Table S1. Data Information

Type		Data Set	Unit	Resolution
Regional geomorphology	elevation	SRTMDEMUTM digital elevation data product	m	90m
	slope	SRTMSLOPE slope data product	°	
	aspect	SRTMASPECT aspect data	°	
Climate change	temperature	1-km monthly mean temperature dataset for china [57]	0.1°C	1km
	precipitation	1-km monthly precipitation dataset for China [58]	0.1mm	
	solar radiation	High spatial resolution (10km) surface solar radiation dataset with by merging sunshine hours over China China [59]	W/m^2	10km
Ecological environment	evapotranspiration	Terrestrial evapotranspiration dataset across China [60]	mm	0.1°
	soil moisture	Soil moisture in China dataset [61]	m^3/m^3	0.05°
	clay/sand content	A China soil characteristics dataset [62]	%	0.0083°
	NDVI	MOD3Q1 product	1	250m
Permafrost environment	LST	Daily 1-km all-weather land surface temperature dataset for Western China [63]	°C	1km
	LRad	China meteorological forcing dataset [64]	W/m^2	10km
Water environment	lake	China lake dataset [65]	m^2	-

Note: NDVI: Normalized difference vegetation index; LST: Land surface temperature; LRad: download long-wave radiatio

Table S2. Response Relationship between Elevation and Risk Factors

Factors	Maximum Value		Minimum Value		Variation Characteristics	
	mean	region	mean	region	criticality	characteristics
MAAT (°C)	-2.01	< 4200m	-17.12	> 6000m		decrease slowly, then quickly
MAP (mm)	14.83	< 4200m	37.70	> 6000m	level 7	increase quickly, then slowly
SR (W/m2)	2586.10	5200 ~ 5400m	2470.93	< 4200m		increase first quickly, then decrease quickly
ET (mm)	369.23	5200 ~ 5400m	107.75	> 6000m	level 7	increase first slowly, then decrease quickly
FVC (%)	38.34	4800 ~ 5000m	8.25	> 6000m	level 5	increase first slowly, then decrease quickly
SM (m^3/m^3)	0.0640	< 4200m	0.0969	4600 ~ 4800m	level 4	increase first quickly, then decrease quickly
CC1 (%)	13.53	4600 ~ 4800m	6.31	5800 ~ 6000m	level 4	increase first, then decrease
CC2 (%)	17.71	4600 ~ 4800m	11.26	> 6000m	level 4	
SC1 (%)	56.94	4200 ~ 4400m	36.20	5800 ~ 6000m	level 3, 5	decrease first, then increase
SC2 (%)	54.69	4200 ~ 4400m	36.67	5800 ~ 6000m	level 3, 4	and finally decrease
ABC (MPa)	0.23	< 4200m	1.31	> 6000m	level 7	decrease slowly, then quickly
ALT (m)	3.74	> 6000m	1.42	5000 ~ 5200m	level 6	decrease first, then increase
VIC (%)	29.38	4600 ~ 4800m	14.89	5200 ~ 5400m	level 7	increase first, then decrease to about 15%
MAGT (°C)	0.40	< 4200m	-4.97	> 6000m	level 7	decrease slowly, then quickly
MAST (°C)	2.96	< 4200m	-14.59	> 6000m	level 7	decrease slowly, then quickly

Table S3. Response Relationship between Slope and Risk Factors

Factors	Peak Value		Sub-peak Value		Valley Value	
	mean	region	mean	region	mean	region
MAAT (°C)	-4.11	0 ~ 3°	-5.01	3 ~ 6°	-6.63	> 15°
MAP (mm)	29.62	10 ~ 15°	29.41	> 15°	24.36	0 ~ 3°
SR (W/m^2)	2583.78	0 ~ 3°	2583.08	3 ~ 6°	2553.07	> 15°
ET (mm)	354.36	10 ~ 15°	349.11	6 ~ 10°	337.02	> 15°
FVC (%)	37.96	3 ~ 6°	37.87	6 ~ 10°	31.38	> 15°
SM (m^3/m^3)	0.0938	3 ~ 6°	0.0931	0 ~ 3°	0.0819	> 15°
CC1 (%)	12.75	0 ~ 3°	12.73	0 ~ 3°	9.73	> 15°
CC2 (%)	17.71	0 ~ 3°	17.24	3 ~ 6°	14.41	> 15°
SC1 (%)	52.74	> 15°	51.99	10 ~ 15°	43.92	0 ~ 3°
SC2 (%)	44.08	> 15°	42.94	10 ~ 15°	41.31	0 ~ 3°
ABC (MPa)	0.59	> 15°	0.56	10 ~ 15°	0.41	0 ~ 3°
ALT (m)	2.83	0 ~ 3°	2.18	3 ~ 6°	1.78	10 ~ 15°
VIC (%)	28.98	0 ~ 3°	28.77	3 ~ 6°	13.50	> 15°
MAGT (°C)	-0.55	0 ~ 3°	-0.88	3 ~ 6°	-1.41	> 15°
MAST (°C)	0.59	0 ~ 3°	0.10	3 ~ 6°	-1.26	> 15°

Table S4. Response Relationship between Aspect and Risk Factors

Factors	Peak Value		Sub-peak Value		Valley Value	
	mean	region	mean	region	mean	region
MAAT (°C)	-4.66	southeast	-4.67	east, northeast	-5.19	west
MAP (mm)	26.78	west	26.61	northwest	25.68	southeast
SR (W/m^2)	2583.75	southeast	2581.86	east	2574.69	northwest
ET (mm)	347.40	northeast	347.39	east	342.92	southwest
FVC (%)	35.13	northeast	35.11	north	33.20	southwest
SM (m^3/m^3)	0.0929	northeast	0.0928	southeast	0.0900	west
CC1 (%)	12.34	southeast	12.28	south	11.84	west
CC2 (%)	17.39	southeast	17.18	east	16.63	southwest
SC1 (%)	47.55	southwest	47.29	west	45.70	southeast
SC2 (%)	42.67	southwest	42.64	south	41.04	east
ABC (MPa)	0.50	southwest	0.49	west	0.44	northeast
ALT (m)	2.54	southeast	2.53	east	2.30	west
VIC (%)	28.35	southwest	27.81	west	24.10	northeast
MAGT (°C)	-0.62	northeast	-0.63	north	-1.03	southwest
MAST (°C)	0.37	southeast	0.25	east	-0.24	northwest

Table S5. Response Relationship between RDLS and Risk Factors

Factors	Peak Value		Sub-peak Value		Valley Value	
	mean	region	mean	region	mean	region
MAAT (°C)	-3.89	plain	-4.43	platform	-8.70	moderate relief mountain
MAP (mm)	30.13	low relief mountain	27.77	hill	23.66	plain
SR (W/m^2)	2584.58	platform	2584.47	plain	2482.36	moderate relief mountain
ET (mm)	350.53	hill	347.90	low relief mountain	235.73	moderate relief mountain
FVC (%)	38.42	plain	35.86	platform	20.07	moderate relief mountain
SM (m^3/m^3)	0.0942	hill	0.0941	platform	0.0682	moderate relief mountain
CC1 (%)	13.19	platform	12.65	plain	8.77	moderate relief mountain
CC2 (%)	17.90	plain	17.23	platform	13.06	moderate relief mountain
SC1 (%)	57.27	moderate relief mountain	52.30	low relief mountain	42.79	plain
SC2 (%)	59.16	moderate relief mountain	42.49	platform	40.87	plain
ABC (MPa)	0.73	moderate relief mountain	0.57	low relief mountain	0.40	plain
ALT (m)	2.98	plain	2.58	platform	1.85	low relief mountain
VIC (%)	29.90	platform	29.18	plain	10.46	moderate relief mountain

Table S6. Response Relationship between VIC and Risk Factors

Factors	Peak Value		Sub-peak Value		Valley Value	
	mean	region	mean	region	mean	region
MAAT (°C)	-3.89	talik	-4.08	IR	-5.63	IP
MAP (mm)	32.23	IP	26.28	IC	24.24	IL
SR (W/m^2)	2591.42	IP	2590.96	IR	2562.05	IL
ET (mm)	370.06	IP	352.32	IR	334.94	IL
FVC (%)	35.80	IS	34.99	IP	31.81	talik
SM (m^3/m^3)	0.0985	IR	0.0940	IS	0.0881	IC
CC1 (%)	13.07	IR	12.27	talik	9.63	IP
CC2 (%)	18.27	talik	17.72	IS	14.15	IP
SC1 (%)	53.37	IP	46.90	IC	42.24	IR
SC2 (%)	42.90	IS	42.77	IR	38.24	IP
ABC (MPa)	0.52	IC	0.51	IP	0.39	talik
ALT (m)	2.92	talik	2.85	IR	1.85	IP
MAGT (°C)	-0.43	talik	-0.52	IR	-1.09	IR
MAST (°C)	1.29	talik	1.06	IR	-0.78	IL

Table S7. Response Relationship between ET and Influencing Factors

	FVC	MAP	SM	SR	MAAT
Partial correlation coefficient range	-0.66~0.90	-0.87~0.54	-0.48~0.92	-0.64~0.62	-0.26~0.80
Mean value of partial correlation coefficient	0.256	-0.357	0.544	0.017	0.335
Significant positive correlation ratio / %	6.47	0.00	48.28	0.01	1.38
Significant negative correlation ratio / %	0.01	14.16	0.00	0.01	0.00
Insignificant positive correlation ratio / %	82.87	10.24	48.54	45.35	94.79
Insignificant negative correlation ratio / %	10.65	75.60	3.18	54.63	3.83
Significant areas ratio / %	6.48*	14.16*	48.28*	0.02*	1.38*
Significant areas	Buqu River, Laowenquan	Beilu River, Fenghuo Mountain, Chumar River	Xidatan, Chumar River, Beilu River, Fenghuo Mountain, Buqu River, Tanggula	Xidatan, Chumar River	Buqu River, Laowenquan, Tanggula
Proportion of influence degree / %	9.24	12.46	66.42	0.08	11.80

Note: * indicates significant at the 0.05 level (T two-side significance test).

Table S8. Response Relationship between FVC and Influencing Factors

	ET	MAP	SM	SR	MAAT
Partial correlation coefficient range	-0.66~0.91	-0.84~0.68	-0.87~0.73	-0.77~0.69	-0.82~0.60
Mean value of partial correlation coefficient	0.255	0.055	-0.084	0.278	-0.073
Significant positive correlation ratio / %	6.32	0.07	0.04	0.31	0.00
Significant negative correlation ratio / %	0.01	0.18	2.13	0.01	0.14
Insignificant positive correlation ratio / %	82.75	63.78	38.28	97.22	32.57
Insignificant negative correlation ratio / %	10.93	35.97	59.55	2.46	67.29
Significant areas ratio / %	6.33*	0.25*	2.17*	0.32*	0.14*
Significant areas	Wudaoliang, Buqu River, Laowenquan	Kunlun Mountain, Qingshui River, Wudaoliang, Buqu River	Xidatan, Wudaoliang, Tuotuo River, Buqu River, Laowenquan	Xidatan, Qingshui River, Fenghuo Mountain, Buqu River	Buqu River
Proportion of influence degree	39.48	5.76	7.66	45.09	2.01

Note: * indicates significant at the 0.05 level (T two-side significance test).

Table S9. Response Relationship between SM and Influencing Factors

	ET	MAP	SM	SR	MAAT
Partial correlation coefficient range	-0.48~0.92	-0.89~0.73	-0.51~0.96	-0.74~0.46	-0.82~0.62
Mean value of partial correlation coefficient	0.546	-0.085	0.454	-0.318	-0.301
Significant positive correlation ratio / %	48.57	0.04	35.08	0.00	0.02
Significant negative correlation ratio / %	0.00	2.16	0.00	11.54	1.68
Insignificant positive correlation ratio / %	48.24	38.26	51.53	9.72	9.48
Insignificant negative correlation ratio / %	3.19	59.54	13.38	78.74	88.82
Significant areas ratio / %	48.57*	2.19*	35.08*	11.51	1.70
Significant areas	Xidatan, Chumar River, Wudaoliang, Fenghuo Mountain, Buqu River, Tanggula	Buqu River, Laowenquan	Qingshui River, Tuotuo River	Xidatan, Budongquan, Qingshui River, Beilu River	Buqu River, Laowenquan
Proportion of influence degree	43.30	0.31	45.67	9.04	1.67

Note: * indicates significant at the 0.05 level (T two-side significance test).

Table S10. Response Relationship between ABC and Influencing Factors

	ALT	FVC	MAST	MAP	SM	SR	MAAT
partial correlation coefficient range	-0.95~0.98	-0.96~0.90	-0.98~0.93	-0.97~0.92	-0.98~0.96	-0.89~0.96	-0.99~0.71
Mean value of partial correlation coefficient	-0.014	0.042	-0.045	-0.060	-0.021	0.043	-0.618
Significant positive correlation ratio / %	18.63	2.38	2.01	0.76	12.92	3.63	0.01
Significant negative correlation ratio / %	19.00	2.68	3.78	1.65	18.30	2.13	52.10
Insignificant positive correlation ratio / %	29.73	57.17	43.92	46.91	38.43	51.72	7.91
Insignificant negative correlation ratio / %	32.64	37.77	50.29	50.68	30.35	42.52	39.97
Significant areas ratio / %	37.63*	5.06*	5.79*	2.41*	31.22*	5.76*	52.11*
Significant areas	Kumlun Mountain, Chumar River, Beilu River, Laowenquan	Laowenquan	Xidatan, Budongquan, Chumar River, Beilu River, TuotuoRiver, Buqu River	Kunlun Mountain, Chumar River, Beilu River, Fenghuo Mountain, Tuotuo River, Buqu River	Budongquan, Chumaer River, Kaixinling, Tanggula	Beilu River, Tuotuo River	Xidatan, Wudaoliang, Beilu River, Buqu River, Tanggula
Proportion of influence degree / %	45.88	0.88	5.25	13.35	32.76	1.89	-

Note: * indicates significant at the 0.05 level (T two-side significance test).

Table S11. Response Relationship between ALT and Influencing Factors

	ET	FVC	MAST	MAP	SM	SR	MAAT
partial correlation coefficient range	-0.92~0.85	-0.73~0.91	-0.95~0.88	-0.94~0.94	-0.89~0.96	-0.76~0.92	-0.97~0.99
Mean value of partial correlation coefficient	-0.286	0.242	-0.108	-0.196	0.467	0.152	0.754
Significant positive correlation ratio / %	4.25	0.01	2.27	1.39	0.52	0.02	5.27
Significant negative correlation ratio / %	17.49	82.65	36.20	23.85	73.69	68.97	2.96
Insignificant positive correlation ratio / %	77.92	14.94	61.08	74.39	7.20	29.55	1.31
Insignificant negative correlation ratio / %	-0.286	0.242	-0.108	-0.196	0.467	0.152	0.754
Significant areas ratio / %	4.58*	2.40*	2.72*	2.41*	19.10*	1.48*	95.73*
Significant areas	Xidatan, Xieshui River, Fenghuo mountain, Tuotuo River, Kaixingling, Buqu River	Chumar River, Kaixinling, Buqu River	Xieshui River, Chumar River, Beilu River	Kunlun Mountain, Chumar River, Beilu River, Fenghuo Mountain, Tuotuo River, Buqu River	Xidatan, Kunlun Mountain, Xieshui River, Beilu River, Fenghuo Mountain, Tuotuo River, Buqu River	Xidatan, Xieshui River, Chumar River, Beilu River, Fenghuo Mountain	Kunlun Mountain, Wudaoliang, Fenghuo Mountain, Tuotuo River, Tanggula
Proportion of influence degree / %	4.95	3.01	14.35	1.24	71.87	4.58	-

Note: * indicates significant at the 0.05 level (T two-side significance test).

Table S12. Response Relationship between MAGT and Influencing Factors

	ET	FVC	MAST	MAP	SM	SR	MAAT
partial correlation coefficient range	-0.96~0.86	-0.82~0.82	-0.95~0.94	-0.91~0.89	-0.92~0.95	-0.93~0.94	-0.55~0.99
Mean value of partial correlation coefficient	-0.018	0.005	0.014	-0.004	0.036	-0.018	0.936
Significant positive correlation ratio / %	17.31	0.48	3.26	0.59	5.18	2.54	99.73
Significant negative correlation ratio / %	19.05	0.84	2.58	1.55	3.78	4.41	0.00
Insignificant positive correlation ratio / %	31.80	52.14	48.36	50.33	48.83	46.63	0.27
Insignificant negative correlation ratio / %	31.84	46.54	45.80	47.54	42.20	46.43	0
Significant areas ratio / %	4.58*	1.32*	2.72*	2.41*	8.96*	6.94*	99.73*
Significant areas	Kunlun Mountain, Xieshui River, Wudaoliang, Tuotuo River, Kaixingling, Laowenquan	Kaixinling	Xidatan, Chumar River, Wudaoliang, Tuotuo River, Buqu River	Xidatan, Budongquan, Tuotuo River	Tuotuo River, Tanggula	Beilu River, Kaixinling, Buqu River	Xidatan, Wudaoliang, Tuotuo River, Tanggula
Proportion of influence degree / %	82.36	0.27	2.50	3.75	8.66	2.46	-

Note: * indicates significant at the 0.05 level (T two-side significance test).

Table S13. Response Relationship between MAST and Influencing Factors

	ET	FVC	MAP	SM	SR	MAAT
partial correlation coefficient range	-0.70~0.94	-0.93~0.72	-0.90~0.91	-0.96~0.87	-0.75~0.94	-0.89~0.82
Mean value of partial correlation coefficient	0.386	-0.209	0.136	-0.467	0.132	-0.160
Significant positive correlation ratio / %	0.55	3.00	0.20	3.32	0.05	16.03
Significant negative correlation ratio / %	3.98	0.05	36.93	1.30	6.41	0.04
Insignificant positive correlation ratio / %	30.18	65.05	10.11	63.82	25.19	75.11
Insignificant negative correlation ratio / %	65.28	31.90	52.76	31.56	68.35	8.82
Significant areas ratio / %	4.53*	3.05*	37.14*	4.62*	4.62*	16.07*
Significant areas	Budongquan, Wudaoliang, Tuotuo River, Tanggula	Tuotuo River, Tanggula	Fenghuo Mountain, Tanggula	Xidatan, Budongquan, Chumar River, Wudaoliang, Tuotuo River, Tanggula	Fenghuo Mountain, Laowenquan	Xidatan, Budongquan, Chumar River, Wudaoliang, Tuotuo River, Kaixinling
Proportion of influence degree / %	4.42	5.35	53.76	4.68	6.56	25.24

Note: * indicates significant at the 0.05 level (T two-side significance test).

References

57. [dataset] Peng, S.Z. 1-km monthly mean temperature dataset for china (1901-2017). National Tibetan Plateau Data Center. 2019. doi: 10.11888/Meteoro.tpdc.270961.

58. [dataset] Peng, S.Z. 1-km monthly precipitation dataset for China (1901-2017). National Tibetan Plateau Data Center. 2020. doi: 10.5281/zenodo.3185722.

59. [dataset] Feng, F.; Wang, K.C. High spatial resolution (10km) surface solar radiation dataset with by merging sunshine hours over China China (1983-2017). National Tibetan Plateau Data Center. 2020. doi:10.11888/Meteoro.tpdc.271023.

60. [dataset] Ma, N.; Szilagyi, J.; Zhang, Y.S.; Liu, W.B. Terrestrial evapotranspiration dataset across China (1982-2017). National Tibetan Plateau Data Center. 2019. doi: 10.11888/AtmosPhys.tpe.249493.file.

61. [dataset] Mao, K.B. SMC dataset: Soil Moisture in China dataset (2002-2018). National Tibetan Plateau Data Center. 2021. doi: 10.5281/zenodo.4738556.

62. [dataset] Shang, G.W.; Dai, Y.J. A China soil characteristics dataset (2010).National Tibetan Plateau Data Center. 2019. doi: 10.11888/Soil.tpdc.270466.

63. [dataset] Zhang, X.D.; Zhou, J.; Tang, W.B.; Ding, L.R.; Ma, J.; Zhang, X. Daily 1-km all-weather land surface temperature dataset for the Chinese landmass and its surrounding areas (TRIMS LST; 2000-2020). National Tibetan Plateau Data Center. 2021. doi: 10.11888/Meteoro.tpdc.271252.

64. [dataset] Yang, K.; He, J. China meteorological forcing dataset (1979-2018). National Tibetan Plateau Data Center. 2019. doi: 10.11888/AtmosphericPhysics.tpe.249369.file.

65. [dataset] Zhang, G.Q. China lake dataset (1960s-2020). National Tibetan Plateau Data Center. 2019. doi:10.11888/Hydro.tpdc.270302.