

Supplementary Material

Table 1. Classification, physical and chemical parameters of soils in the 7 sites.

Site	Soil (WRB)	Elevation (m a.s.l.)	Slope and aspect	Horizons	Depth (cm)	pH	CEC (meq 100 g ⁻¹)	TOC (%)	TN (%)	C/N	Extract. P (mg kg ⁻¹)	Clay (%)	Silt (%)	Sand (%)
1	Dystric Leptic Regosol	2840	0° -	A	0-7	4.6	7.8	1.84	0.14	13	N/A	1	13	86
				AC	7-20	5.4	4.8	0.77	0.05	14	N/A	1	17	82
				C	20-40	7.2	8.8	1.55	0.08	18	N/A	1	17	82
2	Dystric Lithic Leptosol	2800	0° -	A	0-3	4.4	13.1	3.88	0.30	13	N/A	1	22	77
				C	3-10	4.7	14.3	2.62	0.18	14	N/A	2	31	67
6	Dystric Skeletic Cambisol (Humic)	2854	15° SE	A	0-3	4.5	39.0	6.2	0.44	14	67.22	4	8	88
				AB	3-12	4.7	11.4	1.6	0.16	10	13.10	1	13	86
				BW	12-50+	4.9	13.1	1.1	0.11	10	13.63	2	13	85
7	Dystric Skeletic Cambisol	2813	5° S	A	0-5	4.2	18.5	5.4	0.36	15	86.15	2	18	80
				AB	5-10	4.8	6.2	0.8	0.07	12	10.16	1	14	85
				BW	10-33+	5.4	8.8	0.7	0.06	11	9.32	0	32	68
8	Eutric Endoskeletal Regosol (Arenic, Turbic)	2749	0° -	A1	0-3	5.3	14.9	4.2	0.34	12	28.98	1	15	84
				A2	3-8	5.4	7.1	0.9	0.08	11	7.53	1	16	83
				A3	8-13	5.7	5.1	0.6	0.06	11	5.85	1	15	84
				AC1	13-25	6.1	6.5	0.8	0.06	13	9.42	2	11	87
				AC2	25-33	6.1	6.9	0.8	0.06	12	8.16	2	22	76
				CA	33+	6.1	11.2	0.8	0.07	11	11.53	0	22	78
9	Skeletal Umbrisol (Endoeutric, Arenic, Turbic)	2720	5° SE	A1	0-3/5	4.6	38.9	14.5	0.92	16	63.00	2	31	67
				A2	3/5-36	4.7	6.7	0.9	0.08	11	10.10	2	8	90
				2BC1	36-40	5.2	4.7	0.1	0.02	5	2.10	1	10	89
				3BC2	40-50+	5.3	5.4	0.5	0.09	6	5.64	1	12	87
10	Skeletal Umbrisol (Arenic)	2686	2° S	A1/OH	0-3/5	4.6	89.0	18.4	1.23	15	85.3	2	16	82
				A2	5-28/35	4.8	10.4	1.4	0.12	12	10.2	6	14	80
				BC	28/35-60+	5.1	7.9	1.0	0.07	15	12.7	1	18	81

Table 2. List of the plant species recorded in the botanical transects, with associated the corresponding demand for moisture level (F), soil nitrogen content (N) and soil pH level (R) according to Landolt et al. (2010). Moreover, for each species it is displayed the species percentage cover (%SC) per each site averaged amongst the four years of the study.

Species	Landolt indicator value			Site							
	F	N	R	1	2	3	6	7	8	9	10
<i>Agrostis alpina</i>	2	2	4	0.06	0.00	0.16	0.06	0.00	0.00	0.06	0.00
<i>Agrostis rupestris</i>	2.5	2	2	4.10	0.44	4.20	3.00	1.30	5.40	4.60	5.50
<i>Agrostis schraderiana</i>	3.5	3	2	0.00	0.00	0.34	0.00	0.00	0.00	0.06	0.12
<i>Alchemilla pentaphyllea</i>	4	3	2	0.00	0.00	7.20	13.30	30.50	2.10	15.00	21.90
<i>Androsace alpina</i>	4	1	2	0.34	0.00	0.00	0.00	0.00	0.00	0.06	0.00
<i>Anthoxanthum alpinum</i>	3	2	3	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
<i>Arabis alpina</i>	3	2	5	0.22	0.00	0.06	0.00	0.00	0.00	0.00	0.06
<i>Arenaria biflora</i>	4	2	2	0.00	0.30	0.90	1.30	11.50	0.34	0.38	0.62
<i>Bartsia alpina</i>	4	3	3	0.18	0.00	0.30	0.52	0.00	0.30	0.76	0.30
<i>Campanula excisa</i>	2	2	2	0.06	0.00	0.52	0.00	0.06	0.00	0.00	0.06
<i>Cardamine alpina</i>	4	2	2	0.52	0.82	0.30	0.30	4.20	0.62	0.52	0.06
<i>Cardamine resedifolia</i>	3	2	2	0.18	0.06	0.06	0.24	0.30	0.10	0.00	0.00
<i>Carex curvula</i>	2	2	2	0.00	1.30	2.30	0.24	0.42	6.80	4.50	6.40
<i>Carex foetida</i>	3.5	3	2	0.00	0.00	2.46	0.00	0.34	9.40	1.04	0.58
<i>Carex parviflora</i>	3.5	2	5	0.00	0.30	0.00	5.20	0.00	0.30	0.60	1.36
<i>Carex sempervirens</i>	2	2	3	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
<i>Cerastium cerastoides</i>	4	2	2	0.38	0.12	0.52	0.22	0.58	0.30	0.18	0.24
<i>Cerastium uniflorum</i>	3	2	2	0.00	0.00	0.00	0.86	0.34	0.24	0.30	0.30
<i>Erigeron alpinus</i>	2	2	3	0.12	0.06	0.18	0.00	0.00	0.00	0.00	0.00
<i>Euphrasia minima</i>	2.5	2	2	4.20	0.34	5.30	3.80	4.40	4.30	4.20	1.80
<i>Festuca halleri</i>	2	2	2	0.30	0.06	0.38	0.16	0.12	0.38	0.48	1.40
<i>Festuca quadriflora</i>	2.5	2	5	0.16	0.00	0.00	0.06	0.00	0.00	0.00	0.10
<i>Festuca violacea</i>	3	3	3	0.12	0.00	0.42	0.00	0.00	0.16	0.06	0.10
<i>Galium anisophyllum</i>	2.5	2	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
<i>Gentiana bavarica</i>	4	2	3	0.34	0.24	0.06	0.62	0.30	0.66	0.38	0.34
<i>Geum montanum</i>	3	2	2	0.00	0.00	0.06	0.00	0.18	0.12	0.00	0.00
<i>Gnaphalium supinum</i>	4	2	2	2.60	5.80	21.30	1.20	5.20	1.80	0.50	1.50
<i>Homogyne alpina</i>	3.5	2	2	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
<i>Juncus jacquinii</i>	3.5	2	2	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.30
<i>Leontodon helveticus</i>	3	2	2	0.30	0.92	1.10	0.34	0.24	0.30	0.18	0.38
<i>Leucanthemopsis alpina</i>	3	2	2	0.82	2.30	1.60	0.60	10.90	0.62	0.52	0.34
<i>Ligusticum mutellina</i>	3.5	2	3	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00
<i>Linaria alpina</i>	3.5	2	4	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>Luzula alpinopilosa</i>	3.5	2	2	9.80	6.30	0.30	0.48	0.48	1.60	4.40	29.00
<i>Luzula spicata</i>	2.5	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
<i>Minuartia recurva</i>	2	1	2	0.06	0.06	0.00	0.06	0.00	0.06	0.06	0.00
<i>Minuartia sedoides</i>	2.5	1	3	0.18	0.46	0.24	0.42	1.26	0.34	0.22	0.34
<i>Oxyria digyna</i>	3.5	2	4	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.24

<i>Pedicularis kernerii</i>	2	2	2	0.00	0.00	0.44	0.18	0.00	0.30	0.00	0.30
<i>Phyteuma globulariifolium</i>	2	2	2	0.06	2.00	0.00	0.10	0.00	0.00	0.00	0.10
<i>Phyteuma hemisphaericum</i>	2.5	2	1	0.12	0.40	0.34	0.06	0.24	0.06	0.06	0.72
<i>Poa alpina</i>	3.5	4	3	3.26	18.00	4.90	6.70	7.40	23.80	18.20	7.70
<i>Poa laxa</i>	3.5	2	2	1.26	0.28	0.24	0.42	0.72	0.72	0.06	0.12
<i>Polygonum viviparum</i>	3	2	3	0.00	0.00	0.00	1.50	0.16	1.30	0.34	1.00
<i>Ranunculus glacialis</i>	3.5	2	2	1.10	0.12	0.28	4.80	2.00	4.00	1.50	3.70
<i>Ranunculus montanus</i>	3.5	4	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
<i>Sagina saginoides</i>	3.5	2	3	7.10	2.10	0.76	0.44	0.42	1.86	3.70	2.00
<i>Salix herbacea</i>	3.5	2	2	68.80	57.30	40.80	58.20	36.70	53.40	73.50	63.90
<i>Salix serpyllifolia</i>	3	2	4	0.00	0.00	0.00	0.00	0.00	0.00	2.40	0.00
<i>Saxifraga oppositifolia</i>	3.5	2	4	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00
<i>Saxifraga seguieri</i>	4	2	2	0.42	0.12	0.00	5.10	0.06	0.30	0.62	3.90
<i>Sedum alpestre</i>	2	2	3	0.42	0.62	0.38	0.00	0.52	0.48	0.18	0.24
<i>Senecio halleri</i>	2	2	2	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00
<i>Senecio incanus</i>	2	2	2	0.00	0.00	0.06	0.00	0.30	0.00	0.00	0.00
<i>Sibbaldia procumbens</i>	3	3	2	0.12	0.30	0.06	0.30	0.06	0.32	0.06	0.24
<i>Silene acaulis</i>	2	1	2	0.24	0.68	0.00	0.38	0.72	0.38	0.34	1.66
<i>Taraxacum alpinum</i> s. l.	3.5	4	3	0.30	7.70	1.06	0.80	6.70	0.06	0.66	0.72
<i>Thlaspi rotundifolium</i>	3	2	3	0.56	0.82	0.00	0.34	0.00	0.00	0.00	0.00
<i>Veronica alpina</i>	4	2	2	2.40	2.10	0.30	0.80	3.40	0.72	1.50	2.10

Table 3. Ranking of the effect of climatic-pedoclimatic and vegetation variables on soil C and N forms derived from GLMMs. The numbers in bold represent the rank on a scale of decreasing importance of the variables for each C and N forms; the non-bolded numbers are the beta values of the model; not significant variables are not shown: PRD (proportion of raining days), Snow Cover Duration (SCD), Melt Out Day (MOD), Duration of Soil Freezing (DSF), Freeze/Thaw Cycles (FTCs), Mean soil temperature during soil freezing (MTF), Mean soil temperature during the snow-free season (MTSF), Intensity of Soil Freezing (ISF), and Gravimetric Water Content (GWC), *Salix herbacea* Phenology (SP), Landolt Moisture indicator value (Fm), Landolt Nutrient indicator value (Nm), Landolt Reaction indicator value (Rm) on C and N forms (i.e., 1 is the most important variable, 5 the least). The following number is the value derived from the GLMMs and expresses positive (+) or negative (-) relations (* p<0.05, ** p<0.01, *** p<0.001, ^{ns} not significant). The Akaike Information Criterion (AIC) value for each model is reported in the bottom line.

	N-NH₄⁺	N-NO₃⁻	DOC	TDN	DON	C_{micr}	N_{micr}	C:N_{micr}
<i>Climatic-pedoclimatic variables</i>								
PRD		2 -0.30 ***	-0.08 ^{ns}				4 -6.38 **	
SCD			3 -0.12 ***		+0.2 ^{ns}			
MOD	3 +0.72 **	1 +0.49 ***	2 +0.20 ***	2 +0.24 ***		2 +0.14 **	1 +12.76 ***	
DSF				3 +0.11 *	1 +0.23 *			
MTF								
FTCs								3 +0.11 **
MTSF	4 +0.29 ^{ns}					3 +0.10 *	3 +6.81 ***	
GWC	2 +0.90 ***	3 +0.22 ***	1 +0.25 ***	1 +0.28 ***	+0.13 ^{ns}	1 +0.36 ***	2 +9.60 ***	1 +0.16 ***
<i>Vegetation variables</i>								
SP	1 -2.16 ***		4 +0.09 **					
Fm								
Nm					2 -0.15 *		5 -5.13 *	+0.11 ^{ns}
Rm					+0.2 ^{ns}		+2.91 ^{ns}	2 -0.13 *
<i>Model AIC</i>	255.79	-22.35	712.16	535.30	529.28	1006.55	653.47	456.83
Residual degrees of freedom	68	69	67	69	67	69	66	68