

Supplemental material

- **Table S1** Environmental characteristics between and within hummocks for A) Southern study site Skalluvaara and B) Northern study site Pulmankijärvi.
- **Table S2** Effects of permafrost, topography, shrub canopy (and site) on environmental characteristics for A) both sites together as well as for B) southern site Skalluvaara and C) northern site Pulmankijärvi separately.
- **Table S3** Effects of permafrost, topography, shrub canopy and tree species on cumulative tree seedling survival over four periods: July 2014-August 2014, July 2014-August 2015, July 2014-August 2016 and July 2014-July 2019
- **Table S4** Effects of permafrost, topography, shrub canopy on cumulative tree seedling survival per tree species over the whole experimental period: July 2014-August 2019
- **Table S5** Number and height (cm) of surviving planted seedlings in August 2019.
- **Table S6** Effects of environmental variables and vegetation biomass and cover across plots on cumulative tree seedling survival per tree species for the early experimental period: July 2014-August 2014 (both) and July 2014-August 2015 (environmental only).

Table S1 Environmental characteristics between and within hummocks for A) Southern study site Skalluvaara and B) Northern study site Pulmankijärvi. N = number of observations. Means of and standard errors of untransformed data on **Vegetation**: Total cover, % woody, % herbaceous = % of hits per plot, herbaceous are all non-woody vascular plants, mean vegetation height (cm), number of plant species per plot, aboveground biomass removed from clipped plots (g/m²), **Microclimate**: Soil temperature: °C, Soil moisture: Vol%, Irradiance: W m⁻². Data are based on point measurements in July 2014 and 2015. **Soil nutrients**: N, P, K: mg kg⁻¹ resin. Means have been calculated as averages of point measurements per plot that are in turn averaged over the years 2014 and 2015 (see methods). For statistical analyses, see Tables S2A, S2B and S2C.

A) Southern site Skalluvaara

Permafrost Topography Shrub canopy	Permafrost present									Permafrost absent								
	Top					Side				Top				Side				
	intact	removed				intact	removed			intact	removed				intact	removed		
	N	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se	
Vegetation																		
Total cover	120	104	14	95	12	146	11	142	14	109	8	98	8	141	14	130	16	
% woody	120	53.9	5.7	51.8	6.0	72.8	3.3	64.6	4.1	62.7	3.5	61.4	4.0	68.6	3.2	67.7	4.4	
% herbaceous	120	21.1	3.3	21.4	3.1	18.3	2.3	21.5	3.1	21.7	2.2	20.0	2.5	22.5	3.0	16.3	1.7	
Height	120	10.3	1.0	9.5	0.8	22.3	2.4	21.9	1.9	12.9	0.9	12.8	1.3	27.7	4.0	29.0	4.1	
Number of species	120	3.3	0.2	3.5	0.2	5.3	0.2	5.3	0.2	4.3	0.3	4.3	0.3	5.5	0.3	5.7	0.4	
Biomass	60	-	-	572	100	-	-	628	47	-	-	557	70	-	-	633	142	
Microclimate																		
Summer soil T	120	9.2	0.4	9.3	0.3	9.4	0.3	9.6	0.3	11.0	0.2	10.8	0.2	10.1	0.2	10.1	0.2	
Soil moisture	120	15.8	1.6	17.6	1.5	24.6	1.5	25.3	2.0	17.6	1.6	17.6	1.4	21.9	1.5	21.4	1.6	
Irradiance	120	10.6	0.7	11.8	0.6	7.6	0.7	10.1	0.6	11.6	1.1	13.1	1.0	8.9	0.9	11.8	1.1	
Soil nutrients																		
Nitrogen	30	46.6	3.6	-	-	-	-	-	-	71.4	17.3	-	-	-	-	-	-	
Phosphorous	30	19.4	7.0	-	-	-	-	-	-	30.1	12.2	-	-	-	-	-	-	
Potassium	30	358.6	57.9	-	-	-	-	-	-	442.5	67.7	-	-	-	-	-	-	

B) Northern site Pulmankijärvi

Permafrost Topography Shrub canopy	Permafrost present								Permafrost absent								
	Top				Side				Top				Side				
	intact	removed			intact	removed			intact	removed			intact	removed			
	N	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se
Vegetation																	
Total cover	120	96	10	90	7.9	127	15	126	12	111	12	105	11	146	12	134	9
% woody	120	63.5	7.4	61.3	6.1	65.0	4.8	68.5	4.9	63.7	5.9	64.2	4.3	72.5	4.4	66.3	3.6
% herbaceous	120	12.9	3.3	17.0	3.9	22.8	5.4	17.0	3.2	20.1	4.4	15.6	4.0	14.0	2.9	13.9	3.0
Height (cm)	120	10.6	0.9	12.3	1.1	26.8	2.5	23.6	2.2	18.0	2.2	17.8	2.0	32.6	3.2	30.6	3.7
Number of species	120	3.6	0.3	3.6	0.3	5.0	0.4	5.4	0.4	4.1	0.4	4.3	0.4	5.9	0.4	5.9	0.3
Biomass (g)	60	-	-	1108	191	-	-	1160	161	-	-	1204	102	-	-	970	105
Microclimate																	
Summer soil T	120	9.1	0.2	8.5	0.2	9.0	0.4	9.3	0.4	11.3	0.2	10.9	0.2	11.0	0.3	10.7	0.2
Soil moisture	120	19.0	2.0	19.1	1.6	26.5	2.2	24.2	1.7	17.3	2.3	18.7	2.1	29.4	2.8	33.8	3.0
Irradiance	120	50.2	5.1	62.0	5.9	44.3	6.2	65.3	7.9	41.0	3.4	59.1	5.3	43.5	5.6	62.0	6.3
Soil nutrients																	
Nitrogen	30	189.4	31.3	-	-	-	-	-	-	179.9	19.2	-	-	-	-	-	-
Phosphorous	30	19.9	3.0	-	-	-	-	-	-	18.3	3.3	-	-	-	-	-	-
Potassium	30	483.0	43.7	-	-	-	-	-	-	435.7	55.4	-	-	-	-	-	-

Table S2 Statistical analyses of environmental characteristics for A) both sites together as well as for B) southern site Skalluvaara and C) northern site Pulmankijärvi separately. Data on vegetation and microclimate (Table 1) were analysed with linear mixed models (*lmer*) with hummock and site, where applicable, as (nested) random factors. N = number of observations; E = parameter estimates; t-values in bold indicate statistical significance (see methods in manuscript) relative to intercept. Intercept has been set to: no permafrost, hummock sides with canopy intact. Soil nutrients were analysed with a linear model (*lm*). Here site was included as a fixed factor when both sites were analysed together.

A) Both sites together

Lmer	N	Permafrost		Topography		Shrub canopy		P*T		P*C		T*C	
		E	t	E	t	E	t	E	t	E	t	E	t
Vegetation													
% woody	240	-220	-0.59	-827	-3.34	-302	-1.22	-247	-0.50	8	0.02	141	0.282
% herbaceous	240	0.03	0.12	-0.00	-0.01	-0.12	-0.61	-0.75	-1.87	0.43	1.07	0.15	0.37
Total cover	240	-0.04	-0.92	-0.17	-7.09	-0.03	-1.34	-0.05	-1.02	0.03	0.61	-0.01	-0.12
Height	240	-0.07	-1.90	-0.26	-9.98	-0.01	-0.37	-0.07	-1.96	-0.00	-0.03	0.02	0.47
Species number	240	-0.64	-3.15	-1.61	-11.96	0.13	0.93	-0.28	-1.05	0.05	0.19	-0.02	-0.06
Biomass	120	0.14	0.08	-0.12	-0.10	-	-	-3.63	-1.51	-	-	-	-
Microclimate													
Summer soil T	240	-1.16	-5.07	0.52	3.59	-0.11	-1.04	-0.81	-3.98	0.21	1.05	0.31	1.53
Soil moisture	240	-0.04	-0.29	-0.88	-10.08	0.08	0.97	0.14	0.82	-0.10	-0.60	0.10	0.57
Irradiance	240	-0.01	-0.21	0.09	4.81	0.16	8.38	0.04	1.37	-0.01	-0.53	-0.07	-2.45
Lm	N	Permafrost			Site			P*S					
		E	t	Pr > t	E	t	Pr > t	E	t	Pr > t			
Soil nutrients													
Nitrogen	59	-0.07	-1.12	0.27	-0.49	-7.91	<0.001	-0.08	-0.62	0.54			
Phosphorous	59	-0.01	-0.08	0.94	-0.14	-1.26	0.21	-0.15	-0.65	0.52			
Potassium	58	-0.04	-0.62	0.54	-0.02	-0.29	0.77	-0.18	-1.60	0.12			

B) Southern site Skalluvaara

Lmer	N	Permafrost		Topography		Shrub canopy		P*T		P*C		T*C	
		E	t	E	t	E	t	E	t	E	t	E	t
Vegetation													
% woody	120	-345	-0.84	-1235	-3.69	-331	-0.99	-850	-1.27	-552	-0.82	390	0.58
% herbaceous	120	-0.07	-0.25	0.11	0.43	-0.07	-0.28	-0.26	-0.52	0.57	1.14	0.10	0.20
Total cover	120	-0.18	-5.28	-0.00	-0.03	-0.04	-1.18	-0.09	-1.36	0.03	0.43	-0.01	-0.10
Height	120	-0.09	-1.99	-0.32	-11.37	-0.01	-0.27	-0.04	-0.76	-0.01	-0.25	-0.03	-0.61
Species number	120	-0.62	-2.47	-1.58	-9.68	0.12	0.71	-0.63	-1.95	-0.03	-0.10	0.03	0.10
Biomass	60	0.34	0.17	-1.48	-0.86	-	-	-2.15	-0.62	-	-	-	-
Microclimate													
Summer soil T	120	-0.61	-2.00	0.81	4.09	0.02	0.13	-1.06	-3.79	0.25	0.88	-0.16	-0.57
Soil moisture	120	0.32	1.44	-0.48	-3.29	0.06	0.61	-0.44	-2.11	0.16	0.75	0.17	0.80
Irradiance	120	-0.04	-1.00	0.14	7.15	0.14	7.05	0.03	1.00	0.00	0.04	-0.08	-2.88
Soil nutrients													
Lm	N	Permafrost		Pr > t									
		E	t										
Nitrogen	30	-0.11	-1.51	0.14									
Phosphorous	29	-0.08	-0.40	0.69									
Potassium	30	-0.19	-1.81	0.08									

C) Northern site Pulmankijärvi

Lmer	N	Permafrost		Topography		Shrub canopy		P*T		P*C		T*C	
		E	t	E	t	E	T	E	t	E	t	E	t
Vegetation													
% woody	120	-97	-1.15	-419	-1.15	-273	-0.75	355	0.48	568	0.7	-107	-0.146
% herbaceous	120	0.14	0.29	-0.11	-0.34	-0.18	-0.55	-1.24	-1.96	0.29	0.46	0.20	0.32
Total cover	120	-0.07	-1.33	-0.16	-4.69	-0.02	-0.70	-0.00	-0.06	0.03	0.41	-0.00	0.07
Height	120	-0.08	-1.35	-0.23	-6.54	-0.01	-0.26	-0.10	-2.07	0.01	0.25	0.07	1.39
Species number	120	-0.67	-2.02	-1.63	-7.58	0.13	0.62	0.07	0.15	0.13	0.30	-0.07	-0.15
Biomass	60	-0.07	-0.03	1.23	0.73	-	-	-5.10	-1.54	-	-	-	-
Microclimate													
Summer soil T	120	-2.00	-6.73	-0.05	-0.31	-0.23	-1.54	-0.56	-1.91	0.18	0.61	-0.46	-1.57
Soil moisture	120	-0.55	-2.08	-1.42	-7.58	0.11	0.81	0.73	2.74	-0.37	-1.38	0.03	0.13
Irradiance	120	0.03	0.51	0.02	0.79	0.15	7.03	0.05	1.03	-0.03	-0.67	-0.05	-1.16
Lm	N	Permafrost											
		E	t	Pr > t									
Soil nutrients													
Nitrogen	29	-0.03	-0.29	0.77									
Phosphorous	30	0.06	0.70	0.49									
Potassium	29	0.05	0.75	0.46									

Table S3 Effects of permafrost, topography, shrub canopy presence and tree species on cumulative tree seedling survival over three periods: July 2014-August 2014, July 2014-August2015 and July 2014-August2016. Data were analysed with generalised linear mixed models (*glmer*) with hummock as random factor, or nested within site (for both sites together). N = number of observations; E = parameter estimates; z-values and probabilities indicate significance relative to intercept. Intercept has been set to: northern site (Pulmankijärvi; for both sites together), no permafrost, hummock sides with canopy intact and tree species birch.

Glmer	N	July14-Aug14				July14-Aug15				July14-Aug16				July14-Aug19			
		E	se	z	Pr> z	E	se	z	Pr> z	E	se	z	Pr> z	E	se	z	Pr> z
Both sites																	
Intercept		0.72	0.25	2.84	0.004	0.01	0.26	0.04	0.97	-0.91	0.31	-2.91	0.004	-1.48	0.31	-4.78	<0.001
Site	2	-0.14	0.22	-0.61	0.54	0.69	0.24	2.82	0.005	0.73	0.23	2.48	0.01	0.58	0.26	2.24	0.03
Permafrost	60	-0.67	0.22	-3.01	0.003	-0.48	0.24	-1.97	0.05	-0.19	0.29	-0.65	0.51	-0.23	0.26	-0.90	0.37
Topography	120	-0.41	0.16	-2.59	0.009	-0.42	0.16	-2.70	0.007	-0.56	0.18	-3.073	0.002	-0.66	0.20	-3.27	0.001
Shrub canopy	120	-0.88	0.16	-5.44	<0.001	-0.87	0.16	-5.50	<0.001	-1.37	0.19	-7.12	<0.001	-1.15	0.21	-5.48	<0.001
Tree species					<0.001				<0.001				<0.001				<0.001
Spruce	240	1.92	0.23	8.46	<0.001	0.59	0.20	2.90	0.004	0.54	0.23	2.32	0.02	0.76	0.26	2.91	0.004
Larch	240	1.50	0.21	7.00	<0.001	-2.16	0.28	-7.68	<0.001	-2.13	0.38	-5.69	<0.001	-2.06	0.50	-4.14	<0.001
Pine	240	1.98	0.23	8.63	<0.001	0.39	0.20	1.92	0.06	0.36	0.23	1.54	0.12	0.85	0.26	3.24	0.001
Southern site																	
Intercept		0.93	0.33	2.85	0.004	0.57	0.32	1.76	0.08	-0.39	0.34	-1.135	0.26	-1.31	0.37	-3.54	<0.001
Permafrost	30	-0.63	0.33	-1.92	0.05	-0.57	0.32	-1.77	0.08	-0.09	0.34	-0.25	0.80	-0.17	0.31	-0.56	0.58
Topography	60	-0.56	0.22	-2.51	0.01	-0.38	0.22	-1.74	0.08	-0.45	0.24	-1.89	0.06	-0.53	0.27	-1.99	0.05
Shrub canopy	60	-1.08	0.23	-4.75	<0.001	-0.80	0.22	-3.62	<0.001	-1.05	0.24	-4.31	<0.001	-0.84	0.27	-3.10	0.002
Tree species					<0.001				<0.001				<0.001				<0.001
Spruce	120	1.66	0.32	5.26	<0.001	0.74	0.28	2.62	0.009	0.49	0.30	1.64	0.10	0.96	0.36	2.65	0.008
Larch	120	1.11	0.30	3.77	<0.001	-2.48	0.41	-5.99	<0.001	-2.84	0.63	-4.50	<0.001	-2.89	1.04	-2.78	0.005
Pine	120	1.89	0.33	5.79	<0.001	0.7785	0.28	2.75	0.006	0.54	0.30	1.79	0.07	1.37	0.35	3.86	<0.001
Northern site																	

Intercept		0.37	0.31	1.19	0.24	0.17	0.35	0.50	0.62	-0.66	0.45	-1.46	0.14	-0.97	0.43	-2.26	0.02
Permafrost	30	-0.74	0.31	-2.35	0.02	-0.41	0.37	-1.10	0.27	-0.36	0.50	-0.71	0.48	-0.32	0.44	-0.72	0.47
Topography	60	-0.26	0.28	-1.14	0.25	-0.48	0.22	-2.12	0.03	-0.74	0.29	-2.52	0.01	-0.85	0.32	-2.68	0.007
Shrub canopy	60	-0.67	0.23	-2.91	0.004	-0.96	0.23	-4.21	<0.001	-1.91	0.33	-5.70	<0.001	-1.66	0.36	-4.66	<0.001
Tree species					<0.001				<0.001				<0.001				<0.001
Spruce	120	2.19	0.33	6.66	<0.001	0.422	0.29	1.45	0.15	0.61	0.37	1.63	0.10	0.53	0.39	1.34	0.18
Larch	120	1.90	0.31	6.06	<0.001	-1.81	0.38	-4.71	<0.001	-1.52	0.51	-2.99	0.003	-1.69	0.61	-2.78	0.006
Pine	120	2.07	0.32	6.42	<0.001	-0.04	0.30	-0.15	0.88	0.07	0.39	0.19	0.85	0.08	0.41	0.21	0.84

Table S4 Effects of permafrost, microtopography and shrub canopy presence on cumulative tree seedling survival per tree species over the whole experimental period: July 2014-August 2019. Data were analysed with generalised linear mixed models (*glmer*). Hummock nested within site was included as random factors. These analyses could not be run for the separate sites, as the number of survivors was too low for the model to converge. N = number of observations; E = parameter estimate; z-values and probabilities indicate significance relative to intercept. Intercept has been set to: northern site Pulmankijärvi (for both sites together), no permafrost, hummock sides with canopy intact.

Glmer	N	Spruce				Mountain birch				Siberian larch				Scots pine			
		E	se	z	Pr> z	E	se	z	Pr> z	E	se	z	Pr> z	E	se	z	Pr> z
Both sites together																	
Intercept		-0.83	0.39	-2.14	0.03	-0.90	0.53	-1.71	0.09	-2.60	0.83	-3.14	0.002	-1.38	0.52	-2.65	0.008
Site	2	0.50	0.37	1.33	0.18	-0.11	0.54	-0.21	0.84	-1.41	1.13	-1.25	0.21	1.57	0.54	2.91	0.004
Permafrost	60	-0.05	0.37	-0.13	0.90	-0.65	0.55	-1.19	0.24	0.42	0.97	0.44	0.66	-0.41	0.51	-0.82	0.41
Topography	120	-0.17	0.34	-0.51	0.61	-1.25	0.47	-2.64	0.008	-1.44	1.13	-1.27	0.20	-0.91	0.38	-2.42	0.02
Shrub canopy	120	-1.54	0.37	-4.12	<0.001	-1.43	0.49	-2.92	0.003	-1.44	1.13	-1.27	0.21	-0.82	0.37	-2.19	0.03

Table S5 Number and height (cm) of surviving planted seedlings for southern study site Skalluvaara and northern study site Pulmankijärvi in August 2019. In July 2014 average seedling height was 3.8 cm for spruce 2.2 cm for birch, 4.4 cm for larch and 4.3 cm for pine (N=20). The tallest individuals per site indicated in bold.

Permafrost Topography Shrub canopy	Permafrost present								Permafrost absent							
	Top				Side				Top				Side			
	intact	removed			intact	removed			intact	removed			Intact	removed		
	N	mean	N	mean	N	mean	N	mean	N	mean	N	mean	N	mean	N	Mean
Southern site																
Spruce	6	6.4	2	5.1	6	6.1	1	3.5	5	4.9	3	4.8	6	6.3	3	4.5
Mountain birch	0	-	0	-	4	5.0	1	2.0	3	2.8	2	2.4	2	2.8	3	1.0
Siberian larch	0	-	0	-	1	9.2	0	-	0	-	0	-	0	-	0	-
Scots pine	3	4.7	4	5.5	10	6.8	4	5.1	5	4.4	4	3.6	6	5.8	4	3.4
Northern site																
Spruce	5	3.6	0	-	6	5.4	2	4.7	4	4.0	2	3.4	5	5.0	0	-
Mountain birch	2	3.8	0	-	4	3.7	1	0.7	2	2.7	0	-	7	3.1	1	8.0
Siberian larch	1	1.5	0	-	0	-	1	4.5	0	-	0	-	3	3.4	0	-
Scots pine	0	-	1	4.7	2	4.8	2	3.4	4	4.8	1	3.0	5	4.4	2	5.3

Table S6 Effects of environmental variables and vegetation biomass and cover across plots on cumulative tree seedling survival per tree species for the early experimental period: July 2014-August 2014 (both) and July 2014-August 2015 (environmental only). Environmental data was analysed with generalised linear mixed models (*glmer*) with hummock nested within site as random factor. Vegetation data was analysed with generalised linear models (*glm*). N = number of observations; E = parameter estimate; z = z-values. Variables were scaled before analyses.

Glmer	N	Spruce				Mountain birch				Siberian larch				Scots pine			
		E	se	z	Pr> z	E	se	z	Pr> z	E	se	z	Pr> z	E	Se	z	Pr> z
Jul 2014-Aug 2014																	
Intercept		1.71	0.28	6.08	<0.001	-0.34	0.16	-2.12	0.03	1.29	0.26	5.00	<0.001	1.94	0.32	6.08	<0.00
Nitrogen	240	-0.03	0.27	-0.10	0.92	-0.17	0.22	-0.76	0.45	-0.00	0.26	-0.00	0.99	-0.08	0.25	-0.31	0.76
Phosphorus	240	-0.62	0.44	-1.43	0.15	0.08	0.32	0.25	0.80	-0.50	0.44	-1.14	0.25	-0.11	0.41	-0.28	0.78
Potassium	240	0.25	0.39	0.64	0.52	0.09	0.27	0.35	0.73	0.08	0.37	0.21	0.84	-0.34	0.37	-0.91	0.36
Soil moisture	240	0.47	0.22	2.17	0.03	0.35	0.16	2.13	0.03	0.47	0.21	2.29	0.02	0.60	0.23	2.62	0.009
Soil temperature	240	0.11	0.21	0.53	0.60	0.15	0.16	0.98	0.33	0.72	0.24	3.00	0.003	0.23	0.22	1.04	0.30
Intercept		1.64	0.25	6.52	<0.001	0.25	0.19	1.32	0.19	1.61	0.25	6.37	<0.001	1.83	0.28	6.60	<0.001
Vegetation cover	120	0.29	0.26	1.11	0.27	0.53	0.20	2.59	0.01	0.30	0.26	1.17	0.24	0.53	0.29	1.85	0.06
Vegetation biomass	120	-0.21	0.23	-0.89	0.37	-0.01	0.19	-0.04	0.97	0.28	0.28	1.01	0.32	-0.10	0.25	-0.38	0.70
Jul 2014-Aug 2015																	
Intercept		0.00	0.18	0.02	0.98	-0.68	0.21	-3.19	0.001	-2.47	0.28	-8.72	<0.001	-0.35	0.23	-1.49	0.14
Nitrogen	239	-0.27	0.19	-1.41	0.16	-0.77	0.26	-2.91	0.004	0.17	0.27	0.61	0.54	-0.78	0.29	-2.74	0.01
Phosphorus	239	0.12	0.23	0.52	0.60	0.00	0.25	0.02	0.99	-0.34	0.59	-0.57	0.57	0.10	0.31	0.33	0.74
Potassium	238	-0.43	0.26	-1.66	0.10	0.27	0.29	0.93	0.35	-0.42	0.37	-1.14	0.26	-0.55	0.33	-1.66	0.10
Soil moisture	240	0.27	0.16	1.63	0.10	0.53	0.19	2.81	0.005	0.36	0.21	1.69	0.09	0.72	0.21	3.40	0.001
Soil temperature	240	0.07	0.17	0.41	0.68	-0.09	0.19	-0.48	0.63	0.18	0.25	0.71	0.48	-0.07	0.20	-0.34	0.74

