Supporting material to the paper

Soil pH and phosphorus drive species composition and richness in semi-natural heathlands and grasslands unaffected by twentieth-century agricultural intensification. *Plant Ecology & Diversity*

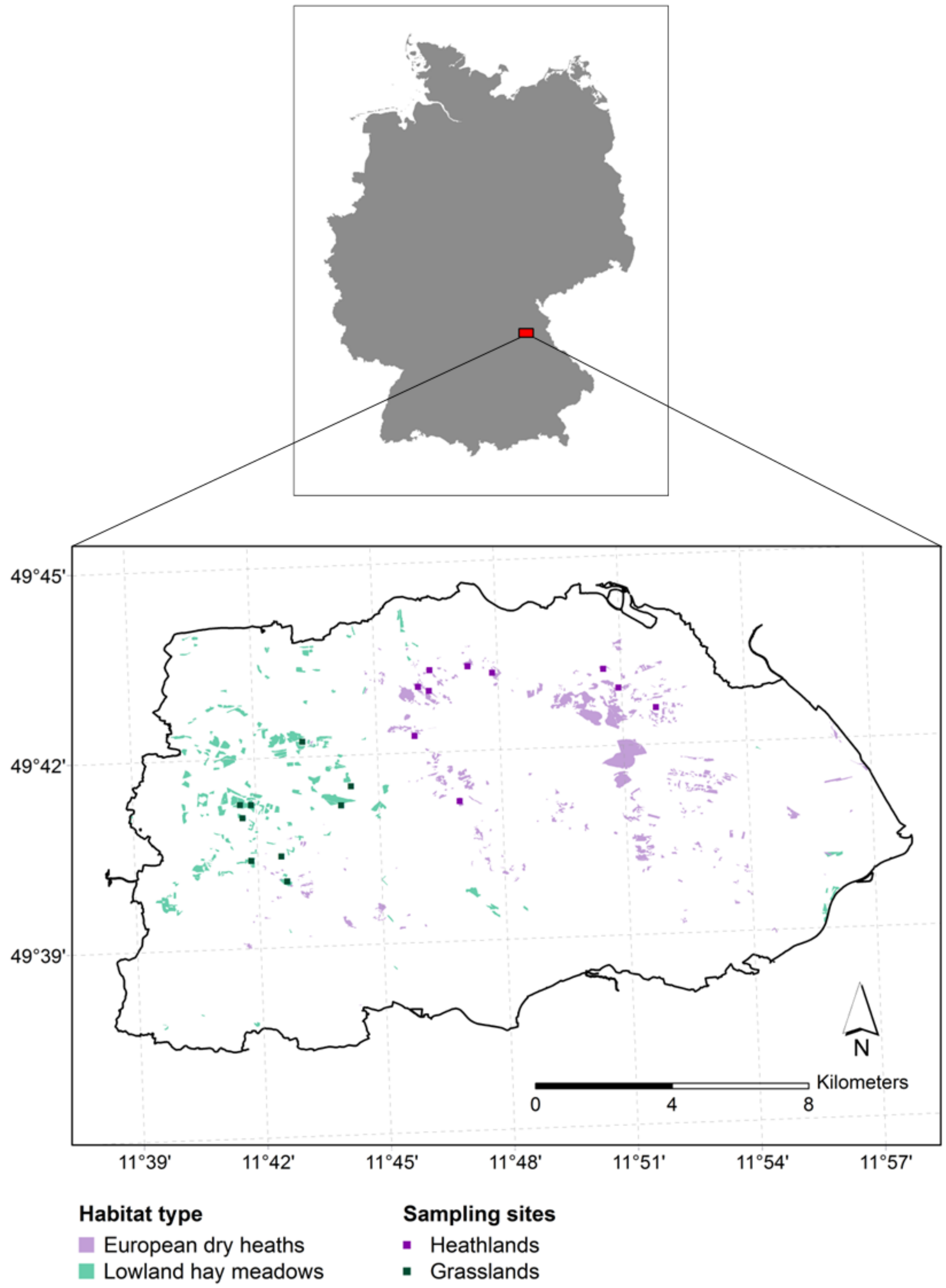

Figure S1. Location of the sampling sites in heathlands (10) and grasslands (nine) at Grafenwöhr military training area (GTA) in Bavaria, Germany. Each site comprised four plots in heathlands and six plots in grasslands, respectively. Shaded areas indicate the occurrence of the Natura 2000 habitat types 4030, European dry heaths, and 6510, lowland hay meadows according to the draft of the Natura 2000 management plan (2013/2014) for the Site of Community Importance and Special Area of Conservation US-Truppenübungsplatz Grafenwöhr (DE6336301).

Appendix S1: Floristic details to the NMDS results

The two-dimensional NMDS analysis of species biomass percentages per plot reached a solution with stress of 0.19 for heathlands (linear fit R^2 = 0.83, non-metric fit R^2 = 0.96) and 0.20 for grasslands (linear fit R^2 = 0.80, non-metric fit R^2 = 0.95). In most cases, sampling sites were well separated from each other representing the spatial nestedness of the data (Figure S2(a) and (c)). The first axis (which was forced to parallel the pH gradient constituted by heathland or grassland plots, respectively) captured the largest spread of plots in the ordination space. The arrangement of species' optima in both heathlands and grasslands reflects this gradient (Figure S2(b) and (d)).

In accordance with the trends in soil chemical parameters (cf. Figure 1 in the main text) the NMDS ordinations allowed to delineate subunits of heathland and grassland plant communities. In heathlands, typical species of the *Vaccinio-Callunetum* Büker 1941 association, such as *Calluna vulgaris* and *Vaccinium* spp., occupy the left part of the ordination space. Moving towards the centre, there are species associated with the alliance *Violion caninae* Schwickerath 1944, e.g. *Potentilla erecta*, *Nardus stricta* and *Arnica montana*. Species related to mesotrophic grassland communities, e.g. *Leucanthemum ircutianum*, gather on the right side of the ordination space. In the ordination of grasslands, species indicating nutrient scarcity scatter from the left to the upper right side of the ordination space. While the left is governed by species indicative of nutrient-poor siliceous grasslands (*Polygalo-Nardetum* Oberd. 1957), such as *Viola canina*, more and more representatives of calcicolous grassland communities, e.g. *Brachypodium pinnatum*, appear on the right side of the ordination space. Species typical of mesotrophic grassland communities occupy the centre of the ordination space and a conspicuous cluster of ruderal plants, e.g. *Aphanes arvensis*, is located at the bottom.

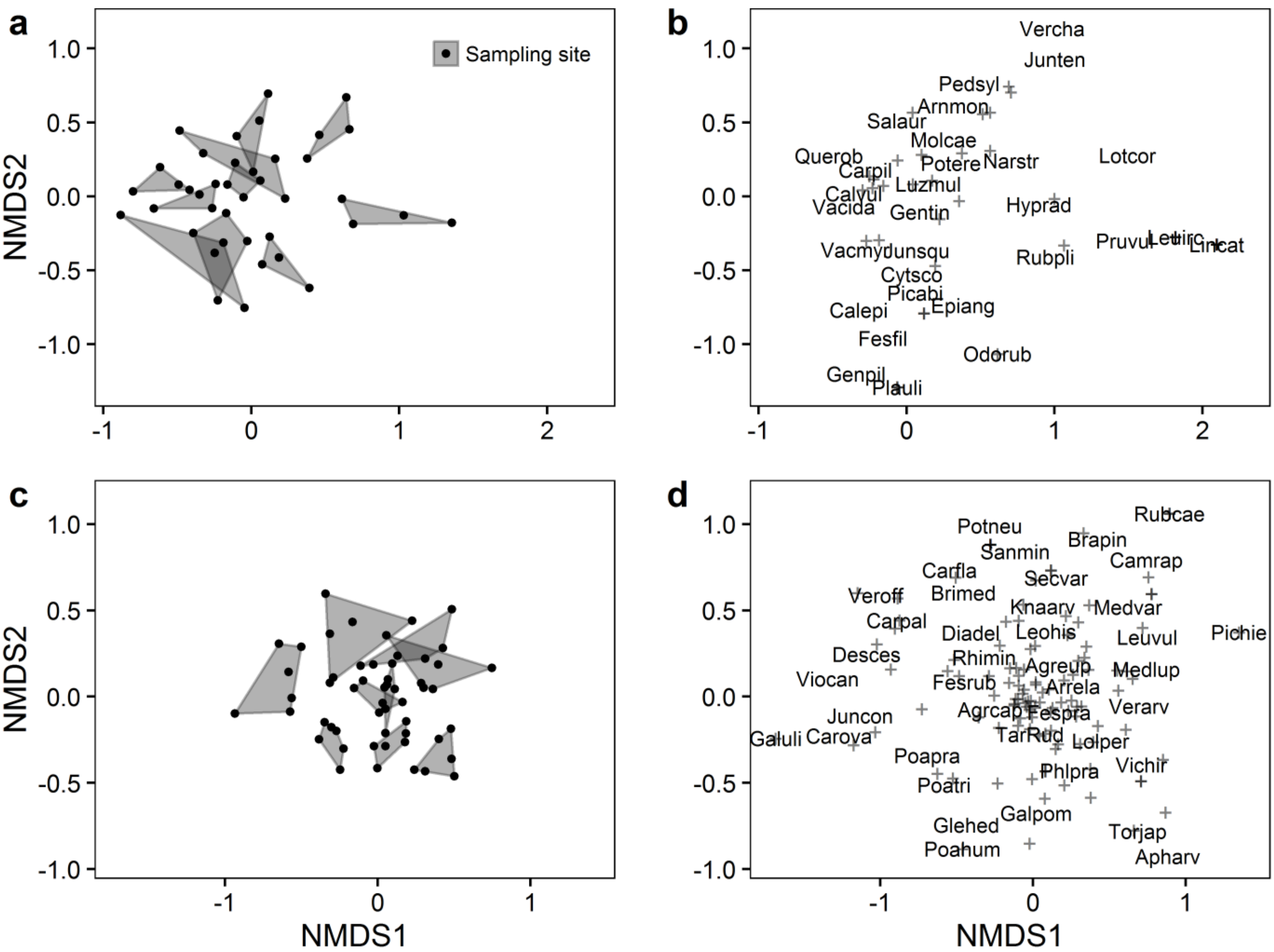

Figure S2: NMDS ordination of vascular plant species composition of (a) 40 plots surveyed in heathlands and (c) 54 plots surveyed in grasslands. Sampling sites are visualised by shaded hulls. The first NMDS axis parallels the soil pH gradient of plots. Individual species scores for (b) heathlands and (d) grasslands are shown in the same ordination space. The name of the species with the higher abundance was printed (30 species in heathlands, 40 species in grasslands) if species' name tags overlapped; remaining species are represented by '+'. See Table S3 for abbreviations of species names.

Table S1: Information on selected studies and their results reported on the relationship between plant species richness (SR) and extractable soil phosphorus (P). *n* is the number of vegetation plots examined. For the studies that used a different P extraction method than CAL, the approximate CAL-P range (mg kg^{-1}) was roughly estimated by CAL-P = Olsen-P * 1.45 (Barberis et al. 1995; Wuenscher et al. 2015) and Olsen-P = EDTA-P * 1.55 (Gilbert et al. 2009). P concentrations referring to soil volume (mg l^{-1}) were converted to the unit g kg^{-1} assuming a soil bulk density of 1.4 g cm^{-3}). Approximate CAL-P values for critical soil P concentrations derived from the literature are given in parentheses.

Study	Location	Vegetation units	Fertilisation	Management	Plot size	*n*	P extraction method	Soil P range	Approximate CAL-P range (mg kg^{-1})	Critical soil P concentrations	Shape of SR ~ P relationship
Ceulemans et al. 2013	North-western Europe (GB, FR, BE)	*Violion caninae* alliance	none	extensive management by cutting or cutting and grazing	4 m^2	132	Olsen	0.4-86.1 mg kg^{-1}	0.6-24.9	< 20 species per 4 m^2 for Olsen-P > 20 mg kg^{-1} (29 mg CAL-P kg^{-1})	negative exponential
Ceulemans et al. 2014	Europe (IE, IM, GB, FR, BE, NL, DE, NO, DK, SE)	*Nardus* grasslands (Habitat type 6230), lowland hay meadows (Habitat type 6510), calcareous grasslands (Habitat types 6210 and 2130)	none	extensive management by cutting or cutting and grazing	4 m^2	501	Olsen	0-305.5 mg kg^{-1}	0-442.9	SR at a constant low level where Olsen-P > 104-130 mg kg^{-1} (150.8-188.5 mg CAL-P kg^{-1})	negative log-linear
Critchley et al. 2002	GB (14 environmen-tally sensitive areas)	38 plant communities within seven main vegetation types (calcareous, mesotrophic and acidic grasslands,	in most cases low or absent	primarily grazing	1 m^2	569	Olsen	1.3-82.2 mg l^{-1}	2.7-166.9	highest SR at 4-15 mg Olsen-P l^{-1} (8.1-30.5 mg CAL-P kg^{-1})	humped-back

Table S1. Continued

Study	Location	Vegetation units	Fertilisation	Management	Plot size	*n*	P extraction method	Soil P range	Approximate CAL-P range (mg kg^{-1})	Critical soil P concentrations	Shape of SR ~ P relationship
		mires, heaths, swamps, underscrub)									
Gilbert et al. 2009	GB (11 lowland grassland sites)	neutral lowland grasslands (*Triseto-Polygonion*, *Alopecurion*, *Centaureo-Cynosuretum*, *Lolio-Cynosuretum*, *Lolio-Plantaginion*, *Calthion*, *Elymo-Rumicion)*	no fertilization during previous decade	different intensities of grazing or cutting	1 m^2	176	Olsen	0.1-37.5 mg kg^{-1}	0.2-54.3	declining SR for increasing Olsen-P > 5 mg kg^{-1} (7.3 mg CAL-P kg^{-1})	humped-back
Hejcman et al. 2010	DE (Rengen Grassland Experiment)	*Nardus* grasslands (*Violion caninae*, *Polygono-Trisetion*, *Arrhenatherion)*	five treatments (Ca, CaN, CaNP, CaNP-KCl and CaNP-$K_2 SO_4$)	2 cuts y^{-1}	0.02-5.76 m^2	30	CAL	4.8-425.9 mg kg^{-1}	4.8-425.9	no species indicative of extensive grasslands, where Olsen-P > 20 mg kg^{-1}	negative linear
Janssens et al. 1998	Western and Central Europe (BE, NL, GB, ES, LU)	old permanent grasslands with different soils and management	not specified	1-2 cuts y^{-1} and autumn grazing in some cases	100 m^2	281	acetate + EDTA extraction	0.8- 346.7 mg kg^{-1}	1.8-779.2	< 20 species per 100 m^2 on soils with EDTA-P > 50 mg kg^{-1} (112.4 mg CAL-P kg^{-1}); maximum of species at 40 mg EDTA-P kg^{-1} (58 mg CAL-P kg^{-1})	humped-back

Table S1. Continued

Study	Location	Vegetation units	Fertilisation	Management	Plot size	*n*	P extraction method	Soil P range	Approximate CAL-P range (mg kg^{-1})	Critical soil P concentrations	Shape of SR ~ P relationship
Marini et al. 2007	IT (Southern Alps)	lowland moderate and high intensive meadows (*Pastinaco-Arrhenatheretum, Ranunculo repentis-Alopecuretum pratensis*), mountain intensive meadows (*Trisetetum flavescentis*), semi-natural low productive meadows (*Bromion erecti*)	0-350 kg N ha^{-1} y^{-1}	1-4 cuts y^{-1}	100 m^2	56	Olsen	5.7-67.6 mg kg^{-1}	8.2-98.1	conservation and restoration of species-rich hay meadows requires low-level soil Olsen-P < 26.2 mg kg^{-1} (38.0 mg CAL-P kg^{-1})	negative log-linear

References (Table S1)

Barberis E, Marsan FA, Scalenghe R, Lammers A, Schwertmann U, Edwards AC, Maguire R, Wilson MJ, Delgado A, Torrent J. 1995. European soils overfertilized with phosphorus: Part 1. Basic properties. Fertilizer Research 45:199–207.

Ceulemans T, Merckx R, Hens M, Honnay O. 2013. Plant species loss from European semi-natural grasslands following nutrient enrichment – is it nitrogen or is it phosphorus? Global Ecology and Biogeography 22:73–82.

Ceulemans T, Stevens CJ, Duchateau L, Jacquemyn H, Gowing DJG, Merckx R, Wallace H, van Rooijen N, Goethem T, Bobbink, R, et al. 2014. Soil phosphorus constrains biodiversity across European grasslands. Global Change Biology 20:3814–3822.

Critchley CNR, Chambers BJ, Fowbert JA, Bhogal A, Rose SC, Sanderson RA. 2002. Plant species richness, functional type and soil properties of grasslands and allied vegetation in English Environmentally Sensitive Areas. Grass and Forage Science 57:82–92.

Gilbert J, Gowing D, Wallace H. 2009. Available soil phosphorus in semi-natural grasslands: assessment methods and community tolerances. Biological Conservation 142:1074–1083.

Hejcman M, Češková M, Schellberg J, Pätzold S. 2010. The Rengen Grassland Experiment: Effect of Soil Chemical Properties on Biomass Production, Plant Species Composition and Species Richness. Folia Geobotanica 45:125–142.

Janssens F, Peeters A, Tallowin JRB, Bakker JP, Bekker RM, Fillat F, Oomes MJM. 1998. Relationship between soil chemical factors and grassland diversity. Plant and Soil 202:69–78.

Marini L, Scotton M, Klimek S, Isselstein J, Pecile A. 2007. Effects of local factors on plant species richness and composition of Alpine meadows. Agriculture, Ecosystems & Environment 119:281–288.

Wuenscher R, Unterfrauner H, Peticza R, Zeheneter F. 2015. A comparison of 14 soil phosphorus extraction methods applied to 50 agricultural soils from Central Europe. Plant, Soil and Environment 61:86–96.

Table S2: Composition of seed mixtures designed for sands (heathlands) and calcareous loamy sands (grasslands) used for occasional reseeding on Grafenwöhr military training area.

	Heathlands		Grasslands	
Functional group	Species	Mass percent	Species	Mass percent
Forbs	*Achillea millefolium*	2.5%	*Achillea millefolium*	4%
	Daucus carota	2%	*Agrimonia eupatoria*	1%
	Hypericum	0.5%	*Cichorium intybus*	4%
	Plantago lanceolata	2%	*Galium verum*	2%
	Plantago major	1%	*Pimpinella major*	1%
	Taraxacum officinale	2%	*Plantago lanceolata*	5%
			Polygonum aviculare	3%
Legumes	*Medicago lupulina*	10%	*Lotus corniculatus*	5%
	Trifolium repens	20%	*Medicago lupulina*	5%
			Trifolium repens	5%
Grasses	*Agrostis capillaris*	5%	*Bromus erectus*	15%
	Agrostis stolonifera	5%	*Dactylius glomerata*	20%
	Dactylis glomerata	20%	*Festuca rubra*	20%
	Festuca rubra	15%	*Phleum pratense*	5%
	Festuca ovina	15%	*Trisetum flavescens*	5%

Table S3. List of vascular plant species found on 40 and 54 plots of 25 m^2 in heathlands and grasslands (abbreviations of species names or symbol '+' relate to the representation in Figure S2(b) and (d)) on Grafenwoehr military training area in Bavaria, Germany. Functional strategy refers to Grime (1979): 'C' – competitive strategy, 'S' – stress-tolerant strategy, 'R' – ruderal strategy (according to Hunt et al. (2004); [cited 2016 Feb 05]; Available from: http://people.exeter.ac.uk/rh203/csr_signature.html). E_F, E_R, and E_N are Ellenberg indicator values for soil moisture, soil reaction and nutrient availability, respectively (Ellenberg & Leuschner 2010); 'x' – indifferent behaviour, '~' – fluctuating water table, '=' – indicator of inundated soils. 'NA' denotes missing information.

Species	Heathlands	Grasslands	Functional strategy	E_F	E_R	E_N
Achillea millefolium	+	+	CR/CSR	4	x	5
Achillea ptarmica		+	CR/CSR	8	4	2
Agrimonia eupatoria		Agreup	CSR	4	8	4
Agrostis capillaris	+	Agrcap	CSR	x	4	4
Alchemilla glaucescens		+	CSR	5	4	3
Alchemilla monticola		+	CSR	5	6	4
Alchemilla sp.		+	NA	NA	NA	NA
Alchemilla subcrenata		+	CSR	5	5	6
Alchemilla vulgaris		+	S/CSR	5	6	6
Alchemilla xanthochlora		+	CSR	7	7	?
Allium vineale		+	S/CSR	4	x	7
Alopecurus pratensis		+	C/CSR	6	6	7
Anthoxanthum odoratum	+	+	SR/CSR	x	5	x
Anthriscus sylvestris		+	CR	5	x	8
Aphanes arvensis		Apharv	R/SR	6	x	5
Arenaria serpyllifolia		+	SR	4	7	x
Arnica montana	Arnmon		CSR	5	3	2
Arrhenatherum elatius		Arrela	C/CSR	x	7	7
Bellis perennis		+	R/CSR	5	x	6
Betonica officinalis		+	S	x~	x	3
Betula pendula	+		C/SC	x	x	x
Brachypodium pinnatum		Brapin	SC	4	7	4
Briza media		Brimed	S	x	x	2
Bromus hordeaceus ssp. *hordeaceus*		+	R/CR	x~	x	3

Table S3. Continued

Species	Heathlands	Grasslands	Functional strategy	E_F	E_R	E_N
Bromus sterilis		+	R/CR	4	x	5
Calamagrostis epigejos	Calepi		C/SC	x~	x	6
Calluna vulgaris	Calvul		SC	x	1	1
Campanula glomerata		+	S	4	7	3
Campanula patula		+	CSR	5	7	5
Campanula rapunculoides		Camrap	CR/CSR	4	7	4
Campanula rotundifolia	+	+	S	x	x	2
Capsella bursa-pastoris		+	R	5	x	6
Cardamine pratensis		+	R/CSR	6	x	x
Carex flacca		Carfla	S	6~	8	4
Carex hirta		+	C/CSR	6~	x	5
Carex leporina		Carova	S/CSR	7~	3	3
Carex pallescens		Carpal	S	6~	4	3
Carex pilulifera	Carpil		S	5~	3	3
Carex spicata		+	CSR	4	6	4
Carlina vulgaris	+		SR	4	7	3
Carum carvi		+	C	5	x	6
Centaurea jacea		+	C	x	x	x
Centaurea scabiosa		+	S/CSR	3	8	4
Centaurium erythraea		+	SR	5	6	6
Cerastium arvense		+	SR/CSR	4	6	4
Cerastium holosteioides	+	+	R/CSR	5	x	5
Cichorium intybus		+	CSR	4	8	5
Cirsium arvense		+	C	x	x	7
Cirsium vulgare		+	CR	5	7	8
Clinopodium vulgare		+	S/CSR	4	7	3
Convolvulus arvensis		+	CR	4	7	x
Crataegus monogyna		+	SC	4	8	4
Crataegus sp.	+	+	NA	NA	NA	NA
Crepis biennis		+	R/CSR	6	6	5
Cruciata laevipes		+	CSR	6	6	7
Cynosurus cristatus		+	CSR	5	x	4

Table S3. Continued

Species	Heathlands	Grasslands	Functional strategy	E_F	E_R	E_N
Cytisus scoparius	Cytsco		SC	4	3	4
Dactylis glomerata		+	C/CSR	5	x	6
Danthonia decumbens	+		S	x	3	2
Daucus carota		+	SR/CSR	4	x	4
Deschampsia cespitosa ssp. *cespitosa*		Desces	SR/CSR	7~	x	3
Deschampsia flexuosa	+		S/SC	x	2	3
Dianthus deltoides		Diadel	S/CSR	3	3	2
Elymus repens ssp. *repens*		+	C/CR	x~	x	7
Epilobium angustifolium	Epiang		C	5	5	8
Equisetum arvense		+	CR	x~	x	3
Erigeron acris ssp. *acris*	+		SR	4	8	2
Euphorbia cyparissias		+	CSR	3	x	3
Euphrasia micrantha	+		R	5	2	1
Festuca filiformis	Fesfil		SC	4	3	2
Festuca ovina	+		S	x	3	1
Festuca pratensis		Fespra	CSR	6	x	6
Festuca rubra ssp. *rubra*		Fesrub	CSR	6	6	x
Fragaria vesca		+	CSR	5	x	6
Fragaria viridis		+	CSR	3	8	3
Galium album		+	C/CSR	5	7	5
Galium pumilum		+	CSR	4~	4	2
Galium uliginosum		Galuli	S/CSR	8~	x	2
Galium verum	+	+	SC/CSR	4~	7	3
Galium x pommeranicum		Galpom	NA	NA	NA	NA
Genista pilosa	Genpil		SC	x	2	1
Genista tinctoria	Gentin		SC	6~	6	1
Geranium columbinum		+	SR	4	7	7
Geranium dissectum		+	R/SR	5	8	5
Geum urbanum		+	S/CSR	5	x	7
Glechoma hederacea		Glehed	CSR	6	x	7
Helictotrichon pubescens		+	S/CSR	3	x	4
Heracleum sphondylium		+	CR	5	x	8

Table S3. Continued

Species	Heathlands	Grasslands	Functional strategy	E_F	E_R	E_N
Hieracium lachenalii	+		S/CSR	4	4	2
Hieracium pilosella	+		S/CSR	4	x	2
Hieracium sabaudum	+		S/CSR	4	4	2
Hieracium sp.	+		S/CSR	NA	NA	NA
Hieracium umbellatum		+	S/CSR	4	4	2
Holcus lanatus	+	+	CSR	6	x	5
Hypericum maculatum agg.		+	CR/CSR	6~	3	2
Hypericum perforatum	+	+	CR/CSR	4	6	4
Hypochaeris radicata	Hyprad	+	CSR	5	4	3
Juncus conglomeratus	+	Juncon	C/SC	7~	4	3
Juncus squarrosus	Junsqu		S/SC	7~	1	1
Juncus tenuis	Junten	+	CSR	6	5	5
Knautia arvensis		Knaarv	CSR	4	x	4
Lathyrus pratensis		+	CSR	6	7	6
Leontodon hispidus ssp. *hispidus*		Leohis	S/CSR	5	7	6
Leontodon saxatile	+		SR/CSR	6~	6	5
Leontodon sp.	+		NA	NA	NA	NA
Leucanthemum ircutianum	Leuirc	+	C	4	x	3
Leucanthemum vulgare		Leuvul	C/CSR	4	x	3
Linum catharticum	Lincat		SR	x	7	2
Lolium perenne		Lolper	CR/CSR	5	7	7
Lotus corniculatus	Lotcor	+	S/CSR	4	7	3
Luzula campestris	+	+	S/CSR	4	3	3
Luzula multiflora	Luzmul		S	5~	5	3
Lychnis flos-cuculi		+	CSR	7~	x	x
Medicago falcata/varia		Medvar	C/CSR	3	9	3
Medicago lupulina		Medlup	R/SR	4	8	x
Melampyrum pratense	+		SR	5	3	2
Melampyrum sylvaticum	+		CR	5	2	2
Mentha arvensis		+	CR	7~	x	x
Molinia caerulea	Molcae		SC	7	x	2
Nardus stricta	Narstr		S	x~	2	2

Table S3. Continued

Species	Heathlands	Grasslands	Functional strategy	E_F	E_R	E_N
Odontites rubra	Odorub	+	R	5~	7	5
Ononis sp.		+	NA	NA	NA	NA
Pedicularis sylvatica	Pedsyl		SR	8~	1	2
Phleum pratense		Phlpra	CSR	5	x	7
Picea abies	Picabi		C	x	x	x
Picris hieracioides		Pichie	R/CSR	4	8	4
Pimpinella major		+	CSR	5	7	6
Pimpinella saxifraga		+	S/SR	3	x	2
Pinus sylvestris ssp. *sylvestris*	+		C	x	x	x
Plantago lanceolata		+	CSR	x	x	x
Plantago major		+	R/CSR	5	x	6
Plantago media		+	S/CSR	4	7	3
Plantago uliginosa	Plauli		R	7=	5	4
Poa angustifolia		+	S/CSR	x	x	3
Poa humilis		Poahum	C	5	6	3
Poa pratensis		Poapra	CSR	5	x	6
Poa trivialis		Poatri	CR/CSR	7	x	7
Polygala serpyllifolia	+		S	6	2	2
Polygala vulgaris		+	S	4	3	2
Populus tremula	+	+	SC	5	x	x
Potentilla anserina		+	CR/CSR	6~	x	7
Potentilla argentea		+	S/CSR	2	3	1
Potentilla erecta	Potere		S/CSR	x	x	2
Potentilla neumanniana		Potneu	S	3	7	2
Potentilla recta		+	CSR	3	5	2
Potentilla reptans		+	CR/CSR	6	7	5
Primula veris		+	S/CSR	4	8	3
Prunella vulgaris	Pruvul	+	CSR	5	7	x
Prunus spinosa		+	SC	4	7	x
Pteridium aquilinum	+		C	5~	3	3
Pyrus communis		+	C	5	8	x
Quercus robur	Querob		SC	x	x	x

Table S3. Continued

Species	Heathlands	Grasslands	Functional strategy	E_F	E_R	E_N
Ranunculus acris ssp. *acris*		+	CSR	6	x	x
Ranunculus bulbosus		+	SR	3	7	3
Ranunculus repens		+	CR	7~	x	7
Rhinanthus minor		Rhimin	R/SR	4	x	3
Rubus caesius		Rubcae	SC	x	8	7
Rubus plicatus	Rubpli		C	5	2	3
Rumex acetosa		+	CSR	x	x	6
Rumex acetosella	+		SR/CSR	3	2	2
Rumex crispus		+	R/CR	x	x	6
Salix aurita	Salaur		C	8~	4	3
Salix caprea	+		C	6	7	7
Sanguisorba minor		Sanmin	S	3	8	2
Saxifraga granulata		+	SR/CSR	4	5	3
Scorzoneroides autumnalis		+	R/CSR	5	5	5
Securigera varia		Secvar	C/CSR	4	9	3
Senecio jacobaea		+	R/CR	4~	7	5
Silaum silaus		+	S/CSR	x~	7	3
Silene vulgaris		+	CSR	4~	7	4
Silenoideae sp.		+	NA	NA	NA	NA
Stellaria graminea		+	CSR	5	4	3
Taraxacum Sect. Ruderalia		TarRud	R/CSR	5	x	8
Thymus pulegioides		+	CSR	4	x	1
Torilis japonica		Torjap	SR/CSR	5	8	8
Tragopogon pratense		+	CR/CSR	4	7	6
Trifolium campestre		+	SR	4	6	3
Trifolium dubium		+	R/SR	4	6	4
Trifolium medium	+	+	SC/CSR	4	6	3
Trifolium pratense		+	CSR	5	x	x
Trifolium repens		+	CR/CSR	5	6	6
Trisetum flavescens		+	CSR	x	x	5
Vaccinium myrtillus	Vacmyr		SC	x	2	3
Vaccinium uliginosum	+		SC	x	1	3

Table S3. Continued

Species	Heathlands	Grasslands	Functional strategy	E_F	E_R	E_N
Vaccinium vitis-idaea	Vacida		S/SC	4~	2	1
Veronica arvensis		Verarv	SR	x	6	x
Veronica chamaedrys	Vercha	+	CSR	5	x	x
Veronica officinalis	+	Veroff	S/CSR	4	3	4
Veronica serpyllifolia		+	R/CSR	5	5	5
Vicia angustifolia		+	R/CSR	x	x	x
Vicia cracca		+	C/CSR	6	x	x
Vicia hirsuta		Vichir	R/CSR	4	x	4
Vicia lathyroides		+	SR	2	3	2
Vicia sepium		+	C/CSR	5	6	5
Vicia tetrasperma		+	R/CR	5	5	5
Viola canina	+	Viocan	S	4	3	2
Viola hirta		+	S	3	8	3

References

Ellenberg H, Leuschner C. 2010. Vegetation Mitteleuropas mit den Alpen. Stuttgart, DE: UTB Ulmer.

Grime JP. 1979. Plant strategies and vegetation processes. Chichester, UK: Wiley.

Hunt R, Hodgson JG, Thompson K, Bungener P, Dunnett NP, Askew AP. 2004. A new practical tool for deriving a functional signature for herbaceous vegetation. Appl Veg Sci. 7:163–170

Table S4. Summary statistics of plot characteristics (species richness, plant cover [%], herbaceous canopy height [cm], functional group ratio and biomass percentage weighted averages of Ellenberg indicator values and Grime strategy type components).

	Heathlands				Grasslands			
Parameter	*Min*	*Max*	*Mean*	*SEM*	*Min*	*Max*	*Mean*	*SEM*
SR	4.00	28.00	14.10	0.81	33.00	61.00	45.89	0.83
cover	35.00	90.00	60.10	2.33	60.00	96.00	83.13	1.35
canopy height	0.00	100.00	59.50	4.85	65.00	120.00	92.69	1.76
FG ratio	0.00	0.82	0.12	0.03	1.00	9.00	3.46	0.30
E_F	4.00	6.81	5.33	0.15	4.33	5.84	5.21	0.05
E_R	1.00	1.51	1.16	0.02	5.14	7.19	6.09	0.07
E_N	1.00	1.66	1.22	0.03	3.81	5.90	5.02	0.06
C strategy	0.45	0.55	0.50	0.00	0.29	0.51	0.36	0.01
S strategy	0.45	0.55	0.50	0.00	0.27	0.39	0.32	0.00
R strategy	0.00	0.03	0.00	0.00	0.23	0.43	0.32	0.01

Table S5: Results of gradient analysis of linear and non-linear relationships between NMDS scores of heathland and grassland communities and plot characteristics including soil chemical parameters. Significance of linear relationships was tested by permutations (n = 10,000) and significance of non-linear relationships was tested in generalised additive models.

	Linear response		Non-linear response	
Parameter	R^2	P^a	P^a	R^2
Heathlands				
pH	0.73	**0.002**	0.86	**<0.001**
P	0.34	0.386	0.60	0.077
K	0.15	0.764	0.61	0.392
Mg	0.20	0.767	0.60	0.409
SR	0.90	**<0.001**	0.93	**<0.001**
cover	0.08	0.991	0.74	0.269
canopy height	0.36	**0.022**	0.59	**0.007**
FG ratio	0.57	**0.020**	0.89	**<0.001**
E_F	0.65	0.080	0.66	**0.001**
E_R	0.32	0.092	0.59	**0.023**
E_N	0.27	0.179	0.53	**0.016**
C strategy	0.06	0.666	0.36	0.675
S strategy	0.02	0.850	0.12	0.970
R strategy	0.32	0.279	0.55	**<0.001**
Grasslands				
pH	0.53	**0.001**	0.52	**<0.001**
P	0.17	0.165	0.50	0.313
K	0.07	0.467	0.38	0.055
Mg	0.16	**0.004**	0.79	**0.013**
SR	0.36	**0.007**	0.41	**<0.001**
cover	0.45	0.050	0.63	**0.002**
canopy height	0.42	0.221	0.55	**0.015**
FG ratio	0.04	0.439	0.51	**<0.001**
E_F	0.40	**<0.001**	0.74	**<0.001**
E_R	0.58	**<0.001**	0.62	**<0.001**
E_N	0.66	**<0.001**	0.74	**<0.001**
C strategy	0.38	0.054	0.52	**<0.001**
S strategy	0.43	**0.003**	0.60	**0.001**
R strategy	0.44	**0.028**	0.67	**0.028**

[a]Bold font indicates statistical significance (*P* <0.05).

Table S6: Overview of candidate linear mixed effects models (cumulative Akaike weight, acc w_i, ≤0.95) explaining species richness in heathlands and grasslands based on soil chemical parameters listing degrees of freedom (*df*), log-likelihood (logLik), small sample size corrected Akaike information criterion (AICc), its difference to the best ranking model (ΔAICc), model weights (w_i), which are standardised to sum to one, as well as marginal ($R_{(m)}^2$) and conditional coefficient of determination ($R_{(c)}^2$). Maximum likelihood estimation was used for AICc-based model comparison, but $R_{(m)}^2$ and $R_{(c)}^2$ were calculated under restricted maximum likelihood estimation.

Model	*df*	logLik	AICc	ΔAICc	w_i	$R_{(m)}^2$	$R_{(c)}^2$
Heathlands							
pH	4	-101.26	215.49	0.00	0.16	0.54	0.70
Mg + pH	5	-99.39	216.51	1.02	0.10	0.55	0.70
K^2 + pH	5	-99.16	217.15	1.66	0.07	0.55	0.68
K + pH	5	-99.65	217.29	1.80	0.07	0.53	0.72
P^2 + pH	5	-100.04	217.66	2.18	0.05	0.55	0.70
Mg^2 + pH	5	-99.92	218.09	2.60	0.04	0.54	0.70
P + pH	5	-100.04	218.14	2.65	0.04	0.53	0.70
Mg + Mg^2 + pH	6	-97.56	218.54	3.06	0.04	0.54	0.71
K^2 + Mg + pH	6	-97.40	218.57	3.08	0.03	0.55	0.69
Mg + P^2 + pH	6	-98.13	218.69	3.20	0.03	0.56	0.70
Mg + P + pH	6	-98.17	219.33	3.84	0.02	0.54	0.70
K + Mg + pH	6	-97.94	219.37	3.88	0.02	0.54	0.70
K^2 + P^2 + pH	6	-97.93	219.49	4.00	0.02	0.56	0.68
K + K^2 + pH	6	-97.71	219.52	4.03	0.02	0.53	0.70
K^2 + Mg^2 + pH	6	-97.51	219.54	4.05	0.02	0.54	0.68
K^2 + Mg + Mg^2 + pH	7	-94.91	219.54	4.05	0.02	0.55	0.69
K + Mg^2 + pH	6	-98.17	219.85	4.37	0.02	0.51	0.73

Table S6.Continued

Model	*df*	logLik	AICc	ΔAICc	w_i	$R_{(m)}^2$	$R_{(c)}^2$
$K + P^2 + pH$	6	-98.53	219.86	4.37	0.02	0.53	0.71
$K + P + pH$	6	-98.17	219.96	4.47	0.02	0.52	0.73
$K^2 + P + pH$	6	-97.93	219.96	4.48	0.02	0.54	0.68
$P + P^2 + pH$	6	-98.63	220.40	4.91	0.01	0.55	0.70
$Mg^2 + P^2 + pH$	6	-98.70	220.44	4.95	0.01	0.54	0.69
$Mg^2 + P + pH$	6	-98.69	220.90	5.41	0.01	0.53	0.70
$K^2 + Mg + P^2 + pH$	7	-96.12	220.91	5.42	0.01	0.56	0.68
$Mg + Mg^2 + P^2 + pH$	7	-96.34	221.00	5.51	0.01	0.55	0.70
$Mg + P + P^2 + pH$	7	-96.61	221.37	5.88	0.01	0.56	0.70
$Mg + Mg^2 + P + pH$	7	-96.32	221.51	6.03	0.01	0.53	0.71
$K^2 + Mg + P + pH$	7	-96.15	221.53	6.04	0.01	0.54	0.68
$K + Mg + P^2 + pH$	7	-96.61	221.53	6.04	0.01	0.56	0.69
$K + Mg + Mg^2 + pH$	7	-96.09	221.54	6.05	0.01	0.53	0.71
$K + K^2 + Mg + pH$	7	-95.95	221.56	6.08	0.01	0.54	0.68
$K + K^2 + Mg^2 + pH$	7	-95.91	221.79	6.30	0.01	0.52	0.70
$K^2 + Mg^2 + P^2 + pH$	7	-96.31	222.15	6.66	0.01	0.55	0.68
$K + K^2 + P^2 + pH$	7	-96.57	222.21	6.72	0.01	0.53	0.69
$K^2 + P + P^2 + pH$	7	-96.46	222.22	6.74	0.01	0.56	0.68
$K^2 + Mg + Mg^2 + P^2 + pH$	8	-93.73	222.25	6.77	0.01	0.56	0.68
$K + K^2 + Mg + Mg^2 + pH$	8	-93.37	222.32	6.84	0.01	0.56	0.68
$K + K^2 + P + pH$	7	-96.21	222.33	6.84	0.01	0.52	0.71
$K + P + P^2 + pH$	7	-96.75	222.38	6.89	0.01	0.53	0.73
$K + Mg + P + pH$	7	-96.50	222.44	6.95	0.00	0.52	0.71

Table S6.Continued

Model	*df*	logLik	AICc	ΔAICc	w_i	$R_{(m)}^2$	$R_{(c)}^2$
Grasslands							
$K^2 + P + P^2 + pH$	7	-150.87	330.86	0.00	0.14	0.44	0.48
$K^2 + P + pH$	6	-154.18	331.38	0.52	0.11	0.41	0.42
$K + P + P^2 + pH$	7	-151.53	331.69	0.83	0.10	0.41	0.50
$K + K^2 + P + P^2 + pH$	8	-148.73	331.94	1.08	0.08	0.44	0.49
$P + P^2 + pH$	6	-154.45	332.43	1.58	0.07	0.39	0.46
$K + K^2 + P + pH$	7	-152.53	333.51	2.65	0.04	0.41	0.43
$K^2 + Mg + P + pH$	7	-152.49	333.55	2.69	0.04	0.41	0.43
$K^2 + Mg^2 + P + P^2 + pH$	8	-149.57	333.64	2.78	0.04	0.43	0.48
$K^2 + Mg^2 + P + pH$	7	-152.72	333.70	2.84	0.03	0.41	0.42
$K^2 + Mg + P + P^2 + pH$	8	-149.38	333.72	2.86	0.03	0.43	0.48
$K + Mg^2 + P + P^2 + pH$	8	-150.07	333.98	3.12	0.03	0.42	0.50
$K + P + P^2$	6	-155.05	334.13	3.28	0.03	0.34	0.47
$K + Mg + P + P^2 + pH$	8	-149.85	334.22	3.37	0.03	0.41	0.50
$Mg^2 + P + P^2 + pH$	7	-153.02	334.70	3.84	0.02	0.39	0.46
$K + K^2 + Mg^2 + P + P^2 + pH$	9	-147.41	334.84	3.99	0.02	0.44	0.49
$K + K^2 + Mg + P + P^2 + pH$	9	-147.20	334.96	4.10	0.02	0.43	0.50
$K + K^2 + P + P^2$	7	-152.49	335.06	4.20	0.02	0.36	0.46
$Mg + P + P^2 + pH$	7	-152.88	335.06	4.20	0.02	0.38	0.47
$K + K^2 + Mg + P + pH$	8	-150.86	335.84	4.99	0.01	0.40	0.43
$P + pH$	5	-158.97	335.85	5.00	0.01	0.31	0.37
$K + K^2 + Mg^2 + P + pH$	8	-151.07	335.92	5.06	0.01	0.40	0.43
$K^2 + P + P^2$	6	-155.62	336.19	5.33	0.01	0.34	0.43
$K + P + pH$	6	-156.50	336.30	5.44	0.01	0.32	0.42

Table S6.Continued

Model	*df*	logLik	AICc	ΔAICc	w_i	$R_{(m)}^2$	$R_{(c)}^2$
K^2 + Mg + Mg^2 + P + pH	8	-150.84	336.38	5.53	0.01	0.40	0.43
K^2 + Mg + Mg^2 + P + P^2 + pH	9	-147.73	336.67	5.81	0.01	0.43	0.48
K + Mg^2 + P + P^2	7	-153.80	336.77	5.91	0.01	0.33	0.47
K + Mg + P + P^2	7	-153.51	336.83	5.97	0.01	0.33	0.47
K + Mg + Mg^2 + P + P^2 + pH	9	-148.15	337.00	6.14	0.01	0.41	0.50
K^2 + Mg + P	6	-156.48	337.40	6.54	0.01	0.33	0.41
Mg + Mg^2 + P + P^2 + pH	8	-151.11	337.58	6.72	0.01	0.39	0.47
K + K^2 + Mg + P + P^2	8	-150.83	337.59	6.73	0.00	0.37	0.47
K + K^2 + Mg^2 + P + P^2	8	-151.09	337.63	6.77	0.00	0.36	0.46
P + P^2	5	-159.25	337.68	6.82	0.00	0.28	0.41
K^2 + P	5	-159.26	337.73	6.88	0.00	0.27	0.37
K^2 + Mg + P + P^2	7	-153.61	337.77	6.91	0.00	0.35	0.45
K + K^2 + P	6	-156.70	337.91	7.05	0.00	0.29	0.41
K + K^2 + Mg + Mg^2 + P + P^2 + pH	10	-145.55	338.04	7.19	0.00	0.43	0.49
K^2 + P + P^2 + pH	7	-150.87	330.86	0.00	0.14	0.44	0.48