

Supplementary Table

Table S1 (a) Circum-Arctic permafrost region

Bootstrap Path Coefficient Validation

Path	Std.Error	95% CI
TOPO → ALT	0.035	[-0.27, -0.13]
TEMP → ALT	0.041	[0.29, 0.45]
TP → ALT	0.0340	[0.1427, 0.2805]
SD → ALT	0.0393	[-0.2584, -0.1139]
Soil → ALT	0.0444	[0.3041, 0.4710]
NDVI → ALT	0.0369	[-0.2212, -0.0822]

Table S1 (b) Bootstrap Validation of Total Effects on ALT

Path	Std.Error	95% CI
TOPO → ALT	0.029	[-0.139, -0.030]
TEMP → ALT	0.029	[0.270, 0.379]
TP → ALT	0.037	[0.146, 0.292]
SD → ALT	0.022	[0.082, 0.167]
Soil → ALT	0.042	[0.301, 0.468]
NDVI → ALT	0.042	[-0.239, -0.073]

Table S1 (c) CR & AVE Table

Latent Variable	Number of Items	Composite Reliability (CR)	Average Variance Extracted (AVE)
TOPO	2	0.694	0.541
TEMP	2	0.873	0.774
Soil	3	0.855	0.665

Table S1 (d) HTMT Table

Latent Variable	Topography	Temperature	Soil
TOPO	1	0.276	0.898
TEMP	0.276	1	0.268
Soil	0.898	0.268	1

Table S1 (e) Effect Size Analysis (Cohen's f²)

Effect Type	Predictor Variable	Cohen's f ²
Overall effect	Model total	0.518
Local effect	TOPO	0.064
Local effect	TEMP	0.185
Local effect	TP	0.067
Local effect	SD	0.045
Local effect	Soil	0.220
Local effect	NDVI	0.026

Sub-Circum-Arctic permafrost region

Table S2 (a) Bootstrap Path Coefficient Validation

Path	Std.Error	95% CI
TOPO → ALT	0.048	[-0.4994, -0.3227]
TP → ALT	0.034	[0.3331, 0.4648]
Soil → ALT	0.0409	[0.1979, 0.3522]
NDVI → ALT	0.0362	[0.2487, 0.3756]

Table S2 (b) Bootstrap Validation of Total Effects on ALT

Path	Std.Error	95% CI
TOPO → ALT	0.0317	[-0.4674, -0.3426]
TEMP → ALT	0.0285	[-0.0439, 0.0627]
TP → ALT	0.0311	[0.3066, 0.4282]
SD → ALT	0.0233	[-0.1074, -0.0146]
Soil → ALT	0.0409	[0.1979, 0.3522]
NDVI → ALT	0.0362	[0.2487, 0.3756]

Table S2 (c) CR & AVE Table

Latent Variable	Number of Items	Composite Reliability (CR)	Average Variance Extracted (AVE)
TOPO	2	0.722	0.572
TEMP	2	0.907	0.830
Snow	2	0.922	0.855

Table S2 (d) HTMT Table

Latent Variable	TOPO	TEMP	Snow
TOPO	1	0.186	0.377
TEMP	0.186	1	0.732
Snow	0.377	0.732	1

Table S2 (e) Effect Size Analysis (Cohen's f²)

Effect Type	Predictor Variable	Cohen's f ²
Overall effect	Model total	0.566
Local effect	TOPO	0.261
Local effect	TP	0.248
Local effect	Soil	0.113
Local effect	NDVI	0.154

QTP

Table S3 (a) Bootstrap Path Coefficient Validation

Path	Std.Error	95% CI
Asp → ALT	0.0647	[-0.6382, -0.3730]
Snow → ALT	0.0491	[-0.2446, -0.0533]
Soil → ALT	0.0757	[0.2520, 0.5446]
NDVI → ALT	0.0641	[0.0606, 0.2952]

Table S3 (b) Bootstrap Validation of Total Effects on ALT

Path	Std.Error	95% CI
Asp → ALT	0.0474	[-0.4209, -0.2419]
TEMP → ALT	0.0394	[0.1129, 0.2715]
TP → ALT	0.0510	[-0.1859, 0.0114]
Snow → ALT	0.0461	[-0.2002, -0.0248]
Soil → ALT	0.0757	[0.2520, 0.5446]
NDVI → ALT	0.0641	[0.0606, 0.2952]

Table S3 (c) CR & AVE Table

Latent Variable	Number of Items	Composite Reliability (CR)	Average Variance Extracted (AVE)
Soil	2	0.809	0.680
TEMP	2	0.941	0.889
Snow	2	0.910	0.835

Table S3 (d) HTMT Table

Latent Variable	TEMP	Snow	Soil
TEMP	1	0.494	0.453
Snow	0.494	1	0.489
Soil	0.453	0.489	1

Table S3 (e) Effect Size Analysis (Cohen's f^2)

Effect Type	Predictor Variable	Cohen's f^2
Overall effect	Model total	0.337
Local effect	Asp	0.056
Local effect	Snow	0.039
Local effect	Soil	0.194
Local effect	NDVI	0.023

References for ALT sites compiled from published literature

The following references correspond to the 136 additional ALT sites compiled from published literature, as described in Section 2.2 of the main manuscript.

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