	0.525	0.289	0.144	-0.087	-0.021	0.142
BIO15	***	***	***		0.509	0.200	0.301	0.155	0.064	0.270
FAL	***	***	***	***		-0.180	0.565	-0.174	-0.148	-0.470
FOL	***	***	***	***	***		-0.197	-0.337	0.124	0.528
RL	***	***	***	***	***	***		-0.051	-0.117	-0.284
OL	***	**	***	***	***	***	***		-0.032	-0.162
MA	***	*	ns	ns	***	**	***	ns		0.100
RE	***	***	***	***	***	***	***	***	*	

*** P<0.001; ** P<0.01; * P<0.05; ns, not significant.

Table S3. Changes through time in climatic and landscape variables in panda habitat at three different ecological scales. Mean values for eight selected variables compared through Student t-tests. Time periods are as follows. TP1: 1985-1988; TP2: 1998-2002; TP3: 2011-2014). See Table S1 for variable unit description.

Grid size	Variables	Mean (SD)			TP1 vs TP2		TP1 vs TP3		TP2 vs TP3	
		TP1	TP2	TP3	t-value	P-value	t-value	P-value	t-value	P-value
5km×5km	BIO1	11.057 (3.638)	11.098 (3.681)	11.764 (3.349)	-0.572	0.567	-10.197	<0.001	-9.536	<0.001
	BIO4	644.048 (59.887)	697.865 (62.064)	654.796 (64.569)	-44.448	<0.001	-8.693	<0.001	34.255	<0.001
	BIO14	3.046 (2.913)	4.234 (2.048)	1.804 (1.315)	-23.763	<0.001	27.683	<0.001	71.127	<0.001
	BIO15	100.034 (11.807)	100.144 (4.817)	108.137 (6.698)	-0.617	0.537	-42.524	<0.001	-69.01	<0.001
	FAL	0.136 (0.226)	0.136 (0.224)	0.134 (0.222)	0.135	0.893	0.435	0.663	0.301	0.764
	FOL	0.437 (0.295)	0.435 (0.294)	0.446 (0.289)	0.258	0.796	-1.656	0.098	-1.918	0.055
	RL	0.005 (0.028)	0.006 (0.03)	0.008 (0.038)	-0.836	0.403	-3.895	<0.001	-3.071	0.002
	OL	0.035 (0.121)	0.035 (0.121)	0.04 (0.129)	0.022	0.982	-1.818	0.069	-1.84	0.066
10km×10km	BIO1	11.027 (3.648)	11.07 (3.69)	11.736 (3.358)	-0.295	0.768	-5.107	<0.001	-4.769	<0.001
	BIO4	644.439 (59.659)	698.269 (62.094)	655.382 (64.797)	-22.313	<0.001	-4.434	<0.001	17.057	<0.001
	BIO14	3.032 (2.914)	4.219 (2.038)	1.793 (1.301)	-11.916	<0.001	13.863	<0.001	35.819	<0.001
	BIO15	100.022 (11.775)	100.132 (4.817)	108.134 (6.653)	-0.308	0.758	-21.407	<0.001	-34.77	<0.001
	FAL	0.135 (0.21)	0.134 (0.208)	0.133 (0.206)	0.069	0.945	0.224	0.823	0.155	0.877
	FOL	0.437 (0.256)	0.435 (0.255)	0.446 (0.249)	0.149	0.882	-0.963	0.336	-1.115	0.265
	RL	0.005 (0.023)	0.005 (0.025)	0.008 (0.032)	-0.503	0.615	-2.286	0.022	-1.803	0.071
	OL	0.035 (0.104)	0.035 (0.104)	0.039 (0.113)	0.013	0.989	-1.058	0.29	-1.071	0.284
15km×15km	BIO1	11.059 (3.651)	11.098 (3.69)	11.765 (3.36)	-0.177	0.859	-3.378	0.001	-3.174	0.002
	BIO4	644.149 (59.707)	698.032 (61.929)	655.079 (64.741)	-14.876	<0.001	-2.948	0.003	11.386	<0.001
	BIO14	3.040 (2.902)	4.241 (2.049)	1.811 (1.334)	-8.025	<0.001	9.142	<0.001	23.605	<0.001
	BIO15	100.014 (11.666)	100.126 (4.811)	108.075 (6.641)	-0.212	0.832	-14.263	<0.001	-23.021	<0.001

FAL	0.137 (0.204)	0.136 (0.202)	0.135 (0.199)	0.050	0.960	0.166	0.869	0.116	0.908
FOL	0.436 (0.234)	0.434 (0.233)	0.446 (0.227)	0.108	0.914	-0.712	0.476	-0.824	0.410
RL	0.005 (0.021)	0.005 (0.022)	0.008 (0.028)	-0.400	0.689	-1.805	0.071	-1.418	0.157
OL	0.035 (0.099)	0.035 (0.099)	0.039 (0.108)	0.009	0.993	-0.744	0.457	-0.752	0.452

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Table S4. Influence of climatic, topographic and landscape factors in determining panda distribution at different spatial scales and time periods. Comparisons of mean importance of these factors examined with variable sets (%) through three-way ANOVA**.** More statistical details of post hoc tests are found in Tables S5-S9. EV1: climatic and non-climatic variable sets, EV2: temperature-related, precipitation-related, land-use and topographic variable sets, TP: Time period (TP1: 1985-1988, TP2: 1998-2002, TP3: 2012-2014), GS: Grid size (5 km×5 km, 10 km×10 km and 15 km×15 km).

Variable	Sum of squares	Mean sum of squares	*df*	*F*	*P*-value
EV1	2140.8	2140.8	1	216192.04	< 0.001
TP	7.6	3.8	2	383.26	< 0.001
GS	12.1	6.0	2	610.89	< 0.001
EV1:TP	189.9	94.9	2	9581.62	< 0.001
EV1:GS	302.5	151.2	2	15272.35	< 0.001
TP:GS	0.9	0.2	4	21.91	<0.001
EV1:TP:GS	21.7	5.4	4	547.73	< 0.001
EV2	13827	4609	3	177843.96	< 0.001
TP	19	9	2	366.47	< 0.001
GS	5	3	2	99.13	< 0.001
EV2:TP	816	136	6	5276.21	< 0.001
EV2:GS	1983	330	6	12820.91	< 0.001
TP:GS	14	3	4	133.82	< 0.001
EV2:TP:GS	455	38	12	1471.88	< 0.001

Table S5. Influence of time period in determining mean importance (%) of variable sets in determining panda distribution at three spatial scales. Comparisons of time periods (TP1: 1985-1988, TP2: 1998-2002, TP3: 2012-2014) evaluated through post hoc pair-wise comparison tests (Tukey's HSD).

Variable sets	Grid size	Time period	Difference	SE	P-value
Climatic *	5km×5km	TP1 vs. TP2	-0.489	0.021	<0.001
	5km×5km	TP1 vs. TP3	-1.871	0.021	<0.001
	5km×5km	TP2 vs. TP3	-1.382	0.021	<0.001
	10km×10km	TP1 vs. TP2	-1.608	0.047	<0.001
	10km×10km	TP1 vs. TP3	-2.940	0.047	<0.001
	10km×10km	TP2 vs. TP3	-1.332	0.047	<0.001
	15km×15km	TP1 vs. TP2	-2.267	0.075	<0.001
	15km×15km	TP1 vs. TP3	-4.241	0.075	<0.001
	15km×15km	TP2 vs. TP3	-1.974	0.075	<0.001
Non-climatic **	5km×5km	TP1 vs. TP2	0.326	0.014	<0.001
	5km×5km	TP1 vs. TP3	1.248	0.014	<0.001
	5km×5km	TP2 vs. TP3	0.922	0.014	<0.001
	10km×10km	TP1 vs. TP2	1.072	0.031	<0.001
	10km×10km	TP1 vs. TP3	1.96	0.031	<0.001
	10km×10km	TP2 vs. TP3	0.888	0.031	<0.001
	15km×15km	TP1 vs. TP2	1.511	0.050	<0.001
	15km×15km	TP1 vs. TP3	2.827	0.050	<0.001
	15km×15km	TP2 vs. TP3	1.316	0.050	<0.001

*: Climatic variable sets: BIO1, BIO4, BIO14 and BIO15;

**: Non-climatic variable sets: FAL, FOL, RL, OL, MA and RE.

Table S6. Influence of spatial scale in determining mean importance (%) of variable sets in determining panda distribution at three time periods (TP1: 1985-1988, TP2: 1998-2002, TP3: 2012-2014). Comparisons of grid sizes (5km×5km, 10km×10km, 15km×15km) evaluated through post hoc pair-wise comparison tests (Tukey's HSD).

Variable sets	Time period	Grid Size	Difference	SE	P-value
Climatic*	TP1	5km×5km vs. 10km×10km	-1.508	0.056	<0.001
	TP1	5km×5km vs. 15km×15km	-2.408	0.056	<0.001
	TP1	10km×10km vs. 15km×15km	-0.900	0.056	<0.001
	TP2	5km×5km vs. 10km×10km	-2.627	0.049	<0.001
	TP2	5km×5km vs. 15km×15km	-4.185	0.049	<0.001
	TP2	10km×10km vs. 15km×15km	-1.558	0.049	<0.001
	TP3	5km×5km vs. 10km×10km	-2.576	0.053	<0.001
	TP3	5km×5km vs. 15km×15km	-4.777	0.053	<0.001
	TP3	10km×10km vs. 15km×15km	-2.201	0.053	<0.001
Non-climatic **	TP1	5km×5km vs. 10km×10km	1.005	0.037	<0.001
	TP1	5km ×5km vs. 15km×15km	1.605	0.037	<0.001
	TP1	10km ×10km vs. 15km×15km	0.600	0.037	<0.001
	TP2	5km×5km vs. 10km×10km	1.751	0.032	<0.001
	TP2	5km ×5km vs. 15km×15km	2.79	0.032	<0.001
	TP2	10km ×10km vs. 15km×15km	1.039	0.032	<0.001
	TP3	5km×5km vs. 10km×10km	1.717	0.035	<0.001
	TP3	5km ×5km vs. 15km×15km	3.185	0.035	<0.001
	TP3	10km ×10km vs. 15km×15km	1.467	0.035	<0.001

*: Climatic variable sets: BIO1, BIO4, BIO14 and BIO15;

**: Non-climatic variable sets: FAL, FOL, RL, OL, MA and RE.

Table S7. Comparisons of the mean importance (%) between climatic and non-climatic variables in determining panda distributions through post hoc pair-wise tests (Tukey's HSD) at three time periods (TP1: 1985-1988, TP2: 1998-2002, TP3: 2012-2014).

Grid size (km)	Period	Difference	SE	P-value
5km×5km	TP1	-11.557	0.015	<0.001
5km×5km	TP2	-10.742	0.019	<0.001
5km×5km	TP3	-8.438	0.018	<0.001
10km×10km	TP1	-9.044	0.045	<0.001
10km×10km	TP2	-6.364	0.028	<0.001
10km×10km	TP3	-4.144	0.044	<0.001
15km×15km	TP1	-7.544	0.067	<0.001
15km×15km	TP2	-3.767	0.063	<0.001
15km×15km	TP3	-0.476	0.061	<0.001

Table S8. Influence of time period (TP1: 1985-1988, TP2: 1998-2002, TP3: 2012-2014) in determining panda distribution through evaluation of mean importance (%) of variable sets (temperature-related, precipitation-related, land-use and topographic) through post hoc pair-wise comparison tests (Tukey's HSD) at three spatial scales.

Variable sets	Grid size (km)	Time period	Difference	SE	P-value
Temperature-related	5km×5km	TP1 vs. TP2	0.711	0.047	<0.001
	5km×5km	TP1 vs. TP3	-6.673	0.047	<0.001
	5km×5km	TP2 vs. TP3	-7.384	0.047	<0.001
	10km×10km	TP1 vs. TP2	-0.331	0.099	0.007
	10km×10km	TP1 vs. TP3	-4.722	0.099	<0.001
	10km×10km	TP2 vs. TP3	-4.390	0.099	<0.001
	15km×15km	TP1 vs. TP2	-2.069	0.129	<0.001
	15km×15km	TP1 vs. TP3	-5.293	0.129	<0.001
	15km×15km	TP2 vs. TP3	-3.224	0.129	<0.001
Precipitation-related	5km×5km	TP1 vs. TP2	-1.689	0.025	<0.001
	5km×5km	TP1 vs. TP3	2.93	0.025	<0.001
	5km×5km	TP2 vs. TP3	4.619	0.025	<0.001
	10km×10km	TP1 vs. TP2	-2.885	0.040	<0.001
	10km×10km	TP1 vs. TP3	-1.158	0.040	<0.001
	10km×10km	TP2 vs. TP3	1.727	0.040	<0.001
	15km×15km	TP1 vs. TP2	-2.464	0.063	<0.001
	15km×15km	TP1 vs. TP3	-3.189	0.063	<0.001
	15km×15km	TP2 vs. TP3	-0.725	0.063	<0.001
Land-use	5km×5km	TP1 vs. TP2	0.067	0.017	0.002
	5km×5km	TP1 vs. TP3	2.531	0.017	<0.001
	5km×5km	TP2 vs. TP3	2.464	0.017	<0.001
	10km×10km	TP1 vs. TP2	1.501	0.034	<0.001
	10km×10km	TP1 vs. TP3	1.752	0.034	<0.001
	10km×10km	TP2 vs. TP3	0.251	0.034	<0.001
	15km×15km	TP1 vs. TP2	3.773	0.051	<0.001
	15km×15km	TP1 vs. TP3	1.938	0.051	<0.001
	15km×15km	TP2 vs. TP3	-1.834	0.051	<0.001
Topographic	5km×5km	TP1 vs. TP2	0.845	0.024	<0.001
	5km×5km	TP1 vs. TP3	-1.318	0.024	<0.001
	5km×5km	TP2 vs. TP3	-2.163	0.024	<0.001
	10km×10km	TP1 vs. TP2	0.214	0.086	0.050
	10km×10km	TP1 vs. TP3	2.376	0.086	<0.001
	10km×10km	TP2 vs. TP3	2.161	0.086	<0.001
	15km×15km	TP1 vs. TP2	-3.012	0.121	<0.001
	15km×15km	TP1 vs. TP3	4.605	0.121	<0.001
	15km×15km	TP2 vs. TP3	7.617	0.121	<0.001

Table S9. Influence of spatial scale on the mean importance (%) of variable sets (temperature-related, precipitation-related, land-use and topographic) determining panda distribution at three time periods (TP1: 1985-1988, TP2: 1998-2002, TP3: 2012-2014). Comparisons of grid sizes (5km×5km, 10km×10km, 15km×15km) evaluated through post hoc pair-wise comparison tests (Tukey's HSD).

Variable sets	Time period	Grid size	Difference	SE	P-value
Temperature-related	TP1	5km×5km vs. 10km×10km	-2.502	0.101	<0.001
	TP1	5km ×5km vs. 15km×15km	-4.513	0.101	<0.001
	TP1	10km ×10km vs. 15km×15km	-2.011	0.101	<0.001
	TP2	5km×5km vs. 10km×10km	-3.544	0.091	<0.001
	TP2	5km ×5km vs. 15km×15km	-7.293	0.091	<0.001
	TP2	10km ×10km vs. 15km×15km	-3.749	0.091	<0.001
	TP3	5km×5km vs. 10km×10km	-0.551	0.102	<0.001
	TP3	5km ×5km vs. 15km×15km	-3.132	0.102	<0.001
	TP3	10km ×10km vs. 15km×15km	-2.582	0.102	<0.001
Precipitation-related	TP1	5km×5km vs. 10km×10km	-0.514	0.060	<0.001
	TP1	5km ×5km vs. 15km×15km	-0.302	0.060	<0.001
	TP1	10km ×10km vs. 15km×15km	0.211	0.060	0.004
	TP2	5km×5km vs. 10km×10km	-1.71	0.033	<0.001
	TP2	5km ×5km vs. 15km×15km	-1.077	0.033	<0.001
	TP2	10km ×10km vs. 15km×15km	0.633	0.033	<0.001
	TP3	5km×5km vs. 10km×10km	-4.602	0.039	<0.001
	TP3	5km ×5km vs. 15km×15km	-6.421	0.039	<0.001
	TP3	10km ×10km vs. 15km×15km	-1.819	0.039	<0.001
Land-use	TP1	5km×5km vs. 10km×10km	-0.676	0.040	<0.001
	TP1	5km ×5km vs. 15km×15km	-2.197	0.040	<0.001
	TP1	10km ×10km vs. 15km×15km	-1.52	0.040	<0.001
	TP2	5km×5km vs. 10km×10km	0.758	0.037	<0.001
	TP2	5km ×5km vs. 15km×15km	1.509	0.037	<0.001
	TP2	10km ×10km vs. 15km×15km	0.751	0.037	<0.001
	TP3	5km×5km vs.10km×10km	-1.455	0.034	<0.001
	TP3	5km ×5km vs. 15km×15km	-2.789	0.034	<0.001
	TP3	10km ×10km vs. 15km×15km	-1.334	0.034	<0.001
Topographic	TP1	5km×5km vs. 10km×10km	4.368	0.109	<0.001
	TP1	5km ×5km vs. 15km×15km	9.208	0.109	<0.001
	TP1	10km ×10km vs. 15km×15km	4.84	0.109	<0.001
	TP2	5km×5km vs. 10km×10km	3.738	0.067	<0.001
	TP2	5km ×5km vs. 15km×15km	5.351	0.067	<0.001
	TP2	10km ×10km vs. 15km×15km	1.614	0.067	<0.001
	TP3	5km×5km vs. 10km×10km	8.062	0.080	<0.001
	TP3	5km ×5km vs. 15km×15km	15.131	0.080	<0.001
	TP3	10km ×10km vs. 15km×15km	7.069	0.080	<0.001

Table S10. Comparisons of the mean importance (%) of variable sets (temperature-related, precipitation-related, land-use and topographic) in determining panda distribution through post hoc pair-wise comparison tests (Tukey's HSD) at three time periods (TP1: 1985-1988, TP2: 1998-2002, TP3: 2012-2014) and three spatial scales.

Variable sets	Time period	Grid size	Difference	SE	P-value
Temperature-related vs. Precipitation-related	TP1	5km×5km	-17.846	0.032	<0.001
	TP2	5km×5km	-20.246	0.037	<0.001
	TP3	5km×5km	-8.243	0.044	<0.001
	TP1	10km×10km	-15.858	0.089	<0.001
	TP2	10km×10km	-18.411	0.045	<0.001
	TP3	10km×10km	-12.294	0.086	<0.001
	TP1	15km×15km	-13.635	0.109	<0.001
	TP2	15km×15km	-14.03	0.103	<0.001
	TP3	15km×15km	-11.531	0.093	<0.001
Temperature-related vs. Land-use	TP1	5km×5km	-20.094	0.032	<0.001
	TP2	5km×5km	-20.739	0.037	<0.001
	TP3	5km×5km	-10.891	0.037	<0.001
	TP1	10km×10km	-18.269	0.086	<0.001
	TP2	10km×10km	-16.436	0.047	<0.001
	TP3	10km×10km	-11.795	0.083	<0.001
	TP1	15km×15km	-17.778	0.096	<0.001
	TP2	15km×15km	-11.936	0.104	<0.001
	TP3	15km×15km	-10.547	0.095	<0.001
Precipitation-related vs. Land-use	TP1	5km×5km	-2.248	0.019	<0.001
	TP2	5km×5km	-0.493	0.013	<0.001
	TP3	5km×5km	-2.648	0.030	<0.001
	TP1	10km×10km	-2.411	0.046	<0.001
	TP2	10km×10km	1.975	0.029	<0.001
	TP3	10km×10km	0.499	0.035	<0.001
	TP1	15km×15km	-4.143	0.073	<0.001
	TP2	15km×15km	2.094	0.052	<0.001
	TP3	15km×15km	0.984	0.043	<0.001
Temperature-related vs. Topographic	TP1	5km×5km	-21.251	0.033	<0.001
	TP2	5km×5km	-21.117	0.041	<0.001
	TP3	5km×5km	-15.896	0.037	<0.001
	TP1	10km×10km	-14.381	0.116	<0.001
	TP2	10km×10km	-13.835	0.064	<0.001
	TP3	10km×10km	-7.284	0.093	<0.001
	TP1	15km×15km	-7.53	0.136	<0.001
	TP2	15km×15km	-8.473	0.115	<0.001
	TP3	15km×15km	2.367	0.123	<0.001

Precipitation-related vs. Topographic	TP1	5km×5km	-3.405	0.021	<0.001
	TP2	5km×5km	-0.871	0.023	<0.001
	TP3	5km×5km	-7.654	0.029	<0.001
	TP1	10km×10km	1.477	0.090	<0.001
	TP2	10km×10km	4.576	0.052	<0.001
	TP3	10km×10km	5.01	0.054	<0.001
	TP1	15km×15km	6.105	0.121	<0.001
	TP2	15km×15km	5.557	0.072	<0.001
	TP3	15km×15km	13.899	0.090	<0.001
Land-use vs. Topographic	TP1	5km×5km	-1.157	0.021	<0.001
	TP2	5km×5km	-0.378	0.023	<0.001
	TP3	5km×5km	-5.006	0.018	<0.001
	TP1	10km×10km	3.888	0.087	<0.001
	TP2	10km×10km	2.601	0.054	<0.001
	TP3	10km×10km	4.511	0.050	<0.001
	TP1	15km×15km	10.248	0.110	<0.001
	TP2	15km×15km	3.464	0.074	<0.001
	TP3	15km×15km	12.914	0.091	<0.001