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Ecology, distribution and conservation status of wet grasslands and fens with *Juncus filiformis* and *Eriophorum angustifolium* in the Süderbergland, Westphalia

Feuchtgrünland und Niedermoore mit *Juncus filiformis* und *Eriophorum angustifolium* im Süderbergland, Westfalen – Verbreitung, Ökologie und Erhaltungszustand

Dario Wolbeck[1, 2 *] & Erwin Bergmeier[1]

[1]Georg-August-Universität Göttingen, Albrecht-von-Haller Institut für Pflanzenwissenschaften, Abteilung für Vegetationsanalyse und Phytodiversität, Untere Karspüle 2, 37073 Göttingen, Germany;
[2]Nordwestdeutsche Forstliche Versuchsanstalt, Abteilung Waldnaturschutz, Sachgebiet Arten- und Biotopschutz, Professor-Oelkers-Str. 6, 34346 Hann. Münden, Germany
**Corresponding autor, e-mail: wolbeck.dario@web.de*

Abstract

Wet grasslands and fens are critically threatened habitats, firstly by abandonment or environmentally inappropriate farming, then possibly as a result of climate change by drying out in periods of lasting drought. To provide comprehensive information on the present species composition, ecology and conservation status of these biodiverse habitats and their plant communities in the Westphalian Süderbergland and as reference for future studies we explored which community types (associations and subunits) of wet grasslands and fens with *Juncus filiformis* and *Eriophorum angustifolium* occur in the study area, where and under which habitat and conservation conditions. It is the first study of its kind to examine wet meadow and fen communities regionwide for the entire Süderbergland. We collected 73 relevés, each with full vascular plant and bryophyte composition and mixed soil sample. We used Turboveg as database programme, Isopam as classification method, NMDS for ordination, and various statistics tools. Soil analyses included moisture, carbon and nitrogen contents, C/N ratio, CEC, pH and phosphate. Apart from soil characteristics we determined indicator values of plant species (groups) per relevé and community. We identified seven plant community types attributable to three associations. The *Juncetum filiformis* as an association of the *Calthion palustris* was found on extensively mown hay meadows chiefly around 400 m a.s.l. in the western part of the study region. The association comprised two variants distinguishable mainly by different species composition and nutrient levels. Wetlands with *Eriophorum angustifolium* differed from the *Juncetum filiformis* apart from species composition by higher soil moisture, geomorphological and soil conditions, and land-use. Two thirds of the relevés were identified as different variants of the *Caricetum nigrae*, distributed chiefly at headwaters between 450 and 650 m a.s.l. Subunits of the *Caricetum nigrae* differed mainly in nutrient levels and soil acidity. Disturbance levels indicated chiefly by various *Molinietalia* species played a role in determining the species richness and structure of the fen vegetation. Best-preserved fens of the *Caricetum nigrae* were comparably poor in vascular plant species, homogeneous in structure and rich in bryophytes. More different were acidic, pronouncedly nutrient-poor *Eriophorum*-rich peatmoss fens

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attributable to the *Carici echinatae-Sphagnetum*, an association of poor-fen vegetation which was recorded for the first time in the region. As a conclusion of our findings and those gathered from literature we make recommendations for conservation action regarding maintenance, restoration and connectivity.

Keywords: bryophytes, *Calthion palustris*, *Caricetalia fuscae*, fen, Germany, grassland management, *Molinietalia caeruleae*, phytosociology, soil analysis, species richness, Süderbergland, wetland

Erweitere deutsche Zusammenfassung am Ende des Artikels

1. Introduction

Upland wet grassland is valued as a key component of an eco-cultural landscape shaped over centuries by non-intensive cattle farming. In Central Europe such ancient wet grasslands comprise chiefly once-mown meadows cut for hay and mires grazed or mown for livestock fodder and bedding (KLAPP 1965, LEUSCHNER & ELLENBERG 2017). As semi-natural habitats, refuge of rare plants and wildlife, and areas of water retention and carbon storage, they are of considerable conservation concern.

In the Sauerland-Siegerland (Süderbergland, Northrhine-Westphalia, NRW, Germany) upland wet grasslands occur widely scattered and are characteristic landscape components of the region. After the pioneering work of BÜKER (1942) their flora and vegetation has not been studied to date except for a few inventories of mostly local scope (e.g., BROCKHAUS 1953, RUNGE 1973, LIENENBECKER 1974, LICHTWARK 1978, SCHRÖDER E. 1983, 1988, SCHRÖDER B. 1984, 1999, PURPS 1990, KÜHN 1998) and general overviews now somewhat out of date (RUNGE 1961, FOERSTER 1983). The present survey focuses on the species composition, distribution and ecology of two types of upland acid grassland, specifically small-sedge fens rich in *Eriophorum angustifolium* and wet meadows with *Juncus filiformis*.

In Germany and much of West and Central Europe, marshy and peaty grasslands are vanishing as a result of drainage, water withdrawal, agricultural intensification, eutrophication and abandonment. What is remaining is often in poor condition and threatened. EU-wide, poor fens (Eionet code D2.2a; EIONET FORUM 2023) have been classified Vulnerable (JANSSEN et al. 2016). In Germany, fen grasslands of the *Caricetum nigrae* J. Braun 1915 were rated Vulnerable (RENNWALD et al. 2002a). The corresponding habitat type of the EU Habitats Directive, 7140 (Transition mires and quaking bogs) has been monitored and found in unfavourable conservation status (BFN 2019). The category "Moist or wet mesotrophic to eutrophic hay meadows" (Eionet code E3.4a; EIONET FORUM 2023), to which *Juncus filiformis* meadows are assignable, have been classified Endangered (JANSSEN et al. 2016). In the German Red list by RENNWALD et al. (2002a), *Juncus filiformis* meadows have not been rated specifically. Permanently wet meadows, unfortunately, have not been included as habitat type in Annex I of the Habitats Directive, but their conservation on a national scale, equivalent to the EU Directive, is equally mandatory, and should anyway be of priority concern.

Currently, apart from contractual nature conservation, large-scale projects aiming at the conservation and management of fen grasslands and wet meadows in the German Uplands are missing despite their scenic, biodiversity and landscape-ecological significance. To this end, the present study has been designed to provide topical and comprehensive information. We assume that our survey covers a considerable proportion of the extant wet grasslands of the higher reaches of the Westphalian Uplands. Some of the areas have been rated among the best-preserved wetlands in the Süderbergland (GÖDDECKE 2002, LANUV NRW 2013, SCHUBERT 1998). Based on a floristic preselection by certain wet grassland indicator species, we collected a representative sample of plots together with environmental data to answer the following research questions: (1) Which plant communities (associations and subunits) are represented in the examined wet grassland and fenland of the study area and how are they distributed? (2) Which correlations exist between the measured habitat conditions and the species composition and abundance? (3) How is the state of preservation of the observed fen grasslands and wet meadows? Based on our findings and the information gathered from literature, we provide recommendations for conservation actions related to the maintenance, restoration, and enhancement of connectivity.

2. Study area

The study area comprises the central and eastern parts of the Süderbergland in Westphalia, a part of the Rhenish Massif corresponding largely to the regions Sauerland and Siegerland (Fig. 1). It covers an area between the towns of Hagen in the northwest, Brilon in the northeast and Siegen in the south. The surveyed sites were located in the districts of Olpe, Märkischer Kreis, Hochsauerlandkreis, Siegen-Wittgenstein and Soest. The terrain of the Süderbergland ascends roughly from north (northwest) to south (southeast). Especially the Rothaar Mountains (in the east) and the Ebbe Mountains (in the west) cause the moist westerly air masses to rise to produce orographic precipitation of more than 1000 mm/a (LANUV NRW 2019). Temperatures are relatively cool with 8.1 °C (1981–2010); the corresponding value for the period 1951–1980 was 7.4 °C (LANUV NRW 2019).

The bedrock consists of Devonian schistose claystone, silty sandstone and greywacke, towards the north also of sedimentary rock of the Lower Carboniferous (GEOLOGISCHER DIENST NRW 2020a). Headwater areas and stream valleys are filled with colluvial deposits of silt and clay which, together with the water collected over schistose rock on the slopes, generate Stagnosols (pseudogley) where stagnating waters above dense subsoils occur as basis for the development of permanently wet grasslands and fens (GEOLOGISCHER DIENST NRW 2020a, b). The study area comprises major parts of the ecoregions Südsauerländer Bergland, Ostsauerländer Gebirgsrand and Rothaargebirge (MEYNEN & SCHMITHÜSEN 1962).

In much of the Süderbergland the most widespread potential natural vegetation in submontane-montane sites without groundwater is typical acid upland beech forest (*Luzulo luzuloidis-Fagetum sylvaticae* Meusel 1937) or slightly more base-containing acid beech forest (*Luzulo luzuloidis-Fagetum milietosum* auct., *Milio effusi-Fagetum* Burrichter & Wittig 1977) (BURRICHTER et al. 1988, SUCK & BUSHART 2010, SUCK et al. 2013, 2014). The vegetation of mountain stream valleys was usually transformed to grassland or later reforested with spruce (*Picea abies*); their natural vegetation may be characterized as complex of more or less nutrient-rich mixed ashwood (*Fraxinus excelsior*) and fern-rich *Acer pseudoplatanus-Alnus glutinosa* forest as well as upland birchwood with *Betula pubescens* (SUCK et al. 2013, 2014). Palynological evidence suggests a decrease of forest cover and increase of grassland since the late Neolithic and Bronze Age, first on moderately nutrient-rich and workable soils in the valleys. Wet grassland habitat continuity in the study area since Bronze Age can thus be assumed. Since the Middle Ages the proportion of grassland in the mountain valleys increased as a result of growing demands of the population with an accordingly growing number of watermills along the streams and the development of new techniques of watering meadows (SPEIER 1994, 1999).

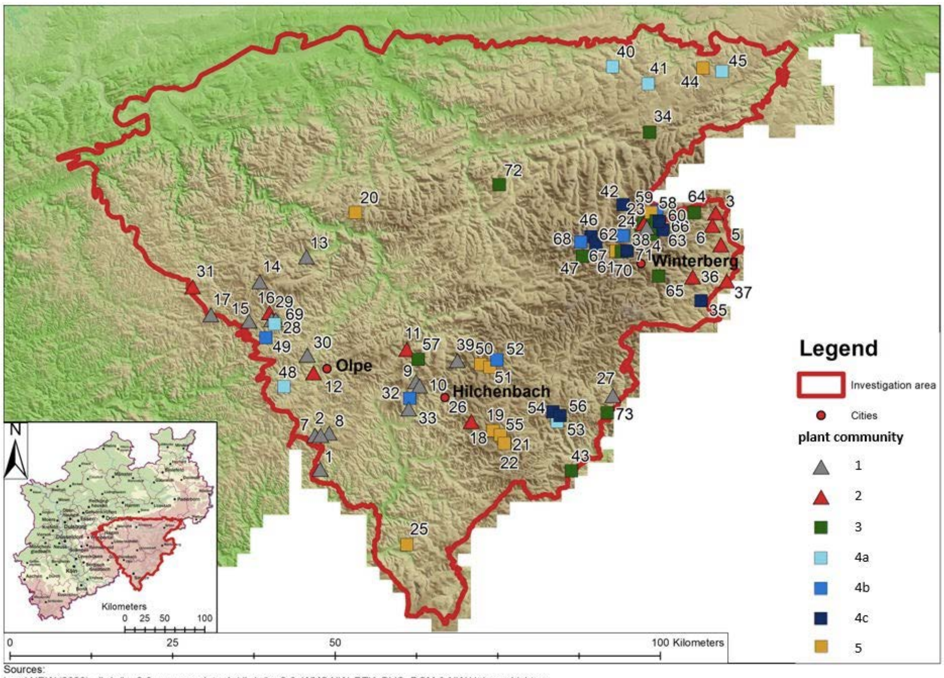

Fig. 1. Study area with relevé plot sites (with plot IDs) of the seven classified plant communities (1, *Juncus filiformis* meadows with *Agrostis capillaris*, *n* = 17; 2, *J. filiformis* meadows with *Taraxacum* and *Lysimachia*, *n* = 11; 3, *Eriophorum angustifolium* fens with *Carex panicea*, *n* = 12; 4a: *Eriophorum angustifolium* fen, variant with *Juncus acutiflorus*, *n* = 7; 4b, *E. angustifolium* fen, variant with *Carex rostrata*, *n* = 6; 4c, *E. angustifolium* fen, variant with *Anthoxanthum odoratum*, *n* = 9; 5, *E. angustifoium* fen, variant with *Molinia* and *Sphagnum*, *n* = 11). Background colorationn reflects differences in elevation.

Abb. 1. Karte des Untersuchungsgebietes mit geographischer Lage und Kennnummer der Probeflächen der sieben klassifizierten Pflanzengesellschaften. (1, *Juncus filiformis*-Feuchtwiese, Variante mit *Agrostis capillaris*, *n* = 17; 2, *J. filiformis*-Feuchtwiese, Variante mit *Taraxacum* und *Lysimachia* *n* = 11; 3, *Eriophorum angustifolium*-Niedermoor, Variante mit *Carex panicea* *n* = 12; 4a, *E. angustifolium*-Niedermoor, Variante mit *Juncus acutiflorus*; 4b, *E. angustifolium*-Niedermoor, Variante mit *Carex rostrata*; 4c, *E. angustifolium*-Niedermoor, Variante mit *Anthoxanthum odoratum*; 5, *E. angustifolium*-Niedermoor, Variante mit *Molinia* und *Sphagnum*. Die Hintergrundfarbgebung zeigt Höhenunterschiede an.

3. Materials and methods

3.1 Field survey and sampling

Eriophorum angustifolium and *Juncus filiformis* were used as target plant species indicating wet grassland. Important occurrence (and cover) data of the two species were provided by the Landesamt für Natur, Umwelt und Verbraucherschutz NRW (LANUV) as GIS shapefiles (polygons and dots) based on various mapping activities (habitat mapping [*Biotopkartierung*], conservation area management plans and plant mapping [*Fundpunkte*]). Other indicator plant species of nutrient-poor grassland such as *Agrostis canina*, *Carex canescens*, *C. echinata* and *Dactylorhiza majalis*

(OBERDORFER 2001, FOERSTER 2008, SCHUBERT et al. 2010) were considered if the primary target species occurred but with low frequency and cover. Species data located in wooded habitats (riparian woodland, carrs) were disregarded. The minimum distance between sites was set to 500 m. On the basis of the established criteria, a total of 110 sites were preselected. Together with a few additional ones spotted during the survey the total number of envisaged sites which met the criteria was 114.

Field data were collected between 21 May and 12 August 2019, the proper date depending on the state of vegetation development and accessibility. One plot per site was selected and a relevé was collected if homogeneously structured vegetation patches with a target species were encountered. If *E. angustifolium* and *J. filiformis* occurred together in a site, relevés were gathered in two different plots. The resulting total sample number (relevés) was 73. The plot size was standardised to 16 m², following recommendations by DIERSCHKE (1994) and CHYTRÝ & OTÝPKOVÁ (2003). All species of vascular plants and bryophytes were recorded. Plants undeterminable in the field, especially bryophytes, were collected for later identification (DIERßEN 1996, FRAHM & FREY 2004, FOERSTER 2008, JÄGER et al. 2013, MÜLLER et al. 2016). The cover-abundance of the plant species was estimated using the extended Braun-Blanquet nine-part scale (WESTHOFF & VAN DER MAAREL 1978). The environmental variables collected per plot are listed in Supplement E1. A mixed soil sample per plot was gathered using an auger. The topsoil and its thickness were identified, in peaty soil by applying a Pürckhauer. Other soil parameters were inferred from the information system of the GEOLOGISCHER DIENST NRW (2020b). The taxonomy of vascular plants follows the German plant checklist (HAND & THIEME 2022), the taxonomy of the bryophytes, CASPARI et al. (2018). The taxonomy of high-ranked syntaxa follows the conspectus by BERGMEIER (2020) which in turn corresponds to the EuroVeg-Checklist by MUCINA et al. (2016). Red list status indication for vascular plants and bryophytes follows LANUV NRW (2010, 2011a, b).

3.2 Soil analyses

The soil sample was analysed at the lab of the Plant Ecology department, University of Göttingen. The fresh (pre-dried) soil was sieved, weighed, and used for measuring pH_{H2O}, pH_{KCl}, cation-exchange capacity (CEC) and exchangeable P (phosphate). The soil sample was dried at 70 °C to establish the dry weight, moisture, carbon (C) and nitrate content as well as the carbon to nitrogen ratio (C/N). CEC was determined by using a solution of $BaCl_2$ percolated with the fresh soil, then, after adding 65% HNO_3, by plasma optical emission spectrometry (ICP-OES) of the ions Al^{3+}, Ca^{2+}, Fe^{2+}, K^+, Mg^{2+}, Mn^{2+}, Na^+ and H^+. C and N contents (mg/g) were measured against acetanilid in a C/N analyser, using finely ground soil after ignition (600 °C). C/N ratio and C_{org} (mg/g) were determined using 5 mg organic or 10 mg mineral soil. Exchangeable P (μmol_c/g) was calculated using fresh soil mixed with anion-exchange resin in demineralized water for 16 h, then mixed with 10% NaCl solution for 30 minutes. After adding a reagent (ascorbic acid-ammonium molybdate) the blue colour of the solution was measured spectrometrically against the original solution's colour.

3.3 Statistical analyses

The relevés were entered in a Turboveg database, vs. 2.140b (HENNEKENS & SCHAMINÉE 2001), and classified by non-hierarchical Isopam (SCHMIDTLEIN et al. 2010) using the *isopam* function in R (*isopam* package vs. 0.9-13; SCHMIDTLEIN 2014). Synoptic tables were created by applying the *syntable* and *synsort* functions in R (*goeveg* package vs. 0.4.2; GORAL & SCHELLENBERG 2019). Differential species were determined using the algorithm by TSIRIPIDIS et al. (2009). One of the five groupings initially classified turned out to be heterogeneous to such an extent to justify subdivision, again by Isopam.

For each Isopam-classified plant community mean cover values of the herb and bryophyte layers as well as class-related cover values of the character species of the classes *Scheuchzerio palustris-Caricetea fuscae* Tx. 1937, *Molinio-Arrhenatheretea* Tx. 1937 and *Nardetea strictae* Rivas Goday et Borja Carbonell in Rivas Goday et Mayor López 1966 combined with *Calluno-Ulicetea* Br.-Bl. et Tx. ex Klika et Hadač 1944 were computed, using transformed mean cover values of the pertinent character species according to OBERDORFER (1983, 2001), ELLENBERG et al. (2001) and, for bryophytes, DIERßEN (2001). Mean cover values of species indicating moisture, nutrient richness and alkalinity were computed in the same way (OBERDORFER 2001, DIERßEN 2001). For all numerical variables mean values (medians of Ellenberg indicator values, EIV, for continentality (C), light (L), moisture (M), nutrients (N), soil reaction (R) and temperature (T)), standard errors and min-max values of the plant communities were calculated based on presence-absence data of the species. Mean pH values were computed by taking the antilogarithm of the values, averaged per plant community and the average values logarithmised.

Non-metric multidimensional scaling (NMDS) was applied (*metaMDS*, *vegan* package vs. 2.5–6, OKSANEN et al. 2017) to assist the ecological interpretation of the classified plant communities and to display the relative position of the relevés in ordination space. Interval or rational-scaled variables were fitted using *envfit* (*vegan* 2.5–6, OKSANEN et al. 2017).

Normality distribution was tested using the Shapiro-Wilk test (*shapiro.test*, *stats* package, R). Levene's test (R package *car*, vs. 3.0–6, FOX & WEISBERG 2019) was used to assess the equality of variances for the variables. Analysis of variance (ANOVA) (*aov*, *stats* package, R) was applied to analyse the differences among means of normally distributed variables between the classified plant communities; if not normally distributed, Kruskal-Wallis test was applied (*col_kruskalwallis*, package *matrixTests* vs. 0.1.8, KONCEVIČIUS 2018). Pairs of plant communities with significantly deviating variables were found by Tukey's honest significance test (*TukeyHSD*, *stats* package, R), adjusted with HOLM (1979). Dunn's test of multiple comparisons (*dunn.test*, package *dunn.test*, DINNO 2017) was used to compare the Isopam classified groupings. Correlations between numerical variables were computed using *cor* (*stats* package, R). By means of Principal component analysis (PCA) (*rda*, *vegan* package, OKSANEN et al. 2017) we identified variables explaining most of the variance in the dataset. Supplement E2 provides an overview of the statistical tools and functions.

4. Results

4.1 Phytosociological classification

On the first pass Isopam computed five groups or plant communities, two of which (1–2) with highest constancy of *Juncus filiformis*, and three (3–5) with highest constancy of *Eriophorum angustifolium* (Table 1). Group 1 was rather poorly differentiated by *Agrostis capillaris*, *Luzula campestris* and *Anemone nemorosa*, while group 2 had *Taraxacum* sect. *Taraxacum* and *Lysimachia nummularia* as main differential species. The *J. filiformis* communities together differed further in high frequencies of *Trifolium pratense*, *Plantago lanceolata*, *Carex leporina*, *Alopecurus pratensis* and *Festuca pratensis* from the communities rich in *E. angustifolium*, which were characterized moreover by *Carex echinata*, *Potentilla erecta*, *Epilobium palustre* and *Viola palustris*. Group 3 was distinguishable by a set of differential species including *Carex panicea*, *Crepis paludosa* and *Dactylorhiza majalis*. *Carex nigra*, *Aulacomnium palustre*, *Carex canescens* and *Straminergon stramineum* were frequent in two of the three *E. angustifolium* communities (4–5). One group (5) differed widely in the presence of differential species such as *Molinia caerulea*, *Avenella flexuosa*, *Galium saxatile*, *Polytrichum commune* and *Sphagnum fallax* and in the (near) absence of differential species of the groups 3 and 4, such as *Cirsium palustre*, *Galium uliginosum*, *Climacium dendroides*, *Juncus acutiflorus* and *Valeriana dioca*, and of other wet meadow species which were more or less common in all other plant communities, such as *Cardamine pratensis*, *Lotus pedunculatus*, *Myosotis nemorosa* and *Ranunculus flammula* (Table 1).

The second run of Isopam turned out to be meaningful for group 4 with regular occurrence of *Agrostis canina*. This group was subdivided into three subgroups 4a–c (Table 2), each with several differential species. Subgroup 4a was rich in *Juncus acutiflorus*

Table 1. Synoptic table with constancy values of positively (**bold**) and negatively (*italics*) differentiating species (as defined and computed by TSIRIPIDIS et al. 2009) as revealed by non-hierarchical Isopam with 5 groups (plant communities). Constancy values are in per cent of occurrences across all plots of a plant community. Only differential species with constancy value higher than 20% in at least one column are shown. The coloration of the head-lines corresponds to Figure 1 as well as NMDS diagram Figure 2 (Suppl. E3, E4). Non-differentiating species were omitted. The underlying data can be found in Suppl. E8. Superscripts after species names: Character species (after DIERßEN 2001, ELLENBERG et al. 2001, OBERDORFER 2001) of the classes *Scheuchzerio palustris-Caricetea nigrae* (S), *Molinio-Arrhenatheretea* (M) and *Calluno-Ulicetea/Nardetea strictae* (C) as well as indicator species for moisture (m), nutrient richness (n) and base richness (b) (after DIERßEN 2001, OBERDORFER 2001).

Tabelle 1. Übersichtstabelle der mit Isopam klassifizierten Gruppen (Pflanzengesellschaften), mit Stetigkeit der Differenzialarten in den jeweiligen Gruppen (in %). Stetigkeiten der positiv differenzierenden Arten sind **fett** gedruckt, die der negativ differenzierenden Arten *kursiv* (definiert nach TSIRIPIDIS et al. 2009). Nur Differenzialarten mit mindestens 20 % Stetigkeit in wenigstens einer Spalte sind enthalten. Die Hintergrundfarben der Kopfreihen bezieht sich auf Abbildung 1 sowie auf das NMDS-Ordinationsdiagramm Abbildung 2 (Anhang E3, E4). Die Einzelaufnahmen finden sich in Anhang E8. Hochgestellte Angaben hinter den Artnamen: Charakterarten (nach DIERßEN 2001, ELLENBERG et al. 2001, OBERDORFER 2001) der Klassen *Scheuchzerio palustris-Caricetea nigrae* (S), *Molinio-Arrhenatheretea* (M) und *Calluno-Ulicetea/Nardetea strictae* (C) sowie Zeigerarten für Feuchtigkeit (m), Nährstoffreichtum (n) und Basenreichtum (b) (nach DIERßEN 2001, OBERDORFER 2001).

Differentiating for group	Group number	**1**	**2**	**3**	**4a-c**	**5**
		Juncus filiformis* meadows with *Agrostis capillaris	***Juncus filiformis* meadows with *Taraxacum* and *Lysimachia***	***Eriophorum angustifolium* fens with *Carex panicea***	***Eriophorum angustifolium* fens with *Agrostis canina***	***Eriophorum angustifolium* fens with *Molinia* and *Sphagnum***
	Number of relevés	17	11	12	22	11
1–2	*Juncus filiformis* ^{M,m}	**100**	**100**	*17*	*0*	*18*
	Trifolium pratense ^{M,mnb}	**76**	**73**	*17*	*0*	*0*
	Plantago lanceolata ^{M,n}	**65**	**64**	*17*	*9*	*0*
	Carex leporina ^{n}	**71**	**73**	*0*	*5*	*9*
	Alopecurus pratensis ^{M,n}	**24**	**64**	*0*	*0*	*0*
	Festuca pratensis ^{M,nb}	**24**	**45**	8	*0*	*0*
3–5	*Eriophorum angustifolium* ^{S,m}	*6*	*0*	**100**	**100**	**100**
	Carex echinata ^{S,m}	*24*	*18*	**83**	**82**	**73**
	Potentilla erecta ^{M}	*0*	*9*	**67**	**59**	**64**
	Epilobium palustre ^{mn}	*6*	*0*	**67**	**86**	**45**
	Viola palustris ^{S,m}	*6*	*9*	**42**	**82**	**45**
	Carex nigra ^{S,m}	*29*	36	58	**82**	**82**
	Aulacomnium palustre ^{S,m}	*12*	*0*	17	**45**	**45**
	Carex canescens ^{S,m}	6	*0*	17	**27**	**36**
	Straminergon stramineum ^{S,m}	*0*	*0*	8	**27**	**36**
1	*Agrostis capillaris*	**53**	27	*8*	*0*	18
	Luzula campestris ^{C}	**47**	*9*	33	23	27
	Anemone nemorosa ^{n}	**41**	*0*	*0*	*5*	18
	Carex pallescens ^{C,b}	**24**	*0*	8	*0*	*0*
2	*Taraxacum* sect. *Taraxacum* ^{M,nb}	*18*	**64**	*8*	*0*	*0*
	Lysimachia nummularia ^{M,nb}	*6*	**45**	17	*5*	*0*
	Bellis perennis ^{M,n}	18	**27**	*0*	*0*	*0*
	Equisetum palustre ^{M,mn}	*0*	**27**	8	*0*	*0*
	Trifolium campestre ^{b}	6	**27**	8	*0*	*0*

	Group number	1	2	3	4a-c	5
3	*Carex panicea* [mb]	47	36	**100**	50	27
	Crepis paludosa [M,mnb]	18	9	**67**	36	9
	Dactylorhiza majalis [M,mn]	6	9	**50**	23	0
	Glyceria fluitans [m]	0	18	**42**	5	0
	Juncus articulatus [mb]	0	0	**33**	14	0
	Juncus bulbosus [m]	0	0	**33**	18	9
	Luzula multiflora [M]	0	0	**33**	9	9
	Ptychostomum pseudotriquetrum [S,mb]	0	0	**33**	14	0
	Equisetum arvense [nb]	0	0	**25**	9	0
	Plagiomnium elatum [S,m]	0	0	**25**	18	0
	Veronica beccabunga [m]	0	0	**25**	0	0
4	*Agrostis canina* [m]	53	55	25	**91**	64
	Brachythecium spp.	24	18	58	**77**	27
	Poa trivialis [M,mnb]	6	18	25	**41**	0
	Carex rostrata	0	0	17	**27**	9
	Pellia spp.	0	0	8	**27**	0
5	*Molinia caerulea* [M,m]	12	9	0	23	**55**
	Deschampsia flexuosa	0	0	0	0	**45**
	Galium saxatile [C]	0	0	0	5	**45**
	Polytrichum commune [m]	0	0	0	5	**45**
	Amblystegium serpens [mn]	0	0	0	14	**36**
	Nardus stricta [C]	0	9	0	14	**36**
	Pleurozium schreberi	0	0	0	0	**36**
	Sphagnum fallax [mn]	0	0	0	0	**36**
	Festuca ovina agg.	0	0	0	0	**27**
	Juncus squarrosus [C,m]	0	0	0	0	**27**
3–4	*Cirsium palustre* [M,m]	59	27	**100**	**95**	36
	Galium uliginosum [M,m]	12	9	**92**	**73**	0
	Climacium dendroides [S,mb]	12	0	**83**	**41**	0
	Equisetum fluviatile [m]	18	0	**75**	**45**	18
	Juncus acutiflorus [M,m]	47	45	**75**	**59**	18
	Valeriana dioica [M,m]	0	0	**75**	**64**	0
	Plagiomnium ellipticum [S,m]	6	0	**67**	**55**	0
	Philonotis caespitosa / Ph. fontana [S]	0	0	**58**	**36**	0
	Plagiomnium undulatum [mn]	0	0	**58**	**23**	0
	Mentha arvensis [mn]	6	18	**50**	**45**	0
	Carex demissa [S,m]	0	9	**33**	**23**	9
	Dactylorhiza maculata agg. [m]	0	0	**25**	**23**	18
	Menyanthes trifoliata [S,m]	0	0	**25**	**23**	0
	Lophocolea bidentata [m]	0	0	**33**	**50**	18
	Chiloscyphus pallescens / Ch. polyanthos [m]	0	0	**33**	**45**	18
	Veronica scutellata [m]	6	0	**33**	**36**	0
	Sphagnum squarrosum [S,mn]	0	0	**25**	**27**	9
4–5	*Sphagnum palustre* [S,m]	0	0	0	**27**	**36**
	Sphagnum flexuosum [S,m]	0	0	0	**23**	**27**
1–3	*Trifolium repens* [M,b]	**41**	**64**	**33**	9	0
2–4	*Caltha palustris* [M,mn]	12	**36**	**92**	**55**	0
	Stellaria alsine	6	**27**	**50**	**32**	0
1–4	*Juncus conglomeratus* [M]	**29**	18	**33**	18	0
	Anthoxanthum odoratum	**88**	**82**	**67**	55	18
	Ajuga reptans [n]	**82**	**64**	**58**	55	18
	Vicia cracca [M,mb]	**35**	**36**	**33**	14	0
	Festuca rubra agg. [M,nb]	**94**	55	**83**	**77**	27
	Lathyrus pratensis [M,mnb]	24	18	**50**	**23**	0
	Rumex acetosa [M,nb]	**76**	55	**83**	**77**	18
	Holcus lanatus [M]	**94**	**64**	**83**	**82**	18

Group number	1	2	3	4a-c	5
Cardamine pratensis [M,m]	**71**	**100**	**83**	**64**	*0*
Lychnis flos cuculi [M,mnb]	**76**	**82**	**67**	**50**	*9*
Ranunculus repens [M,nb]	**47**	**82**	**50**	**32**	*0*
Scirpus sylvaticus [mn]	**59**	**82**	**50**	**27**	*0*
Achillea ptarmica [M,m]	**65**	**73**	**42**	**36**	*0*
Ranunculus flammula [m]	**41**	**73**	**67**	**73**	*0*
Lotus pedunculatus [M,mn]	**94**	**64**	**100**	**82**	*9*
Calliergonella cuspidata [S,mn]	**88**	**73**	**92**	**82**	*0*
Filipendula ulmaria [M,mnb]	**47**	**73**	**92**	**41**	*0*
Cerastium holosteoides subsp. *triviale* [M,mn]	**35**	**45**	**75**	**45**	*0*
Myosotis nemorosa [mnb]	**59**	**73**	**58**	**77**	*0*

and further distinguished by species competitive in nutrient-rich wet habitats such as *Scutellaria galericulata*, *Deschampsia cespitosa* and *Lycopus europaeus*. Subgroup 4b was differentiated by *Carex rostrata*, *Angelica sylvestris*, *Sphagnum palustre* and especially *Chiloscyphus* spec. (collected plants were unidentifiable, they represent *C. pallescens* and/or *C. polyanthemos*). Finally, the subgroup 4c was distinguished by a number of differential species, of which *Anthoxanthum odoratum* occurred in all plots, and *Philonotis* spp., *Climacium dendroides*, *Ranunculus acris*, *R. repens* and *Carex demissa* in some.

Most plots were located in the east of the study area, around the towns of Winterberg in the Hochsauerland district, Hilchenbach in the Siegen-Wittgenstein district, and in the west near the town of Olpe (district of Olpe), while in the northwest Süderbergland almost no suitable sites could be preselected owing to the scarceness of the target species (Fig. 1). Most of the relevés in the west – around Olpe – represented *Juncus filiformis* meadows, while *Eriophorum angustifolium* fen grasslands were rare. Around the town of Hilchenbach all plant communities were present, whereas the plots around Winterberg were mostly of *E. angustifolium* fen grasslands of the groups 3, 4b and 4c. *J. filiformis* meadows with *Agrostis capillaris* (group 1) occurred almost exclusively in the west, in the ecoregion (Naturraum) of the Südsauerländer Bergland, while group 2 plots occurred throughout the study area, yet mostly near Winterberg in the ecoregion of the Ostsauerländer Gebirgsrand. *Eriophorum angustifolium* fen grassland with *Carex panicea* or with *Agrostis canina* and *Anthoxanthum odoratum* (groups 3 and 4c, respectively) were typically encountered around both Winterberg and Hilchenbach, while group 5 plots (*E. angustifolium* fen grassland with *Sphagnum fallax*) were found chiefly around Hilchenbach and less so near Winterberg. While groups 3, 4c and 5 were absent in the region of Olpe, the groups 4a and 4b (fen grasslands with *Juncus acutiformis* or *Carex rostrata*, respectively) occurred throughout the study area, but were mainly recorded in the Rothaar Mountains ecoregion.

Soil moisture (wetness) indicating plants (EIV-M) showed the lowest cover in the *Juncus filiformis* meadows with *Agrostis capillaris* (group 1), while group 2 and group 5 had twice as much cover of wet soil indicator plants, although the difference is not significant (Table 3). Nutrient indicators (EIV-N) were most represented in *J. filiformis* meadows of group 2 and in group 3 (*E. angustifolium* grassland with *Carex panicea*), and least represented in groups 4a and 5 (fen grassland with *Juncus acutiflorus* and *Sphagnum fallax*, respectively). The mean EIV-N plant cover of group 1 *J. filiformis* meadows is lower than of group 2, similar to group 4, yet significantly higher than of group 5 (Table 3). Similarly, alkalinity indicator species (EIV-R) had the lowest cover values in groups 5 and 4b (fen grassland with *Sphagnum fallax* and *Carex rostrata*, respectively) and the highest in group 3 (Table 3).

Table 2. Synoptic table of subgroups 4a–c of group 4 (*Eriophorum angustifolium* fen grassland variants with *Agrostis canina*) with constancy values of positively (**bold**), negatively (*italics*) and positively-negatively (***bold italics***) differentiating species (as defined and computed by Tsiripidis et al. 2009), revealed by non-hierarchical Isopam. Constancy values are in per cent of occurrences across all plots of a plant community. Only differential species with constancy value higher than 20% in at least one column are shown. The coloration of the headlines corresponds to Figure 1 as well as NMDS diagram Figure 2 (Suppl. E3, E4). Non-differentiating species were omitted. The underlying data can be found in Supplement E9. Superscripts after species names: Character species (after Dierßen 2001, Ellenberg et al. 2001, Oberdorfer 2001) of the classes *Scheuchzerio palustris-Caricetea nigrae* (S), *Molinio-Arrhenatheretea* (M) and *Calluno-Ulicetea/Nardetea strictae* (C) as well as indicator species for moisture (m), nutrient richness (n) and base richness (b) (after Dierßen 2001, Oberdorfer 2001).

Tabelle 1. Übersichtstabelle der mit Isopam klassifizierten Gruppe 4 (*Eriophorum angustifolium*-Niedermoorgesellschaften mit *Agrostis canina*), unterteilt in drei Untergruppen 4a–c, mit Stetigkeit der Differenzialarten (in %). Stetigkeiten der positiv differenzierenden Arten sind **fett** gedruckt, die der negativ differenzierenden Arten kursiv, und ***fett-kursiv*** in Gruppen, in denen die Art positiv gegenüber der einen und negativ gegenüber der anderen Gruppe differenziert ist (definiert nach Tsiripidis et al. 2009). Nur Differenzialarten mit mindestens 20 % Stetigkeit in wenigstens einer Spalte sind enthalten. Die Hintergrundfarbe der ersten Reihe bezieht sich auf Abbildung 1 sowie auf das NMDS-Ordinationsdiagramm Abbildung 2 (Anhang E3, E4). Die zugrundeliegenden Daten finden sich in Anhang E9. Hochgestellte Angaben hinter den Artnamen: Charakterarten (nach Dierßen 2001, Ellenberg et al. 2001, Oberdorfer 2001) der Klassen *Scheuchzerio palustris-Caricetea nigrae* (S), *Molinio-Arrhenatheretea* (M) und *Calluno-Ulicetea/Nardetea strictae* (C) sowie Zeigerarten für Feuchtigkeit (m), Nährstoffreichtum (n) und Basenreichtum (b) (nach Dierßen 2001, Oberdorfer 2001).

	Group number	**4a**	**4b**	**4b**
Differentiating for group		**Variant with *Juncus acutiflorus***	**Variant with *Carex rostrata***	**Variant with *Carex rostrata***
	Number of relevés	**7**	**6**	**9**
1	*Juncus acutiflorus* ^{M,m}	**86**	33	56
	Poa trivialis ^{M,mnb}	**57**	17	44
	Scutellaria galericulata ^{m}	**57**	*0*	*0*
	Deschampsia cespitosa ^{mb}	**43**	*0*	*11*
	Lycopus europaeus ^{mnb}	**43**	*0*	*0*
	Straminergon stramineum ^{S,m}	**43**	33	*11*
	Epilobium ciliatum subsp. *adenocaulon* ^{n}	**29**	*0*	*0*
	Galeopsis spec.	**29**	*0*	*0*
	Kindbergia praelonga ^{m}	**29**	*0*	*0*
	Lysimachia vulgaris ^{mb}	**29**	*0*	*0*
2	*Chiloscyphus pallescens / Chiloscyphus polyanthos* ^{m}	*29*	**83**	33
	Angelica sylvestris ^{mn}	29	**67**	*22*
	Carex rostrata	*14*	**67**	*11*
	Sphagnum palustre ^{S,m}	*0*	**67**	***22***
	Aneura pinguis ^{mb}	*0*	**33**	11
	Luzula congesta	*0*	**33**	*0*
	Luzula multiflora ^{M}	*0*	**33**	*0*
	Plagiothecium denticulatum ^{m}	14	**33**	*0*
	Ptychostomum pseudotriquetrum ^{S,mb}	*0*	**33**	11
	Sphagnum subnitens ^{m}	*0*	**33**	11

	Group number	4a	4b	4b
3	*Anthoxanthum odoratum*	*14*	*33*	**100**
	Ranunculus flammula ^{m}	71	*33*	**100**
	Philonotis caespitosa / Philonotis fontana ^{S}	*0*	*17*	**78**
	Ranunculus acris ^{M,n}	*14*	33	**78**
	Climacium dendroides ^{S,mb}	*14*	33	**67**
	Ranunculus repens ^{M,nb}	*14*	*0*	**67**
	Carex demissa ^{S,m}	*0*	17	**44**
	Cynosurus cristatus ^{nb}	*0*	*0*	**44**
	Juncus bulbosus ^{m}	*0*	*0*	**44**
	Luzula campestris ^{C}	*0*	17	**44**
	Veronica chamaedrys	*0*	*0*	**33**
	Juncus articulatus ^{mb}	*0*	17	**22**
	Nardus stricta ^{C}	*0*	17	**22**
	Poa pratensis ^{nb}	*0*	17	**22**
	Prunella vulgaris ^{nb}	14	*0*	**22**
	Taraxacum spec.	*0*	*0*	**22**
	Trifolium repens ^{M,b}	*0*	*0*	**22**
	Vicia cracca ^{M,mb}	*0*	17	**22**
1–2	*Molinia caerulea* ^{m}	**29**	**50**	*0*
2–3	*Carex panicea* ^{mb}	*14*	**50**	**78**
	Dactylorhiza maculata agg. ^{m}	*0*	**50**	**22**
	Plagiomnium elatum ^{S,m}	*0*	**33**	**22**
	Scirpus sylvaticus ^{mn}	*0*	**33**	**44**
1, 3	*Holcus lanatus* ^{M}	**100**	*33*	**100**
	Rumex acetosa ^{M,nb}	**100**	*33*	**89**
	Lychnis flos cuculi ^{M,mnb}	**71**	*17*	**56**
	Cardamine pratensis ^{M,m}	**71**	*17*	**89**
	Cerastium holosteoides subsp. *triviale* ^{M,nb}	**57**	*0*	**67**
	Carex canescens ^{S,m}	**57**	*0*	**22**
	Mentha arvensis ^{mn}	**43**	*0*	**78**
	Veronica scutellata ^{m}	**43**	*0*	**56**

The *J. filiformis* meadow communities showed a high cover of *Molinio-Arrhenatheretea* species. The two groups 1 and 2 differed chiefly in their proportions of soil moisture and nutrient supply indicators which were relatively low in the former and higher in the latter community variant (Table 3). Among the *E. angustifolium* grassland communities (groups 3–5), group 3 (with *Carex panicea*) had the highest mean cover values of *Scheuchzerio-Caricetea* species, *Molinio-Arrhenatheretea* species, soil moisture and base indicators, and it came second in EIV-N cover. Group 5 (*E. angustifolium-Sphagnum* fen grassland) showed a high mean cover of *Scheuchzerio-Caricetea* species and relatively high cover of *Nardetea*/*Calluno-Ulicetea* species, while *Molinio-Arrhenatheretea* species came last. EIV-M equalled that of the wetter *J. filiformis* meadows (group 2) but was lower than in the other *E. angustifolium* grasslands (groups 3–4c). EIV-R was the lowest of all communities (Table 3).

Overall, the *E. angustifolium* grasslands with *Agrostis canina* (groups 4a–c) held an intermediate position between groups 3 and 5, except the *Scheuchzerio-Caricetea* species cover was somewhat lower in group 4 than in groups 3 and 5. Among the groups with *Agrostis canina* the variant with *Juncus acutiflorus* (group 4a) had the lowest cover value of *Scheuchzerio-Caricetea* and the highest in *Molinio-Arrhenatheretea* species. EIV-M mean cover was high in group 4a, while cover values of EIV-N and EIV-R were relatively low. *E. angustifolium* grassland with *Carex rostrata* (group 4b) showed higher mean cover values

Table 3. Mean cover values (%) of character species (selected according to ratings assigned by DIERßEN 2001, ELLENBERG et al. 2001, OBERDORFER 2001, and average cover sum calculated) of the vegetation classes *Scheuchzerio palustris-Caricetea nigrae*, *Molinio-Arrhenatheretea* and *Calluno-Ulicetea/Nardetea strictae* as well as species indicating moisture, nutrient richness, and alkalinity per community. The plant species consulted for this evaluation are indicated in Tables 1 and 2. 1, *Juncus filiformis* meadows, variant with *Agrostis capillaris*; 2, *J. filiformis* meadows, variant with *Taraxacum* and *Lysimachia*; 3, *Eriophorum angustifolium* fen grassland, variant with *Carex panicea*; 4a–c, *E. angustifolium* fen grassland, variants with *Agrostis canina*; 4a, *E. angustifolium* fen grassland, variant with *Juncus acutiflorus*; 4b, *E. angustifolium* fen grassland, variant with *Carex rostrata*; 4c, *E. angustifolium* fen grassland, variant with *Anthoxanthum odoratum*; 5, *E. angustifolium* fen grasslands, variant with *Molinia* and *Sphagnum*.

Tabelle 3. Mittlere Deckungswerte (%) der Charakterarten (ausgewählt nach Einstufung von DIERßEN 2001, ELLENBERG et al. 2001, OBERDORFER 2001, und mittlere Deckungssumme errechnet) der Klassen *Scheuchzerio palustris-Caricetea nigrae*, *Molinio-Arrhenatheretea* und *Calluno-Ulicetea/ Nardetea strictae* sowie der Zeigerarten für Feuchtigkeit, Nährstoffreichtum und Basenreichtum pro Pflanzengesellschaft. Die Pflanzenarten, die für diese Auswertung zurate gezogen wurden, sind in Tabelle 1 und 2 gekennzeichnet. 1, *Juncus filiformis*-Feuchtwiese, Variante mit *Agrostis capillaris*; 2, *J. filiformis*-Feuchtwiese, Variante mit *Taraxacum* und *Lysimachia*; 3, *Eriophorum angustifolium*-Niedermoor, Variante mit *Carex panicea*; 4a–c, *E. angustifolium* Niedermoor, Variante mit *Agrostis canina*; 4a, *E. angustifolium*-Niedermoor, Variante mit *Juncus acutiflorus*; 4b, *E. angustifolium*-Niedermoor, Variante mit *Carex rostrata*; 4c, *E. angustifolium*-Niedermoor, Variante mit *Anthoxanthum odoratum*; 5, *E. angustifolium*-Niedermoor, Variante mit *Molinia* und *Sphagnum*.

Vegetation class	1	2	3	4a–c	4a	4b	4c	5
Scheuchzerio-Caricetea (herbs)	14	25	40	39	33	39	44	39
Scheuchzerio-Caricetea (bryophytes)	10	30	43	25	11	41	26	36
***Scheuchzerio-Caricetea* (total)**	**24**	**55**	**83**	**64**	**44**	**80**	**70**	**75**
Molinio-Arrhenatheretea (herbs)	59	73	60	55	77	30	55	9
Molinio-Arrhenatheretea (bryophytes)	10	30	53	24	9	40	25	6
***Molinio-Arrhenatheretea* (total)**	**69**	**103**	**113**	**79**	**86**	**70**	**80**	**15**
Calluno-Ulicetea/*Nardetea strictae* (herbs and subshrubs)	6	3	3	3	1	5	3	9
Calluno-Ulicetea/*Nardetea strictae* (bryophytes)	10	30	33	18	3	34	18	22
***Calluno-Ulicetea*/*Nardetea strictae* (total)**	**16**	**33**	**36**	**21**	**4**	**39**	**21**	**31**
Moisture indicators (herbs)	46	75	101	94	114	75	91	61
Moisture indicators (bryophytes)	11	30	62	32	17	47	34	47
Moisture indicators (total)	**57**	**105**	**163**	**126**	**131**	**122**	**125**	**108**
Nutrient richness indicators (herbs)	48	60	37	32	40	22	33	9
Nutrient richness indicators (bryophytes)	10	30	40	18	5	29	20	13
Nutrient richness indicators (total)	**58**	**90**	**77**	**50**	**45**	**51**	**53**	**22**
Alkalinity indicators (herbs)	32	35	34	24	25	15	30	6
Alkalinity indicators (bryophytes)	0	0	12	3	0	4	5	0
Alkalinity indicators (total)	**32**	**35**	**46**	**27**	**25**	**19**	**35**	**6**

of *Scheuchzerio-Caricetea* than of *Molinio-Arrhenatheretea* species, and the cover of *Nardetea*/*Calluno-Ulicetea* species was the highest among the wet grassland communities. EIV-M and EIV-N species cover values were about middle, while EIV-R cover values were second lowest, just ahead of group 5. In *E. angustifolium* grasslands with *Anthoxanthum odoratum* (group 4c) we found a relatively high cover of *Molinio-Arrhenatheretea* species, as well as fairly high species cover values of EIV-N and EIV-R. EIV-M cover values ranked between groups 4a and 4b.

4.2 Ordination

The 73 plots were dispersed over the visualized 3-axes ordination space with a stress value of 0.132 (Fig. 2). The *Juncus filiformis* relevés were clustered in the left part of the ordination space of axes 1 and 2, the *Eriophorum angustifolium* plots to the right. The Isopam-generated groups were distributed along the first axis from left to right in the order 2 – 1 – 3 – 4c and 4a – 4b – 5. *Juncus filiformis* meadows (groups 1 and 2) clustered together but were very distinct from the *E. angustifolium* groupings. Most distinct is the *E. angustifolium-Sphagnum fallax* fen grassland (group 5). The groups 3 and 4 clustered together rather tightly (Fig. 3).

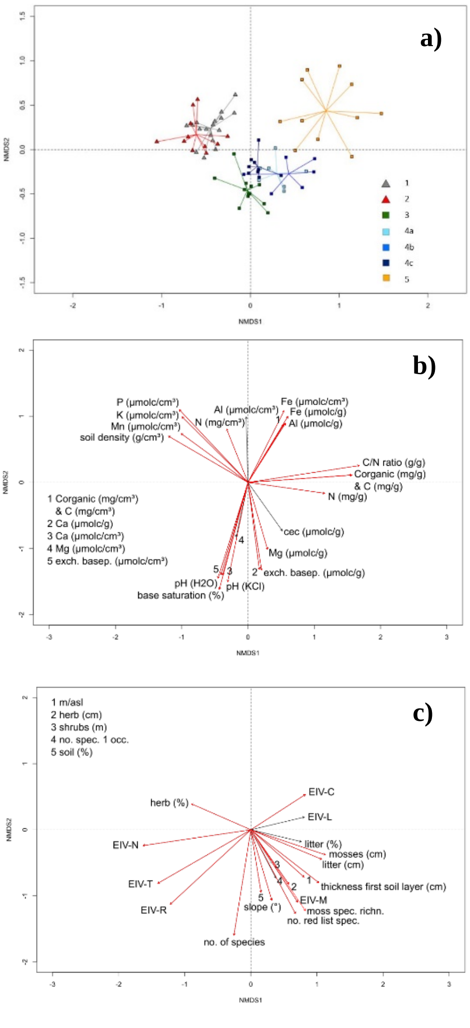

Fig. 2. a) NMDS ordination diagram ("ordi-spider" style) with axes 1 and 2 of all 73 vegetation plots classified to seven groups (symbol, colour). **b)** Soil-related (based on volume resp. dry weight) and **c)** structural and other environmental variables fitted onto the NMDS plot. Arrow colours indicate significance levels of correlation with the axes: grey, $p < 0.05$; black, $p < 0.01$; red, $p < 0.001$. For explanation of numbers at arrowheads see variable names in the legend. Ion/element contents refer to dry soil (Ordination diagrams of axes 1 and 3 and axes 2 and 3 within the attachment: Suppl. E3–E4).

Abb. 2. a) NMDS-Ordinationsdiagramme der sieben Isopam-generierten Gruppen mit den Achsen 1 und 2 aller 73 klassifizierten Aufnahmen. **b)** Darstellung der Achsenkorrelationen der in das NMDS-Diagramm eingepassten bodenchemischen Variablen **c)** und Struktur- und anderen Umweltvariablen. Die Pfeilfarben zeigen Signifikanzniveaus der Korrelation mit den Achsen an: grau, $p < 0{,}05$; schwarz, $p < 0{,}01$; rot, $p < 0{,}001$. Zahlen am Ende einiger Pfeile ersetzen Variablennamen, die aus Platzgründen in die jeweilige Legende geschrieben wurden. Ionen-/Elementgehalte beziehen sich auf trockenen Boden. (Ordinationsdiagramme der Achsen 1 und 3 sowie der Achsen 2 und 3 im Anhang E3–E4).

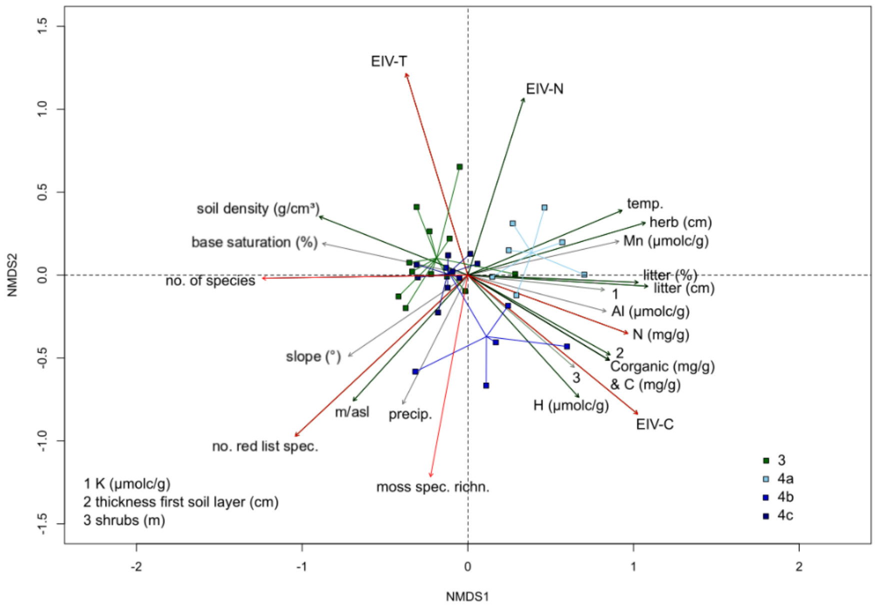

Fig. 3. NMDS "ordispider"-ordination diagram of axes 1 and 2 spanned of plots belonging to the Isopam classified groups 3 and 4 (*Eriophorum* fen grassland variants of *Carex panicea* (3), *Juncus acutiflorus* (4a), *Carex rostrata* (4b) and *Anthoxanthum odoratum* (4c)) with all statistically significant variables fitted as arrows. Arrow colours indicate significance levels of axis correlations: grey, $p < 0.05$; black, $p < 0.01$; red, $p < 0.001$. For explanation of variable numbers at some arrowheads see variable names in the legend. Ion/element contents refer to dry soil.

Abb. 3. NMDS-Ordinationsdiagramm ("ordispider") der Achsen 1 und 2, aufgespannt aus den Vegetationsaufnahmen der Isopam-klassifizierten Gruppen 3 und 4 (*Eriophorum*-Niedermoorgesellschaften mit *Carex panicea* (3), *Juncus acutiflorus* (4a), *Carex rostrata* (4b) und *Anthoxanthum odoratum* (4c)) mit allen statistisch signifikanten Variablen als Pfeile. Die Pfeilfarben stehen für Signifikanzniveaus der Korrelation mit den Achsen: grau, $p < 0{,}05$; schwarz, $p < 0{,}01$; rot, $p < 0{,}001$. Zahlen an Pfeilenden ersetzen Variablennamen aus Platzgründen, siehe Legende. Ionen-/Elementgehalte beziehen sich auf getrockneten Boden.

Out of 58 environmental variables, 45 correlated significantly with NMDS axes 1 and 2, 38 with axes 1 and 3, and 36 with axes 2 and 3 (Fig. 2, Supplement E3–4). The 15% best-fitting species in the ordination spread along axes 1 and 2 (Fig. 4). To the left (where *J. filiformis* meadows clustered) grasses and herbs of mesic to moist grassland assembled, such as *Phleum pratense*, *Lolium perenne*, *Festuca pratensis*, *Bellis perennis*, *Taraxacum* sect. *Taraxacum* and *Trifolium pratense*. At the bottom (where *E. angustifolium* groups 3 and 4 clustered) were some bryophytes together with *Epilobium hirsutum*, *Veronica beccabunga* and *Triglochin palustris*. To the right (featuring group 5, *E. angustifolium-Sphagnum fallax* fen grassland) various *Sphagnum* species and some other bryophytes as well as *Eriophorum vaginatum*, *Dryopteris carthusiana* and *Galium saxatile* were the most pronounced species. The first axis reflected a gradient of retarded mineralization or peat accumulation and decreasing nutrient availability (C, C/N, negative soil density), the second of increasing acidity and decreasing base-saturation (pH, Ca, CEC, Mg, Al, Fe). Distribution patterns in the space spanned by axes 1 and 3, and 2 and 3 (Supplement E3–4), were much less clear, hardly interpretable and not detailed here.

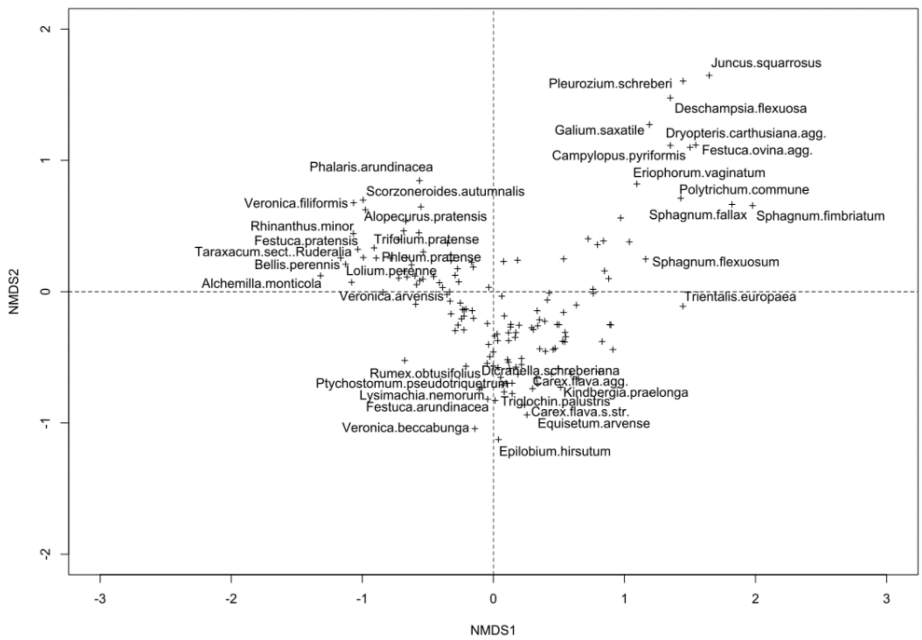

Fig. 4. NMDS ordination diagram with axes 1 and 2 of all 159 species, with 15% most-fitting species labelled. The position of some names was slightly modified to avoid overlap.

Abb. 4. NMDS-Ordinationsdiagramme der Achsen 1 und 2 aller 159 Arten, davon die 15 % am besten zur Ordination der Vegetationsaufnahmen (Abb. 2) passenden mit Pflanzennamen versehen. Die Position einiger Namen wurde aus Gründen der Lesbarkeit leicht verändert.

4.3 Variables and correlations

According to Shapiro-Wilk and Levene’s tests only species richness and exchangeable cations were normally distributed. ANOVA revealed significant differences regarding the two variables between the seven groupings (plant communities). Post-hoc Tukey HSD test revealed further significant differences between groupings, discussed hereafter. Most significant differences were found between group 3 (*Eriophorum angustifolium* grassland with *Carex panicea*) and either of the following: *Juncus filiformis* meadows (groups 1 and 2) as well as *E. angustifolium-Sphagnum* fen grassland (group 5) (Supplement S1). All *E. angustifolium* fen grassland communities showed significant differences in many variables against the *J. filiformis* groupings, but also group 5 against all other communities. In general, ion content-related variables showed more significant differences between communities than variables related to the soil texture and density. One of the variables that most often differed significantly between plant communities was species richness (both with the total number of 225 taxa or with the reduced number of 159 taxa), which was lower in the *J. filiformis* meadows (groups 1 and 2), and *E. angustifolium-Sphagnum* fen grassland (group 5) than in *E. angustifolium* grassland with *Carex panicea* (group 3) and *E. angustifolium* grassland with *Agrostis canina* (group 4). The C/N ratio differed significantly between the *J. filiformis* meadows (groups 1 and 2) and die *E. angustifolium* grassland communities (groups 3–5). The Ellenberg indicator value (EIV) for temperature was significantly different between the *E. angustifolium-Sphagnum* fen grassland (group 5) and

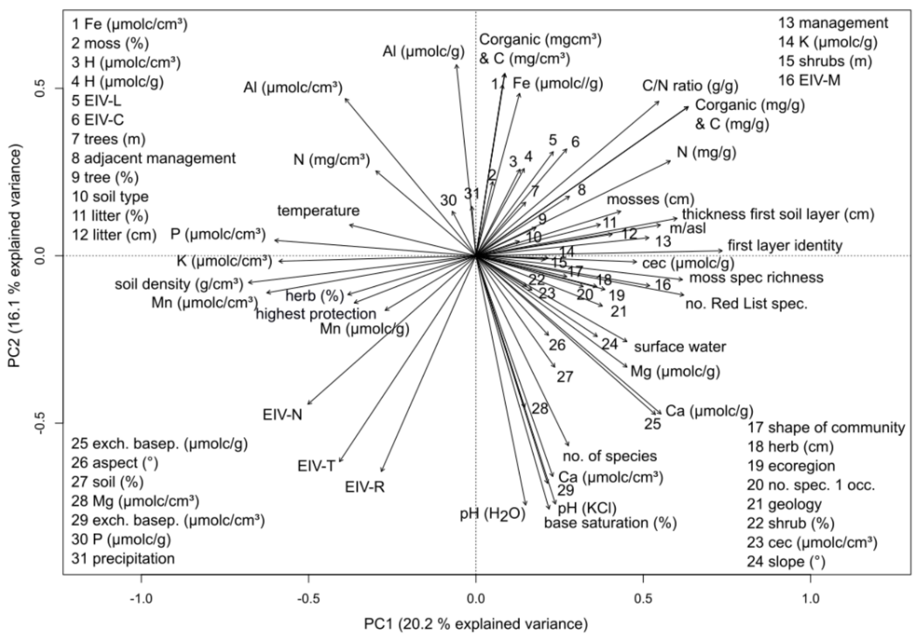

Fig. 5. PCA ordination plot (axes 1 and 2) of all 67 numerical and categorial variables. The closer the arrows of the variables are to axes 1 and 2, the more variance they explain. The closer together the arrows of the variables are, the more they correlate with each other. Arrows of variables pointing in the opposite direction are negatively correlated. Variables that did not fit due to limited space are numbered at the end of the arrows and written as a legend in the corners of the diagram. Ion/element contents refer to dry soil.

Abb. 5. PCA-Plot aller 67 numerischen und kategorialen Variablen, die für die erste und zweite PCA-Achse erfasst wurden. Je näher die Pfeile der Variablen an den Diagrammachsen 1 und 2 liegen, desto mehr Varianz erklären sie. Je näher sie beieinander liegen, desto mehr sind sie miteinander positiv korreliert. Pfeile von Variablen, die in die entgegengesetzte Richtung zeigen, sind negativ korreliert. Variablen, die aus Platzgründen nicht ausgeschrieben sind, sondern am Ende der Pfeile nummeriert, werden in einer Legende in den Ecken des Diagramms erläutert. Ionen-/Elementgehalte beziehen sich auf trockenen Boden.

the others, being lower in the first. Among the categorial variables, significant differences between communities were most often found for topsoil identity, which was more often peat in the *E. angustifolium* grassland communities (groups 3–5), going along with a less-intense land use and the presence of above-ground water (Supplement S1).

Variables negatively correlated with the first PCA axis, explaining 20.2% of the variance, were chiefly P, K^+, Mn^{2+}, soil density and vegetation (herb) cover (Fig. 5). The most important positively correlated variables were C/N ratio, C_{org}, C_{total}, N and CEC, height of bryophyte layer, topsoil depth, litter cover and thickness, and elevation. Positively correlated variables with the second PCA axis were Fe^{2+} and Al^{3+} (µmol/g) ion concentration and C_{org}, C_{total} and Al^{3+} (all µmol/cm³). Negatively correlated were pH (both H_2O and KCl), base saturation, CEC, Ca^{2+} and Mg^{2+} contents (all µmol$_c$/cm³), and species richness.

4.4 Species richness and rarity

We found 125 taxa of herbaceous plants and 34 taxa of bryophytes (= 159 species) occurring at least twice in the surveyed plots in the Süderbergland (NRW). With singletons and woody plant species, a total of 225 taxa was found (Table 4). Correlations were calculated using the 159 species dataset. Species numbers per 16 m² plot varied widely between 11 and 57. Most common were species numbers of 31 to 40. The most species-rich plots were observed in the Rothaar Mountains, chiefly around Winterberg. High mean species numbers were found in relevés of community types of transitory floristic character (*Eriophorum angustifolium* grasslands with *Agrostis canina*, group 4). A total of 43 species of the Red list of NRW were spotted (Table 4, Supplement E5), of which *Sphagnum contortum* is categorized as Critically Endangered, and another ten species as Endangered (six mosses and four vascular plant species). In one particular plot (no. 62) as many as 15 threatened species (all Red list threat categories) were observed.

All six relevés exhibiting a species count of 50 or more were exclusively situated within *E. angustifolium* grassland variants with *Carex panicea* (group 3), *Carex rostrata* (4b) or *Anthoxanthum odoratum* (4c) (Fig. 6, Table 4). The eight plots with species numbers below 20 belonged with a single exception to *Sphagnum*-rich *E. angustifolium* fen grassland (group 5). Mean species numbers were highest in the groups 3 and 4c and lowest in group 5 (Fig. 6, Table 4), the latter being the only plant community with significantly different (lower) species numbers than all others. The NMDS diagram (Fig. 2) delineates the richness pattern of the communities, wherein there is a notable decline in species numbers towards group 5 and the two *J. filiformis* communities (groups 1 and 2), while conversely, an increase in species richness is observed in the direction of groups 3, 4a, 4b, and 4c. Corresponding to the geographical distribution of the relevés (Fig. 1) where species-rich plots occurred mostly in the east of the study area around Winterberg, and most species-poor plots in the central west, near Hilchenbach and Olpe, we found a slightly positive correlation of species richness per plot with elevation. Slope and elevation were significantly different between the *J. filiformis* grasslands and (most of) the *E. angustifolium* grasslands, the former occurring on gentle slopes at lower elevations. Both slope and elevation were positively correlated with Red list species numbers which in turn was strongly correlated with species richness. Both increased with NMDS axes 1 and 3 and decreased with axis 2 (Fig. 2, Supplement E3–E4). Red list species numbers correlated strongly negatively with P, K^+ and Mn^{2+} concentrations and slightly so with nitrate concentrations. Dunn's test revealed significant

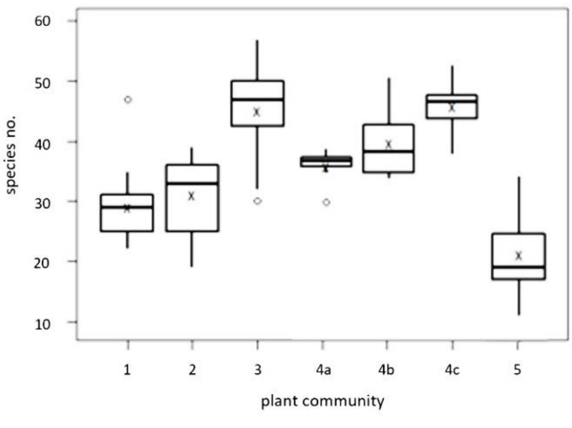

Fig. 6. Boxplot of species richness of the seven communities classified by Isopam. Mean values of species richness indicated by x in the boxes.

Abb. 6. Boxplot zur Verteilung des Artenreichtums der ermittelten Pflanzengesellschaften. Mittelwerte als x in den Kästen.

Table 4. Arithmetic means (standard deviation in parentheses), minimum-maximum values and total species richness per plant community. Lowest and highest mean values in **bold**. For the number of NRW Red list species, genus records of *Fossombronia* were included because all species of this genus are red-listed in NRW (in contrast to *Riccardia* spec.).

Tabelle 4. Arithmetische Mittelwerte (Standardabweichung in Klammern), Minimum-Maximum-Werte und Gesamtartenzahlen je Pflanzengesellschaft. Niedrigste und höchste Mittelwerte fettgedruckt. Bei der Anzahl der Rote-Liste-Arten wurden Gattungsnachweise von *Fossombronia* berücksichtigt, da alle Arten der Gattung in der Roten-Liste NRW verzeichnet sind, dagegen *Riccardia* spec. nicht.

Group no.	**1**	**2**	**3**	**4a–c**	**4a**	**4b**	**4c**	**5**	**1–5**
	***Juncus filiformis* meadows**		**Fen grasslands with *Eriophorum angustifolium***						
Plant community	Variant with *Agrostis capillaris*	Variant with *Taraxacum* and *Lysimachia*	Variant with *Carex panicea*	Variants with *Agrostis canina*	Variant with *Juncus acutiflorus*	Variant with *Carex rostrata*	Variant with *Anthoxanthum odoratum*	Variant with *Molinia* and *Sphagnum*	
Mean species number	29 (6)	31 (6)	45 (8)	41 (6)	36 (3)	40 (6)	**46 (5)**	**21 (7)**	34 (11)
Min-max species numbers	22–47	19–39	29–57	29–53	29–39	34–50	38–53	11–34	11–57
Total species number	91	85	129	151	89	100	111	83	225
Mean bryophyte spec. richness	2 (1)	**1 (1)**	8 (3)	9 (3)	6 (3)	**11 (1)**	9 (3)	6 (3)	6 (4)
Min-max bryophyte species	1–5	0–4	1–13	3–14	3–11	10–14	4–14	1–9	0–14
Total number of bryophyte spp.	7	4	28	38	20	28	30	23	54
Mean Red list species number	**2 (1)**	**2 (1)**	8 (2)	7 (3)	5 (1)	**9 (3)**	8 (2)	5 (2)	5 (3)
Min-max Red list species	1–4	1–5	4–12	4–15	4–6	6–15	6–13	1–9	1–15
Total number of Red list species	13	9	28	31	10	25	25	16	43
Red-listed bryophytes	3	0	10	14	3	12	12	5	20
Mean singleton number	**0.4 (0.6)**	0.5 (0.8)	1.4 (1.4)	1.1 (1.0)	1.3 (1.0)	**1.5 (1.0)**	0.8 (0.8)	0.9 (0.9)	1 (1)
Min-max singleton numbers	0-2	0-2	0–5	0–3	0–3	0–3	0-2	0–3	0–5
Total number of singletons	7	6	17	25	9	9	7	9	64

differences between the communities (Supplement S1). The NMDS diagrams show increase-ing P, K^+ and Mn^{2+} along the first axis towards the *J. filiformis* communities, while the Red list species numbers increase in the opposite direction, towards *E. angustifolium* communities (Fig. 2). Red list species numbers were moreover correlated with EIV-M (Fig. 5).

4.5 Variation in established environmental data among communities

The lowest pH values (both H_2O and KCl) were found in the *Sphagnum*-rich *Eriophorum angustifolium* fen grassland (group 5), in contrast to the fen grasslands with *Carex panicea* (group 3) with highest pH values. The *Juncus filiformis* meadow variant with *Agrostis capillaris* (group 1) was slightly, though not significantly, more acid than the *J. filiformis* meadow variant of group 2.

As Al^{3+}, Fe^{2+} (and H^+) as well as C_{org} and C_{total} showed higher concentrations in more acid grassland, the highest ion values were found in group 5 (Supplement E7). Ion concentrations were lower in communities with soils of higher pH, where in contrast concentrations of Ca^{2+} and Mg^{2+} were high. These variables were correlated along the second PCA axis, explaining 16.1% of total variance (Fig. 5). The total exchangeable base pool ($\mu mol_c/cm^3$), base saturation and CEC ($\mu mol/cm^3$) showed the same trend, with the highest mean value in the *E. angustifolium* grassland with *Carex panicea* (group 3), followed by groups 4c and 4b (Supplement E7). The *E. angustifolium* fen grassland with *Sphagnum fallax* (group 5) had a significantly lower exchangeable base pool than all other communities except the *J. filiformis* meadows with *Agrostis capillaris* (group 1). The *E. angustifolium* grassland with *Carex panicea* (group 3) had a significantly higher exchangeable base pool than both *J. filiformis* meadow variants (groups 1 and 2). The variables base saturation, pH and exchangeable base pool were found to be increasing – towards group 3 – chiefly along axis 3 and less so along axis 1. The Ca^{2+} and Mg^{2+} concentrations, base saturation and exchangeable base pool were strongly positively correlated with the species richness (which decreased along NMDS axis 2; Fig. 2).

Above-surface water during the survey period wasn't observed in the *J. filiformis* meadow plots but in most communities of *E. angustifolium* grassland, with very wet conditions encountered in plots of the subtypes with *Carex panicea* (group 3), *Sphagnum fallax* (group 5) and *Juncus acutiflorus* (group 4a) (Supplement E6). Dunn's test revealed significant differences in this context, especially between *E. angustifolium* groups 3 and 4a versus the *J. filiformis* meadows (groups 1 and 2), which confirmed the impression in the field of generally higher soil water saturation in *E. angustifolium* than in *J. filiformis* communities.

EIV-N was highest in *J. filiformis* meadows with *Taraxacum* and *Lysimachia* (group 2) and lowest in the *Sphagnum*-rich *E. angustifolium* community (group 5). Where mean values of P, K^+ and Mn^{2+} were high, namely in the *J. filiformis* communities (Supplement E7), the herb layer was relatively high in size too. Variables related to the vegetation structure were correlated with P, K^+, Mn^{2+} and soil density along the first PCA axis which explained much of the variance in the data set (20.2%) (Fig. 5).

Variables correlated with the topsoil depth, such as litter cover and depth, EIV-M and elevation, were positively correlated with PCA axis 1 and with NMDA axis 1, with highest values in the *E. angustifolium* communities (Fig. 2 and 5). The surface soil observed in the plots of the *J. filiformis* meadows was a humid Ah (rich in organic matter), whereas in most plots of the *E. angustifolium* grassland communities with *Carex panicea* or *Anthoxanthum odoratum* (groups 3 and 4c) fen peat (nH) prevailed, and raised-bog peat (hH) mostly in group 5 but also in groups 4a and 4b (Supplement E6). Significant differences between the principal groups were confirmed by Dunn's test (Supplement S1). The topsoil depth correlated also with the C/N ratio and the amounts of C_{total}, C_{org} and N (mg/g).

The proportion of open ground was highest in the plots of the *E. angustifolium* grassland with *Carex panicea* (group 3) and lowest in the *J. filiformis* meadows of group 2. Together with low proportion of open ground, the *J. filiformis* meadows showed low mean values of litter cover and depth, and heights of the bryophyte and herb layers. In general, differences of vegetation structure variables were most pronounced between the *J. filiformis* meadows and the *E. angustifolium* grassland (Supplement S1).

The sediment underlying the *J. filiformis* meadows was chiefly Holocene colluvium, while most *E. angustifolium* grasslands occurred over Middle Devonian rock (Supplement E6). The *J. filiformis* communities were most often found in wet depressions, while many plots of the *E. angustifolium* grassland with *Carex panicea* were located around headwaters (Fig. 7). The land use type adjacent to the areas with *J. filiformis* was mainly meadow, while the *E. angustifolium* grassland was often surrounded by woody vegetation including conifer plantations (Supplement E6). Wetter plots, along with higher litter cover and depth, and with higher moss and herb layers, were often managed to a lesser extent, or sometimes not at all (Supplement E6). Kruskal-Wallis and Dunn's tests showed significant differences in management between some of the *E. angustifolium* grassland groupings and the *J. filiformis* meadows (Supplement S1). The latter included most plots with relatively intense management, while abandoned areas were observed chiefly in the *E. angustifolium* fen grassland groups of 3, 4a and 4b (Supplement E6).

Soil moisture (represented in the present study by the variable soil moisture saturation) and soil acidity (pH) turned out to be the principal abiotic environmental factors. As mentioned above a number of other variables were related to, or derived from them, e.g., management options of the sites depend on soil moisture. Acidity correlated with the concentrations of various ions (Fig. 2 and 5). The gradients and the plant communities arranged along them are shown in an ecogram (Fig. 8).

5. Discussion

5.1 Syntaxonomy

We found marked differences in species composition between the communities of *Juncus filiformis* meadows and those of the *Eriophorum angustifolium* fen grasslands. The classification and the resulting characteristic species groups suggest that the two *J. filiformis* groupings belong to the *Juncetum filiformis*, an association of the *Calthion palustris* (wet grassland communities of the order *Molinietalia caeruleae* and the class *Molinio-Arrhenatheretea*) (OBERDORFER 1983, POTT 1995, BURKART et al. 2004, LEUSCHNER & ELLENBERG 2017). The communities with *E. angustifolium* were more heterogeneous but despite being in part transitory to the *Calthion* clearly belong to the order *Caricetalia fuscae*, which comprises acidic sedge-moss fens in the class *Scheuchzerio palustris-Caricetea fuscae* (PHILIPPI 1977, DIERßEN & DIERßEN 2001, PREISING et al. 2012). The groupings 3 (with *Carex panicea*) and 4 (with *Agrostis canina*, comprising subgroups 4a–c) represent the *Caricetum nigrae* in the *Caricion fuscae* alliance (moderately base-poor fen vegetation), while group 5 (with *Sphagnum fallax*) differs consistently in species composition (peat-mosses abundant and transgressive *Molinietalia* species almost absent) and ecology

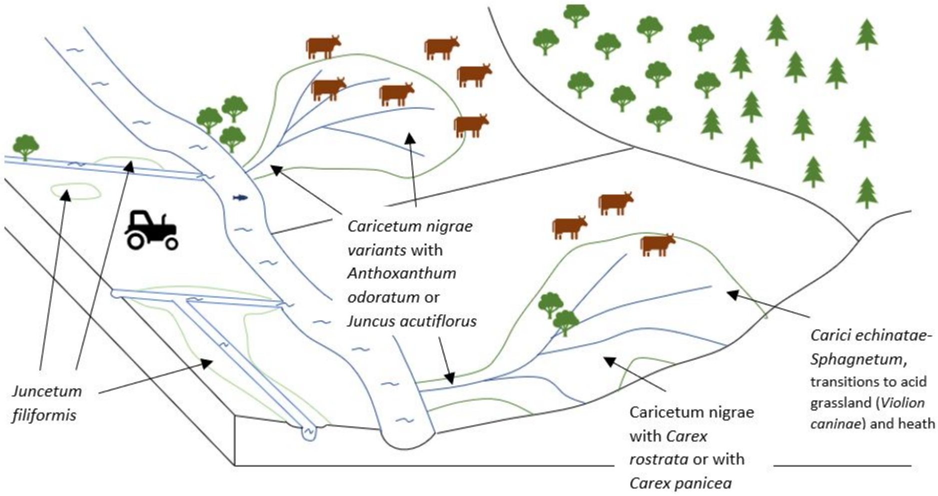

Fig. 7. Geomorphological location of the plant communities approximated in the context of an upland valley in the Süderbergland. The more typical forms of the *Caricetum nigrae* (groups 3 and 4b) occur at nutrient poor headwaters with low disturbance level (lower right part of figure). The *Carici echinatae-Sphagnetum* (group 5) grades into acid grassland and wet heath (*Calluno-Ulicetea/Nardetea strictae*) on the slightly drier slopes above the springheads. Further down in headwater areas with higher nutrient loads or more disturbed by livestock (upper right part of figure), taller vegetation of the *Caricetum nigrae* variants with *Anthoxanthum odoratum* (group 4c) or *Juncus acutiflorus* (group 4a) transitory to *Calthion* meadows may be found. The *Juncetum filiformis* (groups 1 and 2) occurs mostly independently from the other communities on flat, once-mown hay meadows. Which of the two *Juncetum filiformis* variants occurs depends on the nutrient conditions and water quality.

Abb. 7. Darstellung der ungefähren Lage der gefundenen Pflanzengesellschaften im Kontext eines Mittelgebirgstals im Süderbergland. Die typischeren Formen des *Caricetum nigrae* (Gruppen 3 und 4b) treten im oberen Quellbereich auf, wo das Wasser nährstoffarm ist und der Störungseinfluss gering (unterer rechter Teil der Abb.). Das *Carici echinatae-Sphagnetum* (Gruppe 5) bildet den Übergang zu Borstgrasrasen und Heidefragmenten (*Calluno-Ulicetea/Nardetea strictae*) auf den etwas trockeneren Kuppen angrenzend zu Quellmulden. Weiter unten im Quellbereich, bei höherer Nährstofflast oder generell bei hohem Störungsgrad durch Vieh (oberer rechter Teil der Abb.), kann eine etwas höherwüchsige Niedermoorvegetation des *Caricetum nigrae* mit den Varianten von *Anthoxanthum odoratum* (Gruppe 4c) oder *Juncus acutiflorus* (Gruppe 4a) im Übergang zum *Calthion* auftreten. Das *Juncetum filiformis* (Gruppen 1 und 2) kommt meist unabhängig von den anderen Gesellschaften auf flachen einschürigen Mähwiesen vor. Welche Ausprägung des *Juncetum filiformis* vorkommt, hängt von den lokalen Nährstoff- und Wasserbedingungen ab.

(very poor in nutrients and more marked acidity); it thus forms part of the alliance *Sphagno-Caricion canescentis* (pronouncedly acid nutrient-poor fen vegetation). European fen vegetation has been revised recently (PETERKA et al. 2016). The authors found the two alliances under discussion distinguishable in species composition in that the *Caricion fuscae* is characterized chiefly by *Viola palustris* and *Agrostis canina*, and the *Sphagno-Caricion canescentis* by *Sphagnum recurvum* agg. (to which *S. fallax* belongs) and *Polytrichum commune*. According to the synoptic table provided by PETERKA et al. (2016) further differential species between the two alliances (only species mentioned which occur in the dataset of our present study and with more than 25% constancy in the respective synoptic table column of the European-wide classification) are *Calliergonella cuspidata*, *Valeriana*

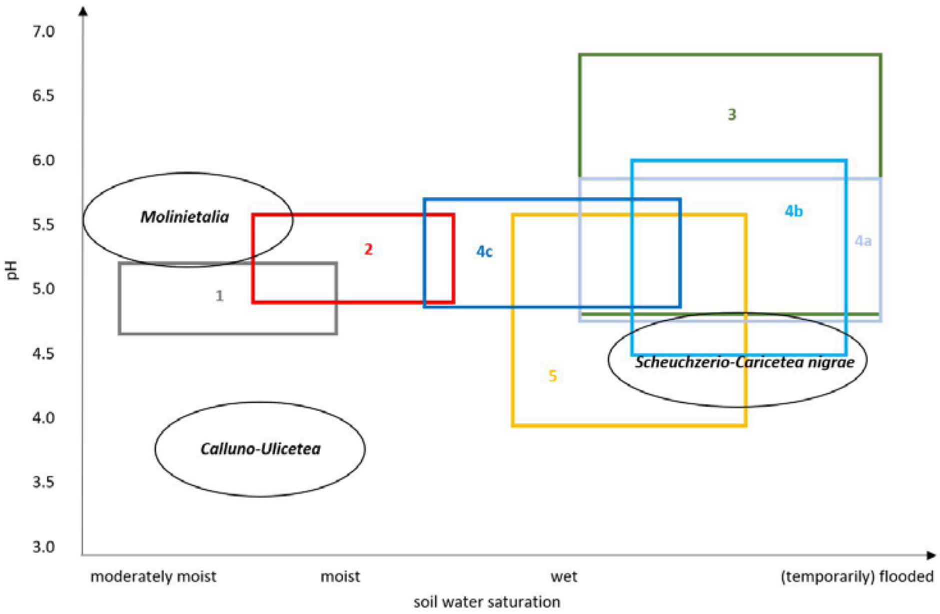

Fig. 8. Ecogram of the classified plant communities with respect to the most important variables found: soil water saturation and pH. The labelling along the horizontal axis was generated according to the Ellenberg moisture values (EIV M) and the soil moisture observed in the field. The vertical axis shows the pH value range as actually measured in the field. Black encircled names of vegetation classes in ellipses show approximate preferences with respect to the variables as stated in the literature. 1, *Juncus filiformis* meadows, variant with *Agrostis capillaris*; 2, *J. filiformis* meadows, variant with *Taraxacum* and *Lysimachia*; 3, *Eriophorum angustifolium* fen grassland, variant with *Carex panicea*; 4a, *E. angustifolium* fen grassland, variant with *Juncus acutiflorus*; 4b, *E. angustifolium* fen grassland, variant with *Carex rostrata*; 4c, *E. angustifolium* fen grassland, variant with *Anthoxanthum odoratum*; 5, *E. angustifolium* fen grasslands, variant with *Molinia* and *Sphagnum*.

Abb. 8. Ökogramm der Pflanzengesellschaften in Bezug auf die wichtigsten gefundenen Variablen: Bodenwassersättigung und pH-Wert. Die Beschriftung entlang der x-Achse resultiert aus den Ellenberg-Feuchtewerten und der im Feld vorgefundenen Bodenfeuchte. Die y-Achse zeigt den in den Probeflächen tatsächlich gemessenen pH-Wert-Bereich. Schwarz umrandete Ellipsen mit Namen der Vegetationsklassen zeigen angenähert die Präferenz der Klassen gemäß den in der Literatur angegebenen Variablen. Abkürzungen: 1, *Juncus filiformis*-Feuchtwiese, Variante mit *Agrostis capillaris*; 2, *J. filiformis*-Feuchtwiese, Variante mit *Taraxacum* und *Lysimachia*; 3, *Eriophorum angustifolium*-Niedermoor, Variante mit *Carex panicea*; 4a, *E. angustifolium*-Niedermoor, Variante mit *Juncus acutiflorus*; 4b, *E. angustifolium*-Niedermoor, Variante mit *Carex rostrata*; 4c, *E. angustifolium*-Niedermoor, Variante mit *Anthoxanthum odoratum*; 5, *E. angustifolium*-Niedermoor, Variante mit *Molinia* und *Sphagnum*.

dioica, *Carex panicea*, *C. nigra* and *C. echinata* in the *Caricion fuscae*, and *Eriophorum vaginatum* in the *Sphagno-Caricion canescentis*. The differential value of these taxa at European scale is consistent with their preferences in our dataset.

At the association level, group 5 matches the *Carici echinatae-Sphagnetum* Soó 1944 but the differences to the *Sphagno recurvi-Caricetum rostratae* Steffen 1931 (which can be synonymized with the *Carici canescenti-Agrostietum caninae caricetosum rostratae* Tüxen 1937) are not very pronounced (see HÁJEK & HÁJKOVÁ 2011: 678–681, 691). The latter occurs chiefly in dominance stands of tall sedges such as *Carex rostrata* (KOSKA & TIMMERMANN 2004, HÁJEK & HÁJKOVÁ 2011). Our records from the Süderbergland show that the *Carici echinatae-Sphagnetum* differs in its higher frequency of (wet) heathland species such as *Molinia caerulea*, *Deschampsia flexuosa*, *Galium saxatile*, *Nardus stricta*, *Pleurozium schreberi* and *Juncus squarrosus* from other *Sphagno-Caricion canescentis* associations such as the *Sphagno recurvi-Caricetum rostratae* (as shown by HÁJEK & HÁJKOVÁ 2011, synoptic table). The *Carici echinatae-Sphagnetum* is widespread in temperate and boreal Europe but in Germany it has frequently been merged with the *Caricetum fuscae* under that name (e.g., DIERßEN & DIERßEN 2001, RENNWALD et al. 2002b) or under the name of *Carici canescentis-Agrostietum caninae* Tüxen 1937 (e.g., KOSKA & TIMMERMANN 2004, PREISING et al. 2012). Accordingly, the alliances *Caricion fuscae* and *Sphagno-Caricion canescentis* of moderately base-poor nutrient-containing vs. pronouncedly nutrient- and base-poor *Sphagnum* fen vegetation, respectively, remained undistinguished and were often lumped together as *Caricion canescenti-nigrae* (e.g., KOSKA & TIMMERMANN 2004, PREISING et al. 2012) which was synonymized under the name of *Caricion fuscae* by MUCINA et al. (2016). In a hierarchical synoptic view, the syntaxonomy of the wet meadow and fen plant communities presented in this paper reads as follows:

Cl.: *Molinio-Arrhenatheretea* Tx. 1937

  Ord.: *Molinietalia caeruleae* Koch 1926

    All.: *Calthion palustris* Tx. 1937

      Ass.: *Juncetum filiformis* Tx. 1937

Cl.: *Scheuchzerio palustris-Caricetea fuscae* Tx. 1937

  Ord.: *Caricetalia fuscae* Koch 1926

    All.: *Caricion fuscae* Koch 1926

      Ass.: *Caricetum nigrae* J. Braun 1915

    All.: *Sphagno-Caricion canescentis* Passarge (1964) 1978

      Ass.: *Carici echinatae-Sphagnetum* Soó 1944

The names *Caricion fuscae* Koch 1926 and *Sphagno-Caricion canescentis* Passarge (1964) 1978 have been proposed for conservation (nom. conserv. propos.; MUCINA et al. 2016). The name *Caricetum nigrae* J. Braun 1915 has been mutated from the original *Caricetum goodenovii* Braun 1915. Mutations of the epithet *fuscae* to *nigrae* have not been carried out to retain the nomenclature of the EuroVegChecklist adopted by MUCINA et al. 2016 (see BERGMEIER 2020).

5.2 *Juncus filiformis* meadows

Distribution patterns in the surveyed sites reveal that the *Juncetum filiformis* occurs chiefly in gently inclined or flat terrain in shallow depressions with high groundwater level or stagnating water, waterlogged especially in spring. They have commonly been used as meadows for hay-making (Fig. 7 and 9c). Among the diagnostic species (against *Eriophorum angustifolium* communities) generalist meadow grasses and herbs prevail, found together with numerous indicator species of mesic to wet grassland forming herb-rich vegetation including *Trifolium pratense*, *T. repens*, *Ajuga reptans*, *Ranunculus acris*, *R. repens*, *R. flammula*, *Rumex acetosa*, *Cardamine pratensis*, *Lychnis flos-cuculi*, *Filipendula ulmaria* and *Myosotis nemorosa*. The *Juncetum filiformis* with *Agrostis capillaris* (group 1) differs in appearance by its more pronounced small sedges, rushes and low grasses (especially *Festuca rubra*) from group 2, which appeared more colourful and richer in insect-pollinated plants (Fig. 9a–9c). In the latter group, taller herbs and grasses predominate and the smaller *J. filiformis* occurs in a sublayer.

Among the two variants of the *Juncetum filiformis* classified above, the variant named after *Agrostis capillaris* tends to be characteristic of drier and more nutrient-deficient habitats than the typical variant. EIV-N values are lower, the C/N ratio wider and the phosphate, K+ and CEC lower (Supplement E7). In floristic composition this is mirrored in the higher constancies of *Agrostis capillaris*, *Luzula campestris* and *Carex pallescens*, and the lower frequencies of *Caltha palustris*, *Trifolium repens* and the tall grasses *Alopecurus pratensis* and *Festuca pratensis*. In contrast, the variant differentiated among others by *Lysimachia nummularia* and *Equisetum palustre* occurs in ground-water influenced gley soil, confirming observations by KLAPP (1965), NOWAK (1983) and OBERDORFER (1983). In contrast to KLAPP (1965), our study shows the variant with the wetter soil occurs on more nutrient-rich soil, with taller and more productive vegetation, than the variant with *Agrostis capillaris* on drier soils.

In the Süderbergland, the *Juncetum filiformis* is well-developed on hay-meadows with many *Molinio-Arrhenatheretea*, *Molinietalia* and *Calthion* species (Fig. 9a–9c). Confirmed by fairly high EIV-N values and by our own measures of narrow C/N ratio as well as high values of phosphate and other nutrients such as K^+ our findings support the phytosociological classification of the *Juncetum filiformis* as a moderately nutrient-demanding *Calthion* community. It appears that most *Juncus filiformis*-rich vegetation records of the past decades have been *Calthion* meadows (NOWAK 1983, BURKART et al. 2004, NEITZKE 2011, STURM et al. 2018). In contrast, older historical data show *J. filiformis* as typical constituent in both *Calthion* (TÜXEN 1937, OBERDORFER 1938) and *Caricetalia fuscae* meadows (JONAS 1933, PREISING et al. 2012). This phytosociological ambivalence has repeatedly prompted discussions about its value as character or differential species (OBERDORFER 1983, PEUKERT 1990, POTT 1995, RENNWALD et al. 2002b, BURKART et al. 2004). In fact, we found *J. filiformis* in *E. angustifolium* fen meadows of the *Caricion fuscae* but only in few plots and with low overall constancy (Fig. 9d). The phytosociological shift appears to be chiefly due to the loss of extensive fen grasslands with unimpaired water regime in the previous century. TÜXEN (1937) remarked that *J. filiformis* becomes a dominant species after drainage of poor fens. PHILIPPI (1963) and STEINER (1992) noted that *J. filiformis* increases in vegetation with increasing elevation, perhaps due to reduced competitive ability of this low-growing species by taller plants in short vegetation periods. *J. filiformis* is among the first wet-meadow plants to shoot in spring (SCHNEDLER 1983). Similar low-competitive conditions occur in late-mown depressions flooded in early spring. The ecological preferences of *J. filiformis* are thus currently better supported in non-intensively used once (to twice-) cut hay-meadows than in present-day remnants of heavily disturbed *Caricetum nigrae* fen grasslands. Such hay-meadows are a typical habitat of the *Juncetum filiformis* in our South Westphalian study area and elsewhere (NOWAK 1983, SCHWABE 1987, BURKART et al. 2004).

To summarize what can be concluded from our findings and literature, *J. filiformis* has been a characteristic species and indicative of once widespread, today largely mountain restricted, little disturbed *Caricetum nigrae* natural fenland and of small-scale secondary mires (KLAPP 1965, NOWAK 1983, BAUMANN 2000). Fen grasslands which are severely disturbed through trampling appear to be degenerative or marginal habitats for *J. filiformis*. This also applies to pioneer sites on artificial lake shores, where the species also occurs (SCHWABE 1987 and own observations). Most probably in the course of the last century,

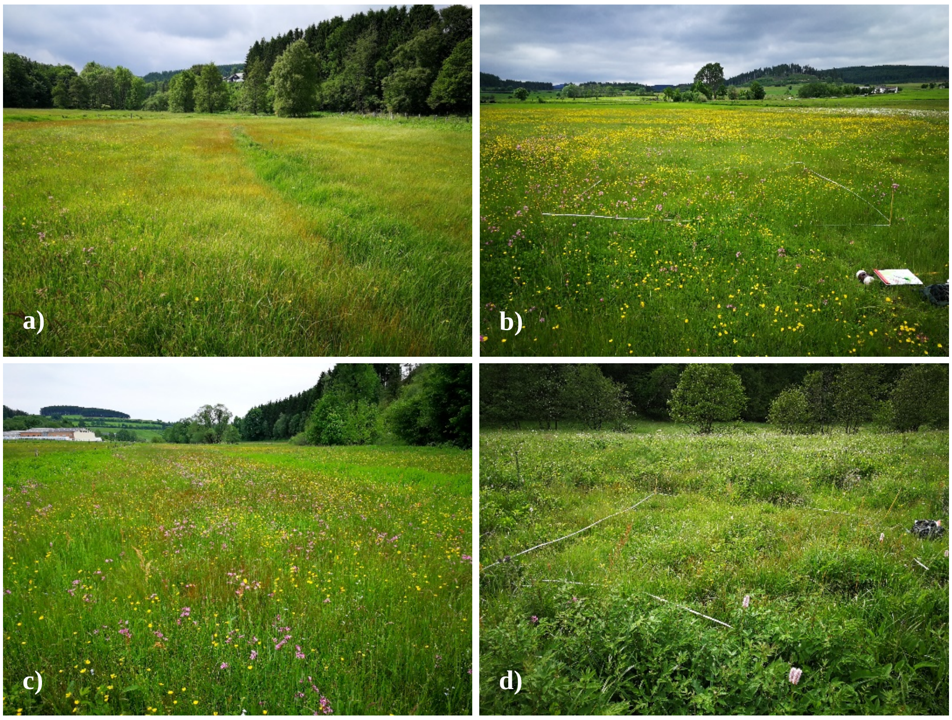

Fig. 9. a) Extensive *Juncetum filiformis* meadow represented by its variant with *Agrostis capillaris*. The picture shows the site of relevé 38 (NSG Irrgeister) north of Winterberg-Grönebach. The brownish-tinged *Juncus filiformis* is recognizable within the meadow here dominated chiefly by small sedges. The meadow is rather low in height, homogeneous and relatively species-poor. **b)** In general, the *Juncetum filiformis* – here represented by the variant with T*araxacum* and *Lysimachia* – occurs in shallow depressions in meadows, here in relevé 5 (upper part of NSG Brühnetal), south of Medebach-Hooren. **c)** Extensive hay-meadow of the *Juncetum filiformis* variant with *Taraxacum* and *Lysimachia* in the plot of relevé 24 (NSG Irrgeister) west of Winterberg-Hildfeld. Compared to the *Juncetum filiformis* variant with *Agrostis capillaris*, the vegetation is taller and more species-rich. **d)** *Juncus filiformis* (brownish-tinged) in a small patch in plot 23 of the *Caricetum nigrae caricetosum paniceae* (NSG Irrgeister) west of Winterberg-Hildfeld (Photos: D. Wolbeck, June 2019).

Abb. 9. a) Ausgedehnter Wiesenbestand des *Juncetum filiformis*, Variante mit *Agrostis capillaris*. Das Foto entstand im Bereich der Vegetationsaufnahme Nr. 38 (NSG Irrgeister) nördlich Winterberg-Grönebach. *Juncus filiformis* ist kenntlich am Braunton zwischen den hier überwiegenden Sauergräsern. In diesen Bereichen ist die Vegetation eher niedrig, homogen und vergleichsweise artenarm. **b)** Das *Juncetum filiformis* – hier vertreten durch die Variante mit *Taraxacum* and *Lysimachia* – kommt oft in Wiesenmulden vor, wie hier in Vegetationsaufnahme Nr. 5 (oberes NSG Brühnetal), südlich Medebach-Hooren. **c)** Großflächige Mähwiese des *Juncetum filiformis* in der Variante mit *Taraxacum* und *Lysimachia* im Bereich der Vegetationsaufnahme Nr. 24 (NSG Irrgeister) westlich Winterberg-Hildfeld. Verglichen mit der Variante mit *Agrostis capillaris* des *Juncetum filiformis* ist die Vegetation höher und artenreicher. **d)** *Juncus filiformis* (kenntlich am Braunton) in Vegetationsaufnahme Nr. 23 in kleinflächigem *Caricetum nigrae caricetosum paniceae* (NSG Irrgeister) westlich Winterberg-Hildfeld (Fotos: D. Wolbeck, Juni 2019).

J. filiformis shifted in terms of number of occurrences and abundance to wet sites in once-cut hay-meadows with *Calthion* vegetation with a traditional mowing regime, often derived from semi-drained small-sedge fens. While lowland to mid-altitude poor fens of low hemeroby with *J. filiformis* are largely lost long-since, meso-hemerobic wet *Juncetum filiformis* meadows themselves have been declining since decades through intensified grassland farming and pervasive conifer plantations (BERGMEIER & NOWAK 1988, DIERSCHKE & WITTIG 1991). In the Süderbergland such meadows are now almost restricted to nature conservation areas with appropriate non-intensive management.

5.3 *Eriophorum angustifolium* fen grasslands

The studied *Eriophorum angustifolium* communities differ considerably in species composition and richness. Typical differential species of the *Caricetum nigrae* subtype with *Carex panicea* such as *C. demissa*, *C. panicea* and *C. pulicaris* (Fig. 10b, c) are indicative of moderately base-containing soils and otherwise characteristic for rich fens (*Caricetalia davallianae* Klika 1934; PHILIPPI 1977, STEINER 1992, DIERßEN & DIERßEN 2001, OBERDORFER 2001, PREISING et al. 2012, PETERKA et al. 2016, STURM et al. 2018). The most similar plant community described in literature is the *Caricetum nigrae caricetosum paniceae* by TÜXEN (1937) which was verified for Hesse (FLINTROP 1990) while not specified by PREISING et al. (2012) and PHILIPPI (1977). In the Czech Republic, HÁJEK & HÁJKOVÁ (2011) restrict the *Caricetum nigrae* to fen vegetation of moderately base-containing soils. This narrowly conceived *Caricetum nigrae* corresponds to the *Caricetum nigrae caricetosum paniceae* of our study. Related with this subassociation in the Süderbergland are poorly developed peat layers (Fig. 10a), low N, C_{org}, C_{total} and relatively narrow C/N ratio. DIERSCHKE (2002) noted relatively thin peat layers at pH above 5 and STEINER (1992), in turn, that pH below 5.5 reduces microbial activity. In the Süderbergland, thin peat layers in the *Caricetum nigrae caricetosum paniceae* may also be an effect of the slope inclination with its swift-flowing spring-water, and locally of cattle-trampling. In our plots, the herb layer cover is positively correlated with phosphate content (Fig. 5), indicating P limitation, probably a result of phosphate immobility due to its adsorption to iron oxyde in oxygen-rich spring-water habitats (PATRICK & KHALID 1974, EGLOFF 1987).

Most *E. angustifolium* communities occur chiefly in sloped seepage sites of headwaters near perennial water springs (Fig. 7). The *Carici echinatae-Sphagnetum* (group 5), typically of brown colour and rich in small sedges and peatmosses, constitutes poor fen vegetation above springheads. Small patches of heath vegetation are often in close contact. The *Caricetum nigrae* with *Carex rostrata* (4b) was also found close to springs. Otherwise similar in appearance to the *Carici echinatae-Sphagnetum*, it is distinguished by taller plants such as *Cirsium palustre*. The *Caricetum nigrae caricetosum paniceae* (group 3), readily identifiable by its glaucous colour, is richer in small herbs and sedges including rare and red-listed species such as *Carex demissa*, *C. flava*, *C. pulicaris*, *Hydrocotyle vulgaris* and *Triglochin palustris*. In contrast to the afore-mentioned *E. angustifolium* communities the *Caricetum nigrae* groupings with *Juncus acutiflorus* (4a) and with *Anthoxanthum odoratum* (4c) occur usually in more extensive areas of waterlogged meadows in more slightly inclined terrain, often abandoned. Both communities resemble nutrient-rich wet meadows in their species richness and abundance of tall plants but differ in their frequency of small plants of nutrient-poor sites such as *Nardus stricta* and various bryophytes.

Fig. 10. a) Typical fen gleysol (Nassgley) profile at the plot of relevé 70 (Festerbach valley in the NSG Namenlose-Talsystem; *Caricetum nigrae caricetosum paniceae*) west of Winterberg. The surface soil is decomposed peat, overlying bleached (and oxidised) gleyed horizons. **b)** Typical *Caricetum nigrae caricetosum paniceae* close to an upland stream in plot no. 70 (Festerbach valley in the NSG Namenlose-Talsystem) west of Winterberg. The vegetation is fairly homogeneous and small-scale with small sedges such as *Carex panicea* and fen plants like *Menyanthes trifoliata* (large leaves in the foreground) indicating base-containing soil. **c)** *Carex pulicaris* and *Eriophorum angustifolium* in a plot of relevé 47 (NSG Kulturlandschaftskomplex Rehsiepen) south of Schmallenberg-Rehsiepen, *Caricetum nigrae caricetosum paniceae*. *Carex pulicaris* is a rare species indicating moderately base-rich conditions (Photos: D. Wolbeck, June and July 2019).

Abb. 10. a) Typisches Nassgley-Profil in Vegetationsaufnahme Nr. 70 (Festerbachtal im NSG Namenlose-Talsystem; *Caricetum nigrae caricetosum paniceae*) westlich Winterberg. Der erste Bodenhorizont hier ist vergleichsweise gut zersetzter Torf, gefolgt von ausgeblichenen (und oxidierten) G-Horizonten. **b)** Typisches *Caricetum nigrae caricetosum paniceae* in der Nähe eines Quellbaches in Vegetationsaufnahme Nr. 70 (Festerbachtal im NSG Namenlose-Talsystem) westlich Winterberg. Die Vegetation ist eher homogen und kleinflächig mit Kleinseggen wie *Carex panicea* und Niedermoorpflanzen wie *Menyanthes trifoliata* (große Blätter im Vordergrund), die auf einen hohen Basengehalt hindeuten. **c)** *Carex pulicaris* und *Eriophorum angustifolium* im Bereich der Vegetationsaufnahme Nr. 47 (NSG Kulturlandschaftskomplex Rehsiepen) südlich Schmallenberg-Rehsiepen, *Caricetum nigrae caricetosum paniceae*. *Carex pulicari*s ist eine seltene Art, die auf basische Bedingungen hinweist (Fotos: D. Wolbeck, Juni und Juli 2019).

Although the *Caricetum nigrae caricetosum paniceae* has relatively high cover of (wet) meadow species (typical of *Molinietalia* and *Molinio-Arrhenatheretea* and indicative of somewhat increased hemeroby), the cover of *Scheuchzerio-Caricetea* species is pronounced, and EIV-M values and surface water proportions are very high. All plots were either grazed by cattle or abandoned around small headwater streams. Apart from the high soil water content the *Caricetum nigrae caricetosum paniceae* has the highest pH (5.4) among the *E. angustifolium* communities. Accordingly, high Ca^{2+} and Mg^{2+} concentrations (and low Al^{3+}, Fe^{2+} and H^{+}) are reflected by high CEC, exchangeable base pool and very high base saturation (96.9%) (Supplement E7). This corresponds with HÁJKOVÁ & HÁJEK (2003) who found correlations between pH, Ca^{2+}/Mg^{2+} amounts and species richness (see also KOERSELMAN & VERHOEVEN 1995, WITTIG 1999).

In the Süderbergland typically located in sloped terrain, the *E. angustifolium* fen grassland vegetation is characterized by seepage conditions. We found surface water in several plots. Apart from being wetter, the *E. angustifolium* grasslands are nutrient-poorer than the *Juncetum filiformis* meadows, with lower mean EIV-N, phosphate and K^{+} values, and wider C/N ratio (Fig. 2, Supplement E7). Similarly wide C/N ratios as in our study (14–27), equivalent to humified humus (C/N = 20; BLUME et al. 2011), were measured by BAUMANN & TÄUBER (1999). Anoxic fens are phosphate-deficient (ROSENTHAL 1995, SCHEFFER 1995). Our results suggest that phosphate limitation can be assumed for the subtype with *Anthoxanthum odoratum* of the *Caricetum nigrae*, and K^{+} limitation possibly in the subtype with *Carex panicea* and in the *Carici echinatae-Sphagnetum*. DE MARS (1996) showed that phosphate deficiency increases in drained fens, as phosphate is linked to oxidised iron (SCHEFFER 1995).

Most species differentiating the *E. angustifolium* fen grasslands from the *J. filiformis* meadows in the Süderbergland are character species of the class *Scheuchzerio-Caricetea fuscae* and its subordinate syntaxa (PHILIPPI 1977, DIERßEN & DIERßEN 2001, OBERDORFER 2001, HÁJEK & HÁJKOVÁ 2011, STURM et al. 2018). In the context of fen habitats, the species richness and productivity of the *Caricetum nigrae* variants with *Agrostis canina* are rather high. Together with the *Caricetum nigrae caricetosum paniceae* they share fairly high constancies of *Molinietalia* species. However, higher EIV-R and lower EIV-N values characterize the habitats of the community variants with *Agrostis canina* as somewhat more acid and nutrient-poor. Soil parameters unanimously indicate more or less intermediate conditions between the *Caricetum nigrae caricetosum paniceae* and the *Sphagnum*-rich fens of the *Carici echinatae-Sphagnetum*. In our study area, *Sphagnum palustre* and *S. flexuosum* are restricted to the *Carici echinatae-Sphagnetum* and to the variants with *Agrostis canina* of the *Caricetum nigrae*. According to FLINTROP (1990) and BAUMANN (1996) peatmosses are typical of least affected small-sedge fens. In general, bryophytes are important indicators of microclimate and topsoil conditions (BLENK 1986, DIERßEN & DIERßEN 2001). In contrast to the *Carici echinatae-Sphagnetum* the *Caricetum nigrae* is more heterogeneous and, especially on grazing ground, characterized by a mixture of species typical of wet grassland (*Molinietalia*) and fen (*Caricetalia fuscae*) vegetation (WITTIG 1999, DIERßEN & DIERßEN 2001). The meso-hemerobic meadow species indicate more disturbance than commonly in the *Carici echinatae-Sphagnetum* (DIERßEN et al. 1985). The considerable proportion and cover of species of the *Molinietalia* and *Molinio-Arrhenatheretea* in all *E. angustifolium* communities except the *Carici echinatae-Sphagnetum* is not unusual for extensively grazed nutrient-containing fens (OBERDORFER 1983, PREISING et al. 2012), although DIERßEN et al. (1985) assumed that fens with high *Molinietalia* species proportions would hardly be preservable as mesotrophic fen habitat in the long run. Local-scale heterogeneity, as encountered in most *Caricetum nigrae* subunits, promotes plant immigration (DIERßEN 1980, STEINER 1992). Quite like abandonment, increasing nutrient availability through increased water-level variation may foster successional processes towards tall-sedge and tall-herb vegetation (BOLLER-ELMER 1977, STURM et al. 2018). Our findings confirm that in the *Caricetum nigrae* disturbance enhances species density and local richness, triggered through patterned nutrient supply and soil openings by cattle trampling (KLAPP 1965, DIERßEN 1980, STEINER 1992, DIERßEN & DIERßEN 2001). Even in historical records of the *Caricetum nigrae* (BÜKER 1942, PHILIPPI 1977) *Molinietalia* species were not uncommon, an effect amplified in drained areas (HÁJEK & HÁJKOVÁ 2011). In our dataset, both the *Caricetum nigrae caricetosum paniceae* and the association variants with *Agrostis canina* are species-rich, show high EIV-M values and in general fen- or bog-peat layers. Rare and specialized species occur, which are easily outcompeted elsewhere (RATHCKE & JULES 1993, HÁJKOVÁ & HÁJEK 2003, ESKILDSEN et al. 2015).

The *Caricetum nigrae* subunit with *Juncus acutiflorus* (Fig. 11a) with its species combination of *Molinietalia* and *Caricetalia fuscae* suggests transitory character between wet, moderately nutrient-rich meadows and moderately poor fens. Dominances of *Juncus acutiflorus* as in some of our plots have been related to nutrient- and oxygen-rich spring-water (BÜKER 1942, OBERDORFER 1983, 2001, SCHWABE 1987, VERBÜCHELN 1987, SPEIER 1999). This is in accordance with our findings in plots well supplied with water and higher EIV-N values than in the other two subtypes of the *Caricetum nigrae* with *Agrostis canina*. Together with other tall herbs and *Deschampsia cespitosa*, *Juncus acutiflorus* dominance may also indicate abandonment. This is not necessarily contradicted by our observations of considerable open ground proportions in the plots rich in *Juncus acutiflorus*. Patches of unvegetated soil may be due to sudden stocking density increase in sites which are eventually nevertheless undergrazed, or by variation in spring flow intensity. Through intensified cattle grazing or by introducing a rigorous cutting regime, a next step of hemeroby can be reached, when the *Juncus acutiflorus* variant of the *Caricetum nigrae* develops into a *Calthion* community (*Crepido paludosae-Juncetum acutiflori* Oberdorfer 1957; OBERDORFER 1983, DIERßEN & DIERßEN 2001). *Juncus acutiflorus* itself has been variously considered characteristic of the *Molinietalia* (as in our compositional computations) (OBERDORFER 1983) or of the *Caricion fuscae* (BRAUN 1915) where it occurs chiefly in disturbed sites (OBERDORFER et al. 1967). In the context of our study, we classify *Juncus acutiflorus* as differential species of a *Caricetum nigrae* variant on rather steep seepage slopes with pasturage management decreasing or ceased.

The subunit of *Carex rostrata* is differentiated by a bryophyte layer of considerable cover and species richness (Fig. 11b). *Sphagnum palustre* and *Chiloscyphus pallescens*/*polyanthos* are frequent. It has thick peat layers and is close in species composition to the *Carici echinatae-Sphagnetum*, but more productive, base- and species-rich. The frequency of the tall umbelliferous herb *Angelica sylvestris* is possibly an indicator of ongoing abandonment or insufficient management. The otherwise rather low proportion of *Molinietalia* species suggests lesser disturbance than in the other *Caricetum nigrae* fen grasslands with *Agrostis canina*. Similar compositional and structural features, namely high moss cover and low mean vegetation height, were found by HÜBSCHMANN (1967), NOWAK (1983) and BAUMANN (1996) for the typical subassociation of the *Caricetum nigrae*. We follow this phytosociological assignment. It is noteworthy – as it indicates relative habitat continuity –

Fig. 11. a) A stand of the *Caricetum nigrae* co-dominated by the tall-growing *Juncus acutiflorus* (group 4a) was found in plot 40 in the upper reaches of the Bibertal southeast of Rüthen. The plant community was found in this valley already by Verbücheln (1987). **b)** The *Caricetum nigrae* variant of *Carex rostrata* (group 4b), typically features a dominance of sedges and considerable bryophyte cover. The photo shows an area at plot no. 68 (NSG Hunau – Langer Rücken – Heidberg, Nasse Wiese) south of Schmallenberg-Bödefeld. This area had been investigated about 25 years ago by Eichhorn (1997) and Poth (1995) who found similar vegetation. **c)** The *Caricetum nigrae* variant with *Anthoxanthum odoratum* (group 4c) forms a transition into species composition of the *Molinietalia*, especially the *Calthion*. It is characterised by high structural and floristic heterogeneity including tall productive meadow species, such as *Holcus lanatus* as in the photo. It shows the plot of relevé 63 in the NSG Hillebachtal east of Winterberg-Grönebach. **d)** The *Carici echinatae-Sphagnetum* (group 5) is a species-poor plant community of small sedges and other cyperaceous species with high bryophyte (*Sphagnum*) covers. The photo was taken at the plot of relevé 19 (NSG Rothaarkamm und Wiesentäler), Dörnbach valley south of Schmale Scheid, north of Erndtebrück-Benfe (Photos: D. Wolbeck, June bis July 2019).

Abb. 11. a) Ein typischer Bestand eines von der hochwüchsigen Binse *Juncus acutiflorus* dominierten *Caricetum nigrae* (Gruppe 4a) im Bereich der Vegetationsaufnahme Nr. 40 im oberen Bibertal südöstlich Rüthen. In diesem Tal wurde die Gesellschaft bereits von Verbücheln (1987) gefunden. **b)** Das *Caricetum nigrae* in der Variante mit *Carex rostrata* (Gruppe 4b) weist einen hohen Anteil an Seggen und Moosen auf. Das Foto zeigt einen Bereich um die Vegetationsaufnahme Nr. 68 (NSG Hunau – Langer Rücken – Heidberg, Nasse Wiese) südlich Schmallenberg-Bödefeld. Diese Fläche wurde bereits von Eichhorn (1997) und Poth (1995) untersucht, die dort ähnliche Bestände des *Caricetum nigrae* fanden. **c)** Die Variante des *Caricetum nigrae* mit *Anthoxanthum odoratum* (Gruppe 4c) bildet einen Übergang zu Feuchtwiesen der *Molinietalia* und besonders des *Calthion*. Sie ist durch ihre Heterogenität mit einem hohen Anteil hochwüchsig-produktiver Arten gekennzeichnet, wie im Bild *Holcus lanatus*. Das Foto zeigt die Fläche der Vegetationsaufnahme Nr. 63 im NSG Hillebachtal östlich Winterberg-Grönebach. **d)** Das typische *Carici echinatae-Sphagnetum* (Gruppe 5) ist eine artenarme Gesellschaft aus Kleinseggen und anderen Sauergräsern mit hoher Deckung an Moosen, vor allem *Sphagnum*. Das Foto entstand im Bereich der Vegetationsaufnahme Nr. 19 (NSG Rothaarkamm und Wiesentäler), Dörnbachtal südlich Schmale Scheid, nördlich Erndtebrück-Benfe (Fotos: D. Wolbeck, Juni bis Juli 2019).

that the site of one of our plots, in the nature reserve "Hunau" (Fig. 11b) had been examined by POTH (1995) and EICHHORN (1997). They found extensive *Caricetum nigrae* stands with species composition similar to our plot.

The *Caricetum nigrae* subunit of *Anthoxanthum odoratum* is more heterogeneous in vegetation structure than the other *E. angustifolium* fen grasslands (Fig. 11c). The high richness and proportion of *Molinio-Arrhenatheretea* species are indicative of more nutrient-rich conditions (OBERDORFER 2001). BAUMANN (1996) and PREISING et al. (2012) noted similar species combinations of the *Caricetum nigrae* (or *Carici canescenti-Agrostietum caninae*, respectively) in the Harz Mountains, adjacent to *Calthion* meadows with rather low ground-water level in summer. Such conditions, typical of drained fens, result from improved soil aeration and thus higher decomposition (STEINER 1992, BAUMANN 1996, WITTIG 1999). High soil density and high concentrations of C_{org}, C_{total} and N, as in our plots, are indicative of decomposed fen peat with high nutrient supply. Phosphate limitation may nevertheless limit plant growth in drained fens (DE MARS et al. 1996b), and indeed the mean herb layer height and cover in our plots are relatively low. Peat decomposition may further be triggered by disturbances such as extensive grazing. Species of wet open ground such as *Ranunculus flammula* and *Juncus bulbosus* indicate where fen peat has been disturbed in trampled spots (PHILIPPI 1963, FOERSTER 1981). The *Caricetum nigrae* variant with *Anthoxanthum odoratum* is comparable to a community transitory between *Calthion* and *Caricetum nigrae* described by FLINTROP (1990) although that grassland was mown, whereas ours were grazed. Moderate grazing appears to be favourable to species of fen grassland which is why our subunit with *Anthoxanthum odoratum* clearly belongs to the *Caricetum nigrae*, albeit strongly affected by drainage or other human impact.

The *Carici echinatae-Sphagnetum* in the Süderbergland (Fig. 11d) resembles some variants of the very widely conceived *Carici canescenti-Agrostietum caninae* classified by PREISING et al. (2012; "*Ausbildung mit Sphagnum fallax*"), based on relevés from both lowland and upland localities in Lower Saxony, and the *Caricetum nigrae sphagnetosum recurvi* described by FLINTROP (1990) in Hesse (named after the *Sphagnum recurvum* species group, where *S. fallax* belongs). Both are similar in habitat specification, scarcity of *Molinietalia* species, pronouncedly acid soil, and richness in mosses. Agricultural land-use is largely absent. Even more similar in its bryophyte composition with *Sphagnum fallax*, *S. palustre*, *S. squarrosum*, *Polytrichum commune* and *Aulacomnium palustre* is the *Caricetum nigrae sphagnetosum* (DIERSCHKE 1979). In addition to those mosses, our plant association was positively differentiated by *Sphagnum flexuosum*. The overall species composition of the *Carici echinatae-Sphagnetum* is fairly rich in species of acid grassland and heaths (*Nardus stricta*, *Galium saxatile*, *Juncus squarrosus*), and indeed it is not uncommon in the Siegerland-Sauerland region that the fen association merges into forms of moist *Nardus* grassland (Fig. 7). Such contact vegetation has also been reported by BÜKER (1942), KLAPP (1965), NOWAK (1983), SCHRÖDER (1999) and SPEIER (1999).

The soil measured in the *Carici echinatae-Sphagnetum* fen is the most acid by far (mean pH 4.34) (Fig. 2, Supplement E7) among the *E. angustifolium* fen grasslands of the Süderbergland, an acidity level justifying the characterization as poor mire where peat accumulation is promoted (STEINER 1992, SUCCOW & JOOSTEN 2001). Similar to findings by BAUMANN (2000) it showed low concentrations of Ca^{2+}, Mg^{2+} and K^{+}, and the widest C/N ratio among our communities. The low phosphate and K^{+} concentrations and the wide C/N ratio indicate poor nutrient availability in plots of the *Carici echinatae-Sphagnetum*. They were also perceived drier and indeed have relatively low EIV-M values. The fact that

Molinietalia species are largely absent may indicate, apart from the low productivity, low disturbance levels of the mire community (KLAPP 1965, PHILIPPI 1977, DIERßEN 1980, STEINER 1992). Among the *E. angustifolium* communities examined, the *Carici echinatae-Sphagnetum* was the least disturbed. Thick moss layers together with a low herb layer have been regarded as characteristic for the most intact poor fens (NOWAK 1983, BAUMANN 1996).

6. Concluding recommendations for nature conservation

Upland fen grasslands with *Eriophorum angustifolium* depend on non-intensive farming systems (STURM et al. 2018), mainly by grazing. However, in the Süderbergland many of the surveyed areas are abandoned (Fig. 12, Supplement E6). Farming on the small, sloped and wet pastures is often difficult and unprofitable, and the numbers of small farmsteads and livestock in the Süderbergland have been decreasing over the past decades (IT NRW 2018), similar to other regions (see LUICK 1995, HAMPICKE 2018, KLÜTER 2018). Despite funding and stipulation compliant with the conservation targets (e.g. HÖGERMEYER 2000, KNOBLAUCH 2000), the management is often inadequate or not carried out at all. Reasons include poor fodder quality of the late plant growth (ERNST 1992, RÖDEL 1993) and potential health risks in wet habitats for sheep and cattle, especially for non-robust breeds. KLAPP (1965) even recommended fencing off fen grasslands to keep cattle out. Only recently are conservation programmes as well as farmers getting acquainted with robust breeds which can cope with the conditions (LUICK 1995, HAMPICKE 2018).

Nevertheless, we could confirm that the conservation status of the area is positively related to the actual state of preservation. The most valuable and best-preserved areas are protected. This is in line with KÖNIG (2003) who found a richer set of wet grassland species in areas under conservation. As conservation area designation in the Süderbergland varies among the districts, sites of high conservation value outside designated conservation areas run a higher risk of degradation through inappropriate management.

The present survey shows the distribution and the core areas of the studied plant communities in the South Westphalian uplands. The fen grasslands (*Caricetum nigrae* and *Carici echinatae-Sphagnetum*) are almost restricted in NRW to the higher elevations of the Süderbergland. Of 46 surveyed plots with (moderately) poor fen vegetation only about 17 plots were found in favourable condition, specifically most of the plots of the *Carici echinatae-Sphagnetum* and some of the *Caricetum nigrae*, especially of its variant with

Fig. 12. In abandoned meadows with a deep layer of dense litter, small, poorly competitive species such as *Dactylorhiza majalis* are vanishing (Photo: D. Wolbeck, 28.05.2017, Attendorn).

Abb. 12. In brach liegenden Wiesen mit mächtiger Streuschicht gehen kleine, konkurrenzschwache Arten wie *Dactylorhiza majalis* zurück, wenn es schwierig wird, die dichte Streudecke zu durchbrechen (Foto: D. Wolbeck, 28.05.2017, Attendorn).

Carex rostrata. About 16 plots of the *Caricetum nigrae* variants of *Juncus acutiflorus* and *Anthoxanthum odoratum* were variously degraded, drained and/or recently abandoned, and were transitory to hydrophilous grasslands and tall-herb fringe communities. Both typical and transitory fen grasslands are important and provide habitats for rare plant and animal species (SCHUBERT 1998, JANSEN 2000, DIERSCHKE 2007). Fens grading into semi-abandoned grasslands may even sustain higher local-scale biodiversity. However, drained and otherwise severely disturbed fens suffer from peat decomposition and may not be restorable (DIERßEN 1985, DE MARS & GARRITSEN 1997) and the quality of occurring species is decreasing because the most sensitive and therefore often rarest species decline first. As the *Caricetalia fuscae* fen grassland communities are particularly sensitive to environmental (hydrological) change (STEINER 1992), they are subject to additional stress by drought through climate change. As was observed in the dry years 2021 and 2022, grazing may affect wetland sites adversely. Animals specifically seek out these areas, resulting in stronger trampling effects in these years. It becomes therefore even more relevant to preserve and manage the fen grasslands and to control the grazing regime appropriately and continously. If headwaters are in favourable condition (low height of herb layer, low litter layer and low proportion of species indicative of disturbance, degradation and peat decomposition), management measures may be sufficient if applied every second or more years.

Juncetum filiformis meadows – in contrast to the *E. angustifolium* fens – are distributed in the study area chiefly in the western Süderbergland, at lower elevations. Although sometimes neglected they are in NRW more widely distributed than the *Caricetalia fuscae* upland fens. *Juncus filiformis* is a rare and threatened species in the state (NRW Red list category 2: Endangered; LANUV NRW 2010), and the same is true for its association in hay-meadows, in adjacent Hesse (BERGMEIER & NOWAK 1988) and in all of Germany (Vulnerable; RENNWALD et al. 2002a, under *Calthion-Basalgesellschaft*). VERBÜCHELN et al. (1998) did not acknowledge the *Juncetum filiformis* for NRW, but it is safe to assume its regional threat status was similar – and today likely worse. The *Juncetum filiformis* meadows of the Süderbergland are of particular relevance for NRW, as the species and the association are more widespread in upland areas (and there threatened to a somewhat lesser extent than in the lowlands where the association is almost lost) (NOWAK 1983, SCHWABE 1987, BERGMEIER & NOWAK 1988, BURKART et al. 2004, BELZ et al. 1992, HAEUPLER et al. 2003, LANUV NRW 2010). Changing moisture conditions caused by drainage or limitations by non-permanent water supply are particularly detrimental for the *Juncetum filiformis* (BURKART et al. 2004). The association is distributed mostly small-scale in shallow depressions (NOWAK 1983, BURKART et al. 2004), often embedded in extensive mesic or wet hay-meadows. The decline of the species and association over the last decades is doubtlessly related to meadow melioration and land “improvement”, which included drainage, drying up of the depressions through infilling, harrowing, and ploughing up of the meadows. Further recent threats include grassland abandonment, groundwater drawdown, drought, or shorter water stagnation duration such as after winters with little snow.

To halt further decline of the wet meadow and fen vegetation, stopping over-exploitation of groundwater resources and suitable management of extant wet grassland will be vital. The most important conservation measures for *Juncetum filiformis* meadows and *Caricetalia nigrae* fen grassland, based on our results and observations, and supported by the conclusions of other researchers cited below, may be summarized as follows:

1) Maintenance of non-intensive management without using mineral fertilizer and liquid manure. High fertilizer application in adjacent fields can adversely affect the vegetation of the target areas. Management of the *Juncetum filiformis* meadows must include regular cutting (usually once to twice a year) to avoid shifts in species composition through abandonment (NOWAK 1983, DIERSCHKE & BRIEMLE 2002). *Juncus filiformis* is also rapidly outcompeted when the grassland productivity is increased by sowing productive grasses or by applying amounts of fertilizer that have become conventional in grassland farming.

2) Maintenance (or restoration) of the soil moisture conditions and hydrology which includes (a) abstaining from drainage, (b) abstaining from water withdrawal in headwaters and upper stream courses, (c) thorough rewetting of formerly drained ground, also in summer, to avoid negative vegetation successional effects by phosphate mobilisation (ROSENTHAL 1995, SCHEFFER 1995, DE MARS et al. 1996a), (d) forestry in compliance with environmental protection regulations, e.g., beech forests retain water much better than conifers (REYNOLDS & HENDERSON 1987, TUŽINSKÝ 2000, ARMBRUSTER et al. 2004).

3) Re-introduction of grazing in succession-prone, just abandoned fens and adaptation of stock density and duration to reduce the risk of adverse effects by trampling and overgrazing (STURM et al. 2018). In non-productive vegetation grazing with robust cattle is preferred. Two livestock units (*Großvieheinheiten*, GVE, Central European grazing livestock unit) at most have been recommended on permanent pasture and up to 4 GVE on late-grazed meadows where wet spots can't be mown. Annual monitoring is vital. In dry years even weekly monitoring is recommended to early detect trampling effects. MAERTENS & WAHLER (1989) suggest grazing with goats and sheep on low-productive wet sites in steep terrain because such animals hardly elicit adverse effects such as soil compaction or opening with subsequent nutrient mobilisation and *Juncus effusus* soil seed bank mobilisation. However, animal health might require a costier animal welfare for goats and sheep.

4) In old fields (fen or meadow sites of advanced abandonment) small-scale topsoil removal may be a restoration measure (JANSEN 2000, PREISING et al. 2012). To reduce phosphate values, TALLOWIN & SMITH (2001) suggested a sod thickness of 20 cm but this depends on local topsoil conditions and topography. As most fen species have a short-term persistent or non-persistent soil seed bank (PFADENHAUER & MAAS 1987, BAKKER et al. 1995, SCHOPP-GUTH 1995, JANSEN 2000), fen restoration from sod-cut old fields requires re-introduction of the target species.

5) Owing to the poor cutting tolerance of many fen species (BRIEMLE & ELLENBERG 1994, LANDOLT et al. 2010, STURM et al. 2018), *Caricetalia fuscae* fen grassland in favourable conservation state (in particular *Carici echinatae-Sphagnetum*) should not be regularly mown. As occasional aftermath (*Krummet* = late-cut hay) it may be compatible with the conservation aims (FLINTROP 1990, KAISER & WOHLGEMUTH 2002). Cutting and removal of mown material may, however, be considered in disturbed fens or anyway in fen meadow stages merging to *Calthion* vegetation.

6) Non-mulching of the grass clippings. According to WOLF et al. (1984) and MAERTENS & WAHLER (1989) mulching has adverse effects in various ways, covering the living plants and potential germination sites, and a sudden fertilizing effect stronger than that of old-field succession.

7) Habitat continuity by well-managed farming is to be maintained (rather than attempting putative treatment optimisation) (KAISER & WOHLGEMUTH 2002).

8) To improve the connectivity between upland wet grasslands and if supported by local farming conditions, principles of landscape-scale management should be respected. (a) Rotational grazing in particular may support long-distance diaspore dispersal. (b) Former spruce plantations (especially where they hinder diaspore dispersal) may swiftly be transformed to wet meadows (BOHN 1987). Large-area grazing projects could at the same time favour the spread of plant and animal species, as well as reduce trampling effects on wetlands.

The present regional case study shows that the ecology of our wetlands in the montane cultural landscape is by no means trivial and its understanding essential for management and maintenance of these biodiverse habitats. As the habitat conditions are complex and varied meticulous scientific investigation is needed to reveal ecological relationships and diversity patterns. Despite their scientific and conservational relevance, projects focused on upland wet grassland and mire conservation are scarce. Without continuous monitoring and the necessary scientific and management capacities, the conservation prospects of upland fens and wet meadows under increasingly unfavourable conditions of climate change will be bleak.

Erweiterte deutsche Zusammenfassung

Einleitung – Feuchtgrünland steht unter Druck durch intensive Landwirtschaft, Drainage sowie durch Verbrachung. Hinzu kommen zunehmende Gefährdungen durch längere saisonale Trockenphasen und aufeinander folgende Trockenjahre, die durch den Klimawandel häufiger auftreten. Auf die Gefährdung dieser artenreichen Lebensräume und vieler ihrer spezialisierten Arten weisen u. a. Rote Listen hin (z. B. RENNWALD et al. 2002a, LANUV NRW 2010, 2011b, JANSSEN et al. 2016, METZING et al. 2018). Trotz der Bedeutung dieser Lebensräume fehlen aktuelle, regional vergleichende Untersuchungen und, abgesehen vom Instrument des Vertragsnaturschutzes, großflächige Schutzprojekte. Für das Süderbergland sollte daher auf Basis einer Vorauswahl von geeigneten Bereichen untersucht werden, (1) welche Pflanzengesellschaften des Feuchtgrünlandes auf den untersuchten Flächen vorkommen und wie sie regional verbreitet sind, (2) welche Korrelationen zwischen gemessenen Lebensraumbedingungen und der Artenzusammensetzung bestehen und (3) wie der Erhaltungszustand des untersuchten Feuchtgrünlandes in der Region ist.

Material und Methoden – Grundlage einer Vorauswahl der aufzusuchenden Bereiche waren Vorkommen von *Eriophorum angustifolium* und *Juncus filiformis* sowie nachrangig weiterer Feuchtgrünlandzeiger in Grünlandflächen nach Daten des Landesamtes für Natur, Umwelt und Verbraucherschutz NRW (LANUV). Zwischen 21. Mai und 12. August 2019 wurden 114 den Kriterien entsprechende Bereiche aufgesucht, und Vegetationsaufnahmen angefertigt, wenn eine strukturell homogene Fläche von mindestens 16 m² vorlag. Alle Gefäßpflanzen- und Moosarten wurden nach der erweiterten Braun-Blanquet-Skala aufgenommen, gemischte Bodenproben entnommen und die Mächtigkeit und Identität der oberen Bodenhorizonte notiert. Die Bodenproben wurden in der Abteilung für Pflanzenökologie der Universität Göttingen gesiebt, gewogen, getrocknet und die Wasser-, Kohlenstoff- und Stickstoffgehalte sowie das C/N-Verhältnis ermittelt. Kationenaustauschkapazität (Al^{3+}, Ca^{2+}, Fe^{2+}, K^{+}, Mg^{2+}, Mn^{2+}, Na^{+}, H^{+}), pH_{H2O}, pH_{KCl} und Phosphat wurden ebenfalls gemessen.

Die Vegetations- und Umweltdaten wurden in Turboveg eingegeben und eine Klassifikation mittels Isopam nach SCHMIDTLEIN et al. (2010) in R durchgeführt. Differentialarten wurden ermittelt und geordnete und synoptische Tabellen erstellt. Für die klassifizierten Gruppen wurden mittlere Deckungswerte der Krautschicht, Moosschicht sowie der Arten verschiedener Vegetationsklassen und Zeigerartengruppen ermittelt. Mediane der Ellenberg-Zeigerwerte und mittlere pH-Werte wurden errechnet. Eine Ordination (NMDS) wurde durchgeführt und die Umweltvariablen mittels *envfit* (*vegan* 2.5–6;

OKSANEN et al. 2017) daraufgelegt. Die Daten wurden statistisch weiter analysiert durch die Testverfahren Shapiro-Wilk, Levene, ANOVA, Kruskal-Wallis, Tukey, Dunn sowie durch eine Korrelationsanalyse und eine PCA (zum Zweck der einzelnen Verfahren siehe Anhang E2).

Ergebnisse und Diskussion – Wir fanden deutliche Unterschiede in der Artenzusammensetzung zwischen den Gesellschaften der *Juncus filiformis*-Wiesen und den Niedermooren mit *Eriophorum angustifolium*. Die beiden *J. filiformis*-Vegetationseinheiten erwiesen sich als zum Feuchtwiesenverband *Calthion palustris* gehörig und sind der Assoziation *Juncetum filiformis* zuzurechnen. Die Gesellschaften mit *E. angustifolium* waren heterogener, gehören aber trotz teilweiser Übergänge zum *Calthion* eindeutig zur Ordnung *Caricetalia fuscae*, die saure seggen- und moosreiche Niedermoore umfasst. Die Gesellschaften mit *E. angustifolium* unterschieden sich in Artenzusammensetzung, Nährstoffgehalt und Azidität erheblich voneinander. Die Gruppen 3 (mit *Carex panicea*) und 4 (mit *Agrostis canina*, bestehend aus den Untergruppen 4a–c) repräsentieren das *Caricetum nigrae* im Verband *Caricion fuscae* (mäßig basenarme Niedermoorvegetation), während Gruppe 5 (mit *Sphagnum fallax*) durch Torfmoosreichtum und fast fehlende *Molinietalia*-Arten sowie ökologisch durch Nährstoffarmut und ausgeprägten Säuregrad stärker abweicht. Sie ist damit dem Verband *Sphagno-Caricion canescentis* (betont saure, nährstoffarme Niedermoorvegetation) und der Assoziation *Carici echinatae-Sphagnetum* zuzurechnen, welche u. a. durch die Häufigkeit von Arten der (feuchten) Heiden gekennzeichnet ist. Das *Carici echinatae-Sphagnetum* ist im gemäßigten und borealen Europa weit verbreitet, wurde aber in Deutschland häufig mit dem *Caricetum fuscae* zusammengefasst oder als *Carici canescentis-Agrostietum caninae* bezeichnet. Die in diesem Beitrag vorgestellten Pflanzengesellschaften der Feuchtwiesen und Niedermoore umfassen in hierarchischer Anordnung gemäß EuroVegChecklist (MUCINA et al. 2016, BERGMEIER 2020) die folgenden Syntaxa:

Kl.: *Molinio-Arrhenatheretea* Tx. 1937
- O.: *Molinietalia caeruleae* Koch 1926
  - V.: *Calthion palustris* Tx. 1937
    - Ass.: *Juncetum filiformis* Tx. 1937

Kl.: *Scheuchzerio palustris-Caricetea fuscae* Tx. 1937
- O.: *Caricetalia fuscae* Koch 1926
  - V.: *Caricion fuscae* Koch 1926
    - Ass.: *Caricetum nigrae* J. Braun 1915
  - V.: *Sphagno-Caricion canescentis Passarge* (1964) 1978
    - Ass.: *Carici echinatae-Sphagnetum* Soó 1944

Wiesen mit *Juncus filiformis* treten in zwei Varianten auf, einer Variante mit *Agrostis capillaris* von trockeneren, nährstoffärmeren Standorten sowie einer Variante feuchterer produktiverer Standorte mit u. a. *Lysimachia nummularia* und *Equisetum palustre*. Im Süderbergland kommen beide Varianten besonders auf Mähwiesen mit vielen Klassen-, Ordnungs- und Verbandscharakterarten der *Molinio-Arrhenatheretea*, *Molinietalia* bzw. *Calthion* vor, die vergleichsweise gut nährstoffversorgt sind. Eine Zugehörigkeit der Faden-Binse und damit der durch sie gekennzeichneten Assoziation zu den *Caricetalia fuscae*, wie in der früheren Literatur verschiedentlich diskutiert, ist aufgrund unserer Daten im Untersuchungsgebiet heute nicht mehr vertretbar. Das ökologische Optimum der Art liegt offenbar in Lebensräumen mit einem moderaten Störungsregime, in denen ihre Konkurrenzvorteile früh im Jahr wirksam werden.

Die Niedermoorwiesen und Nasswiesen mit *Eriophorum angustifolium* in unserer Untersuchung weichen in Artenzusammensetzung und Artenreichtum sehr stark von den Flächen mit *Juncus filiformis* ab, unterscheiden sich aber auch untereinander. Aufgrund der größeren Nässe und oft hohen Torfmächtigkeiten finden sich viele Arten der *Scheuchzerio palustris-Caricetea fuscae*. Die Bestände sind nicht nur feuchter, sondern auch nährstoffärmer als die *Juncetum filiformis*-Wiesen, mit niedrigeren durchschnittlichen Ellenberg-N-, Phosphat- und K^+-Werten und einem weiteren C/N-Verhältnis. Eine Phosphat- oder K^+-Limitierung kann für viele Flächen angenommen werden. Die *Caricetum* *nigrae*-Bestände mit *E. angustifolium* unterscheiden sich erheblich in ihrer Artenzusammensetzung. Die stärkste Durchdringung mit *Molinietalia*-Arten besitzen die Varianten mit *Agrostis canina*, besonders diejenige mit *Juncus acutiflorus*, sowie die Ausbildung mit *Anthoxanthum odoratum*. Dies geht mit höheren Nährstoffgehalten und geringerer oder schwankender Feuchtigkeit einher. *Molinietalia*-Arten werden durch Störungen und Niedermoorentwässerung gefördert. So sind solche Bestände artenreicher als wenig gestörte Gesellschaften, mögen im Übergang zum *Calthion* aber nicht dauerhaft zu halten sein. Seltene und spezialisierte Arten kommen jedoch eher in den schwächerwüchsigen, ungestörteren Bereichen vor. Geringeren Einfluss durch *Molinietalia*-Arten weist die Subassoziation des *Caricetum nigrae* mit *Carex rostrata* auf. Sie bildet Übergänge zum nährstoffarmen, torfmoos-reichen, sauren und wenig gestörten *Carici echinatae-Sphagnetum*. Die als *Caricetum nigrae caricetosum paniceae* klassifizierte Gruppe zeichnet sich durch kleinwüchsige Seggenarten wie *Carex demissa*, *C. panicea* und *C. pulicaris* aus. In Beständen dieser Subassoziation wurden die höchsten Basengehalte und pH-Werte von über 5 gemessen. Dies fördert möglicherweise geringe Torfauflagen durch höhere Zersetzungsraten trotz der starken Nässe. Dennoch sind die Nährstoffgehalte eher niedrig, K^+ kann als limitierend für das Pflanzenwachstum angenommen werden.

Betrachtet man die Seltenheit der hier untersuchten Gesellschaften, die regionale Beschränkung ihrer Vorkommens und den Reichtum spezialisierter Arten, muss es Besorgnis erregen, wie viele der untersuchten Gebiete nicht oder nicht angepasst bewirtschaftet werden. Schutzbemühungen müssen starker auf das Vorkommen von kleinflächigen Nassbereichen in größeren Flächen abgestimmt werden. Neben der Vermeidung von generell unpassenden Bewirtschaftungsmethoden auf für den Naturschutz wertvollen Flächen, wie Düngung, Mulchmahd oder Entwässerung, ist es besonders im Klimawandel unabdingbar, Nassgrünlandflächen jährlich zu kontrollieren und Bewirtschaftungsweisen auch kurzfristig anzupassen. Ohne die Einrichtung von entsprechenden Projekten, (Personal-)Kapazitäten und einer engen Abstimmung zwischen Naturschutzpersonal und Vertragslandwirten werden solche Lebensräume in absehbarer Zeit verloren gehen.

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Author contribution statement

D.W. carried out this study in 2019 as part of his Master's thesis supervised by E.B. E.B. and D.W. worked together to write a manuscript and prepare it for publication. E.B. led the implementation of changes requested by the editorial team and D.W. completed these.

ORCID iDs

Erwin Bergmeier https://orcid.org/0000-0002-6118-4611

Supplements

Supplement S1. Significance levels of differences between plant communities regarding environmental variables (see Supplement E1).

Beilage S1. Signifikanzniveaus der Unterschiede von Umweltvariablen (vgl. Anhang E1) zwischen den klassifizierten Pflanzengesellschaften.

Additional supporting information may be found in the online version of this article.

Zusätzliche unterstützende Information ist in der Online-Version dieses Artikels zu finden.

Supplement E1. Environmental and geographical variables.

Anhang E1. Umwelt- und geografische Variablen.

Supplement E2. Used statistical tools, functions and their purposes.

Anhang E2. Genutzte statistische Instrumente, Funktionen und ihr Zweck.

Supplement E3. (A) NMDS ordination diagram ("ordispider" style) with axes 1 and 3 of all 73 vegetation plots classified to seven groups (symbol, colour). (B) Soil-related (based on volume resp. dry weight) and (C) structural and other environmental variables fitted onto the NMDS plot.

Anhang E3. (A) NMDS-Ordinationsdiagramme der sieben ISOPAM-generierten Gruppen mit den Achsen 1 und 3 aller 73 klassifizierten Aufnahmen. Darstellung der Achsenkorrelationen der in das NMDS-Diagramm eingepassten bodenchemischen Variablen (B) und Struktur- und anderen Umwelt-variablen (C).

Supplement E4. NMDS ordination diagram ("ordispider" style) with axes 2 and 3 of all 73 vegetation plots classified to seven groups (symbol, colour). (B) Soil-related (based on volume resp. dry weight) and (C) structural and other environmental variables fitted onto the NMDS plot.

Anhang E4. NMDS ordination diagram ("ordispider" style) with axes 2 and 3 of all 73 vegetation plots classified to seven groups (symbol, colour). (B) Soil-related (based on volume resp. dry weight) and (C) structural and other environmental variables fitted onto the NMDS plot.

Supplement E5. All Red List species found in relevé plots with relevé numbers and their NRW Red list status (LANUV NRW 2010, 2011a, b).

Anhang E5. Alle in den Vegetationsaufnahmen gefundene Rote-Liste-Arten mit Probeflächennummern und ihrem Status in der Roten Liste von NRW (LANUV NRW 2010, 2011a, b).

Supplement E6. The classified plant communities characterized by categorial variables (see Supplement E1).

Anhang E6. Die klassifizierten Pflanzengesellschaften durch kategoriale Variablen charakterisiert (vgl. Anhang E1).

Supplement E7. All numeric variables with arithmetic means / medians of Ellenberg indicator values (standard deviation in parentheses) and minimum-maximum values in the respective rows below.

Anhang E7. Alle numerischen Variablen mit arithmetischen Mittelwerten / Medianen der Ellenberg-Indikatorwerte (Standardabweichung in Klammern) und Minimum-Maximum-Werten jeweils in den Zeilen darunter.

Supplement E8. Vegetation table of all investigated plots (no. 1–73) in the region of Süderbergland, NRW.

Anhang E8. Vegetationstabelle aller untersuchten Plots (no. 1–73) in der Region Süderbergland, NRW.

Supplement E9. Vegetation table the plots of communities 4a–c in the region of Süderbergland, NRW.

Anhang E9. Vegetationstabelle der Plots der Gesellschaften 4a–c in der Region Süderbergland, NRW.

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Supplement S1. Significance levels of differences between plant communities regarding environmental variables (see Supplement E1), between all communities as revealed by Kruskal-Wallis test (column K-W test), and between single communities as revealed by Dunn's test. Exchangeable base pool (μmol$_c$/cm³) and species richness (both 159 species and 225 species) were tested using ANOVA and subsequent TukeyHSD. Significance levels are indicated by asterisks and also by background colour: dark brown and ***, p < 0.001; medium brown and **, p < 0.01; light brown and * = p < 0.05; others (empty, white fields) not significant. 1, *Juncus filiformis* meadows, variant with *Agrostis capillaris*; 2, *J. filiformis meadows*, variant with *Taraxacum* and *Lysimachia*; 3, *Eriophorum angustifolium* fen grassland, variant with *Carex panicea*; 4a, *E. angustifolium* fen grassland, variant with *Juncus acutiflorus*; 4b, *E. angustifolium* fen grassland, variant with *Carex rostrata*; 4c, *E. angustifolium* fen grassland, variant with *Anthoxanthum odoratum*; 5, *E. angustifolium* fen grasslands, variant with *Molinia* and *Sphagnum*.

Beilage S1. Signifikanzniveaus der Unterschiede von Umweltvariablen (vgl. Anhang E1) zwischen den klassifizierten Pflanzengesellschaften; zwischen allen Gesellschaften mittels Kruskal-Wallis-Rangsummentest (Spalte K-W test) und beim Vergleich einzelner Gesellschaften durch Dunn's Test. Austauschbarer Basenpool (μmol$_c$/cm³) und Artenreichtum (225 Arten bzw. 159 Arten) wurden mittels ANOVA und anschließendem TukeyHSD getestet. Signifikanzstufen: dunkelbrauner Hintergrund und ***, p < 0,001; mittelbrauner Hintergrund und **, p < 0,01; hellbrauner Hintergrund und *, p < 0,05; leere, weiße Felder => nicht signifikant. 1, *Juncus filiformis*-Feuchtwiese, Variante mit *Agrostis capillaris*; 2, *J. filiformis*-Feuchtwiese, Variante mit *Taraxacum* und *Lysimachia*; 3, *Eriophorum angustifolium*-Niedermoor, Variante mit *Carex panicea*; 4a, *E. angustifolium*-Niedermoor, Variante mit *Juncus acutiflorus*; 4b, *E. angustifolium*-Niedermoor, Variante mit *Carex rostrata*; 4c, *E. angustifolium*-Niedermoor, Variante mit *Anthoxanthum odoratum*; 5, *E. angustifolium*-Niedermoor, Variante mit *Molinia* und *Sphagnum*.

	K-W test	2/1	3/1	4a/1	4b/1	4c/1	5/1	3/2	4a/2	4b/2	4c/2	5/2	4a/3	4b/3	4c/3	5/3	4a/5	4b/5	4c/5	4b/4a	4c/4a	4c/4b
pH (H_2O)	***		*													***	*					
pH (KCl)	***		***													***	*					
C/N (g/g)	***		**	*	**	*	***	**	*	**	*	***										
Base saturation excl. Na (%)	***		***		*	*		*								***		*	**			
C (mg/g)	***			*	***		***			*		***				*						
N (mg/g)	***			*	***		***			*		*		*								
C_{org} (mg/g)	***			*	*		***			*		***				*						
P (μmol$_c$/g)	**							*			*											
Al^{3+} (μmol$_c$/g)	***		***													***						
Ca^{2+} (μmol$_c$/g)	***		***	**	***	*		*								***		**				
Fe^{2+} (μmol$_c$/g)	*						*									*						
K^{+} (μmol$_c$/g)	**													*								*
Mg^{2+} (μmol$_c$/g)	***		**	**	***	*				*								*				
Mn^{2+} (μmol$_c$/g)	***		*			*	**						*				*				*	
H (μmol$_c$/g)	***											*				***	*					
CEC excl. Na (μmol$_c$/g)	***		***	**	***					*												
Exchangeable base pool (μmol$_c$/g)	***		***	**	***	*		*		*						**		**				
Soil density (g/cm³)	***			**	***		**		*	**		*										
C (mg/cm³)	**															*						
N (mg/cm³)	*							*														
C_{org} (mg/cm³)	**															*						
P (μmol$_c$/cm³)	***		**	*			*	***	**			**										
Al^{3+} (μmol$_c$ /cm³)	***		***	*	**			*								*						
Ca^{2+} (μmol$_c$ / cm³)	***		***									*				***			**			
Fe^{2+} (μmol$_c$/cm³)	*															*						
K^{+} (μmol$_c$/cm³)	***		**				**	**				**										
Mg^{2+} (μmol$_c$/cm³)	***					*										**		*	**			
Mn^{2+} (μmol$_c$/cm³)	***		***			**	***	*				**										
H (μmol$_c$/cm³)	***		***	*												***	**					
CEC (μmol$_c$/cm³)	**		*													***						
Exchangeable base pool (μmol$_c$/cm³)	***		***			*		*				**				***	*	***	***			
Open soil (%)	***		**					**								*						
Litter (cm)	***			*					**	*		*										
Litter (%)	*																					
Bryophyte layer height (cm)	***							*		**	*	**										
Bryophyte layer cover (%)																						
Herb layer height (cm)	***			***					***													
Herb layer cover (%)	**							*		**		*										
Shrub layer height (m)																						
Shrub layer cover (%)																						
Tree layer height (m)																						
Tree layer cover (%)																						
EIV L																						
EIV T	***				*		***			*		***				***	*		***			
EIV C	***				**					**				***								**
EIV M	***		**	*				**														
EIV R	***						***					***				***	*					
EIV N	***						***			**	*	***				*	*					
Precipitation (mm/a)																						
Temperature (°C)	***	*	**			***																
Elevation (m a.s.l.)	***		**			**	*	*			*											
Inclination (°)	***		**					**		*	*											
Aspect (°)																						
Topsoil depth (cm)	***			**				*	**	**		*										
Plant species richness (225 spp.)	***		***		*	***	*	***			***	*	*			***	***	***	***		*	
Plant species richness (159 spp.)	***		***			***	**	***			***	**				***	***	***	***		*	
Bryophyte species richness	***		**		***	**		***	*	***	***	*										
Red list species richness	***		***		***	***		***		**	***											
Singleton number																						
Categorial variables																						
Conservation area type																						
Geology																						
Ecoregion (*Naturraum*)	*		*																			
Agricultural land-use and intensity	***						*		*	*		*										
Adjacent formation	**						*					*										
Soil type																						
Topsoil identity	***		***	***	**	*	***	**	***	**	*	**										
Moisture	***		***	**				**														
Shape of the stand																						

Supplement E1. Environmental and geographical variables. Cation and other soil measures refer to dry soil. Type of scale of variable: c, categorial; i, interval; o, ordinal; r, rational. 53 - Aspect: East 90°; South 180°; West 270°; North 360°; and intervals. 59 - conservation area type: 1, SAC (Special Area of Conservation); 2, NSG (*nature conservation area*); 3, GB (protected habitat); 4, Other (LSG, *landscape protection area*, BK, *habitat cataster* NRW). 60 - Geology: 1, Holocene; 2, Pleistocene-Holocene; 3, Late Pleistocene; 4, Late Carboniferous; 5, Lower Carboniferous; 6, Late Devonian; 7, Mid-Late Devonian; 8, Mid Devonian; 9, Lower Devonian. 61 - Ecoregion: 1, 336-E1 & 338; 2, 336-E2; 3, 330; 4, 331; 5, 335; 6, 333; 7, 334; 8, 332. 62 - Agricultural land-use type and intensity: 1, mown; 2, grazed; 3, irregular; 4, none. 63 - Adjacent formation (land use): 1, arable land; 2, grassland; 3, heath, clearing; 4, deciduous forest; 5, mixed forest; 6, spruce plantation. 64 - Soil type: 1, *Braunerde*; 2, *Kolluvisol;* 3, *Auengley;* 4, *Pseudogley;* 5, *Nassgley;* 6, *Niedermoorgley*. 65 - Topsoil identity: 1, Ah, humus; 2, aA, peat < 30 cm; 3, hH, peat > 30 cm. 66 - Moisture: 1, very dry; 2, dry; 3, slightly wet; 4, wet; 5, very wet, above-ground water. 67 - Shape of the vegetation stand: 1, linear near ditch; 2, non-linear, non-extensive; 3, shallow depression; 4, flushes, springs; 5, flat, extensive.

Anhang E1. Umwelt- und geografische Variablen. Kationen- und andere Bodenmaße beziehen sich auf Trockenmasse. Skalentyp: c, kategorial; i, Intervall; o, ordinal; r, rational. 53 - Exposition: Ost 90°; Süd 180°; West 270°; Nord 360°; und Himmelsrichtungen dazwischen. 59 - Schutzstatus: 1, FFH-Gebiet; 2, NSG (Naturschutzgebiet); 3, GB (Geschützter Biotop); 4, Sonstige (LSG, Landschaftsschutzgebiet, BK, Biotopkataster NRW). 60 - Geologie: 1, Holozän; 2, Pleistozän-Holozän; 3, Oberes Pleistozän; 4, Oberkarbon; 5, Unterkarbon; 6, Oberdevon; 7, Mittel-Oberdevon; 8, Mitteldevon; 9, Unterdevon. 61 - Naturraum: 1, 336-E1 & 338; 2, 336-E2; 3, 330; 4, 331; 5, 335; 6, 333; 7, 334; 8, 332. 62 – Nutzung und Intensität: 1, gemäht; 2, beweidet; 3, unregelmäßig; 4, keine. 63 - Benachbarte Nutzung: 1, Acker; 2, Grünland; 3, Heide; Rodung; 4, Laubwald; 5, Mischwald; 6, Fichtenwald. 64 - Bodentyp: 1, Braunerde; 2, Kolluvisol; 3, Auengley; 4, Pseudogley; 5, Nassgley; 6, Niedermoorgley. 65 - Oberboden: 1, Ah, Humus; 2, aA, Torf < 30 cm; 3, hH, Torf > 30 cm. 66 - Feuchteschätzung: 1, sehr trocken; 2, trocken; 3, wenig feucht; 4, feucht-nass; 5, sehr nass-Oberflächenwasser. 67 - Bestandsform der Vegetation: 1, linear an Gräben; 2, flächig aber klein; 3, weite Kuhle; 4, flächig aus Quelle entspringend; 5, flächig flach.

Nr.	Variable	Scale type	Remarks, source
1	pH (H_2O)	o	
2	pH (KCl)	o	
3	C/N (g/g)	r	
4	Base saturation excl. Na (%)	r	
5	C (mg/g)	r	
6	N (mg/g)	r	
7	C_{org} (mg/g)	r	
8	P (µmol$_c$/g)	r	
9	Al^{3+} (µmol$_c$/g)	r	
10	Ca^{2+} (µmol$_c$/g)	r	
11	Fe^{2+} (µmol$_c$/g)	r	
12	K^+ (µmol$_c$/g)	r	
13	Mg^{2+} (µmol$_c$/g)	r	
14	Mn^{2+} (µmol$_c$/g)	r	
15	H (µmolc/g)	r	
16	CEC excl. Na (µmol$_c$/g)	r	
17	Exchangeable base pool (µmol$_c$/g)	r	
18	Soil density (g/cm³)	r	
19	C (mg/cm³)	r	
20	N (mg/cm³)	r	
21	C_{org} (mg/cm³)	r	
22	P (µmol$_c$/cm³)	r	
23	Al^{3+} (µmol$_c$/cm³)	r	
24	Ca^{2+} (µmol$_c$/cm³)	r	
25	Fe^{2+} (µmol$_c$/cm³)	r	
26	K^+ (µmol$_c$/cm³)	r	
27	Mg^{2+} (µmol$_c$/cm³)	r	
28	Mn^{2+} (µmol$_c$cm³)	r	
29	H (µmol$_c$/cm³)	r	
30	CEC (µmol$_c$/cm³)	r	
31	Exchangeable base pool (µmol$_c$/cm³)	r	
32	Open soil (%)	i	
33	Litter (cm)	r	
34	Litter (%)	i	
35	Bryophyte layer height (cm)	r	
36	Bryophyte layer cover (%)	i	
37	Herb layer height (cm)	r	
38	Herb layer cover (%)	i	
39	Shrub layer height (m)	r	
40	Shrub layer cover (%)	i	
41	Tree layer height (m)	r	
42	Tree layer cover (%)	i	
43	Ellenberg Light (L)	o	
44	Ellenberg Temperature (T)	o	
45	Ellenberg Continentality (C)	o	
46	Ellenberg Moisture (M)	o	
47	Ellenberg Soil reaction (R)	o	
48	Ellenberg Nutrients (N)	o	
49	Precipitation (mm/a)	r	DWD 2019
50	Temperature (°C)	r	DWD 2019
51	Elevation (m a.s.l.)	r	
52	Inclination (°)	i	
53	Aspect (°)	i	
54	Topsoil depth (cm)	r	
55	Plant species richness	r	225 species dataset
56	Bryophyte species richness	r	225 species dataset
57	Red List species number	r	LANUV NRW 2010, 2011a & b
58	Number of species singletons in the dataset	r	refers to the 225 species dataset
59	Conservation area type	c	Land NRW 2020
60	Geology	c	Geologischer Dienst NRW 2020a
61	Ecoregion (Naturraum)	c	Meynen & Schmithüsen 1962
62	Agricultural land-use and intensity	c	
63	Adjacent formation (land use)	c	
64	Soil type	c	Geologischer Dienst NRW 2020b
65	Topsoil identity	c	
66	Moisture	c	
67	Shape of the stand	c	

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Supplement E2. Used statistical tools, functions and their purposes.

Anhang E2. Genutzte statistische Instrumente, Funktionen und ihr Zweck.

Software	Additional tool	Purpose
TURBOVEG 2.140b (HENNEKENS & SCHAMINEE 2001)	Species list Germansl 1.3; EIV median computations	Entering, storing and exporting of vegetation data
R 3.6.0 (R CORE TEAM 2019): RStudio 1.0.143 (RSTUDIO TEAM 2016)		Analysis of plant communities, their distribution and ecological preferences

Analysis	Method in R	Parameter	Purpose
Classification by non-hierarchical ISOPAM (isometric feature mapping and partitioning around medoids) (SCHMIDTLEIN et al. 2010)	Function *isopam* in package *isopam* vs. 0.9-13 (SCHMIDTLEIN 2014)	Default 5 Cluster (3 for cluster 4 (*Caricetum nigrae*, Variant with Agrostis *canina*); seedling of woody species and singletons removed to reduce noise	Identifying plant communities from relevés
Synoptic table	Function *syntable* in package *goeveg* vs. 0.4.2 (Goral & Schellenberg 2019) using algorithm by TSIRIPIDIS et al. (2009)	"synsort" aus dem "goeveg"-Paket Version 0.4.2 (GORAL & SCHELLENBERG 2019) um zu sortieren und synoptische Tabelle zu erzeugen	Making species-community synoptic table
NMDS (non-metric multidimensional scaling)	Function *metaMDS* of the *vegan* package, vs. 2.5-6 (OKSANEN et al. 2017) using the same dataset as for classification	Seedlings of woody species and singletons (one occurrence only) removed; reproducibility ensured by function *set.seed(1)*; 100-1000 random repetitions	Ordination of relevés and visualisation in floristic similarity space; interpretation of classification results by relating environmental and other variables
Fitting variables on NMDS diagrams	*envfit* of the *vegan* package vs. 2.5-6 (OKSANEN et al. 2017)	reproducibility ensured by function *set.seed(1)*	Find significances in relations between 58 interval or rational scaled variables for 73 plots
Shapiro-Wilk	*shapiro.test* of the *stats* package		Normality test
Levene Test	l*eveneTest* of the *car* package (FOX & WEISBERG 2019)		Homogeneity of variance test
ANOVA für normalverteilte Variablen mit Varianzhomogenität	*aov* function of the *stats* package	Dependency by plant communities	Analysis of variance for normally distributed variables with homogeneity of variance
Tukey Honest Significant Differences (HSD) Test	*TukeyHSD* of the *stats* package	*Holm* applied (HOLM 1979)	Identifying pairs of plant communities with significantly deviating variables
Kruskal-Wallis	*col_kruskalwallis* of the package *matrixTests*, vs. 0.1.8 (KONCEVIČIUS 2018)		Analysis of variance for non-normally distributed variables
Dunn's Test of Multiple Comparisons	*dunn.test* of the package *dunn.test* (DINNO 2017)	*Holm* applied (HOLM 1979)	Comparison of ISOPAM-generated groups
Correlation analysis	*cor* of the *stats*-package	Spearman correlation; use=complete.obs (deletes missing values as long as not all missing)	Find correlations between numerical variables
Principal component analysis (PCA)	*rda* of the *vegan* package vs. 2.5-6 (OKSANEN et al. 2017)	Standardisation	Find variables (among all 67 numerical and categorial variables) explaining most of the variance in the dataset (along axes 1 and 2)

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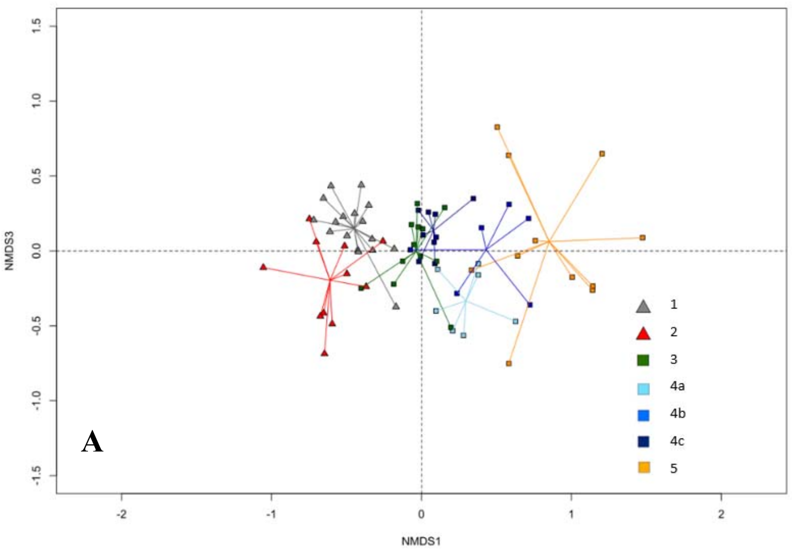
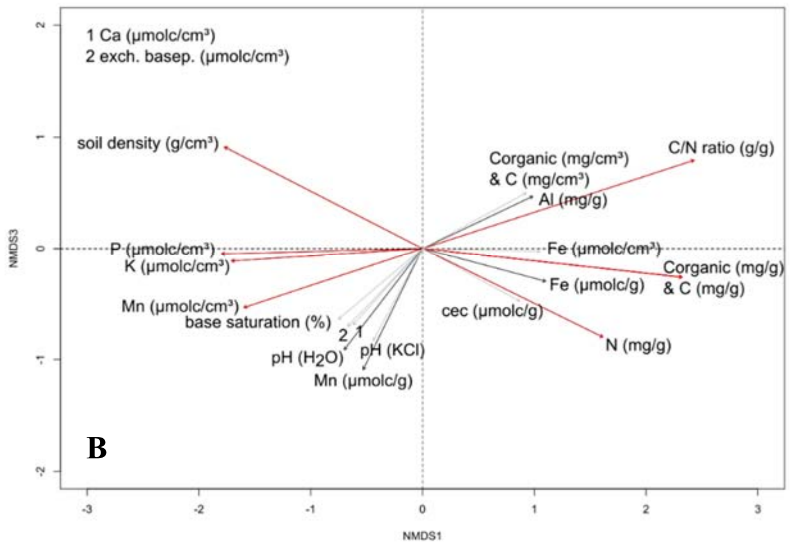
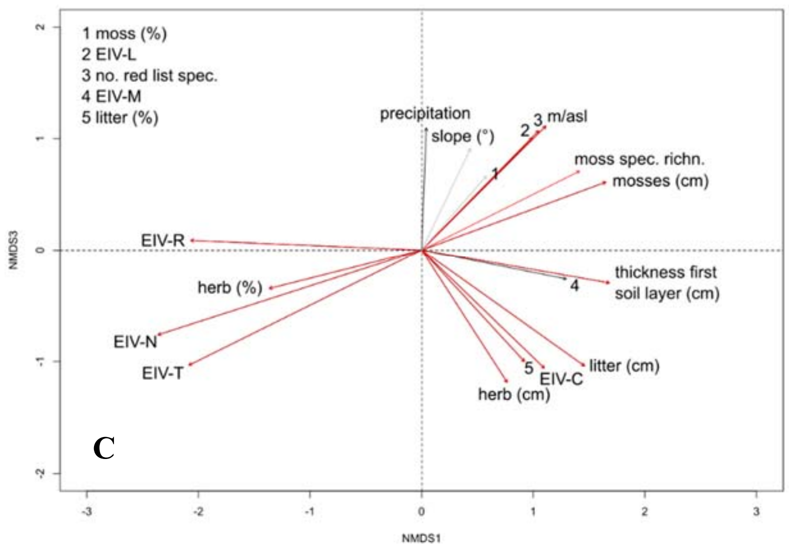
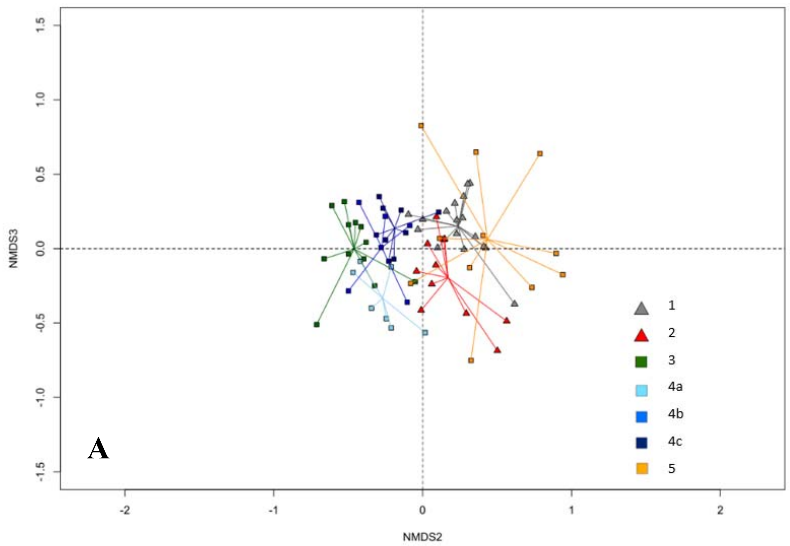


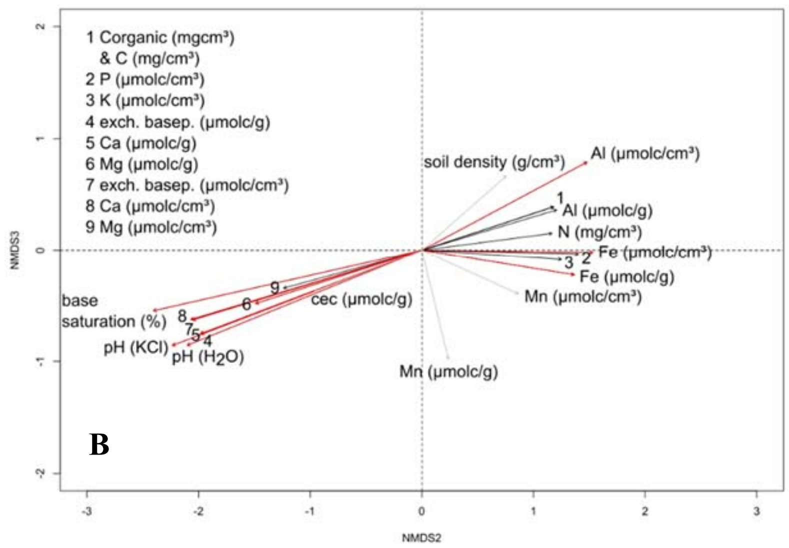


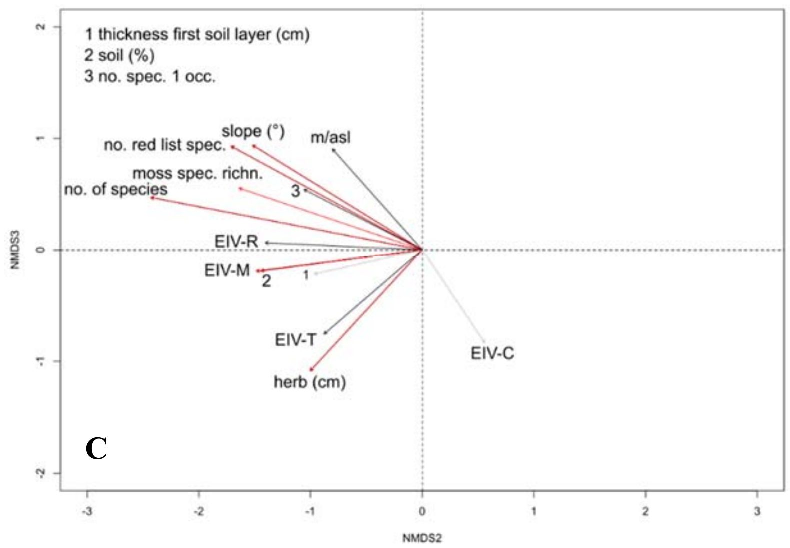


Supplement E3. (A) NMDS ordination diagram ("ordispider" style) with axes 1 and 3 of all 73 vegetation plots classified to seven groups (symbol, colour). (B) Soil-related (based on volume resp. dry weight) and (C) structural and other environmental variables fitted onto the NMDS plot. Arrow colours indicate significance levels of correlation with the axes: grey, $p < 0.05$; black, $p < 0.01$; red, $p < 0.001$. For explanation of numbers at arrowheads see variable names in the legend. Ion/element contents refer to dry soil.

Anhang E3. (A) NMDS-Ordinationsdiagramme der sieben ISOPAM-generierten Gruppen mit den Achsen 1 und 3 aller 73 klassifizierten Aufnahmen. (B) Darstellung der Achsenkorrelationen der in das NMDS-Diagramm eingepassten bodenchemischen Variablen (C) und Struktur- und anderen Umweltvariablen. Die Pfeilfarben zeigen Signifikanzniveaus der Korrelation mit den Achsen an: grau, $p < 0{,}05$; schwarz, $p < 0{,}01$; rot, $p < 0{,}001$. Zahlen am Ende einger Pfeile ersetzen Variablennamen, die aus Platzgründen in die jeweilige Legende geschrieben wurden. Ionen-/Elementgehalte beziehen sich auf trockenen Boden.







Supplement E4. (A) NMDS ordination diagram (“ordispider” style) with axes 2 and 3 of all 73 vegetation plots classified to seven groups (symbol, colour). (B) Soil-related (based on volume resp. dry weight) and (C) structural and other environmental variables fitted onto the NMDS plot. Arrow colours indicate significance levels of correlation with the axes: grey, $p < 0.05$; black, $p < 0.01$; red, $p < 0.001$. For explanation of numbers at arrowheads see variable names in the legend. Ion/element contents refer to dry soil.

Anhang E4. (A) NMDS-Ordinationsdiagramme der sieben ISOPAM-generierten Gruppen mit den Achsen 2 und 3 aller 73 klassifizierten Aufnahmen. (B) Darstellung der Achsenkorrelationen der in das NMDS-Diagramm eingepassten bodenchemischen Variablen (C) und Struktur- und anderen Umweltvariablen. Die Pfeilfarben zeigen Signifikanzniveaus der Korrelation mit den Achsen an: grau, $p < 0{,}05$; schwarz, $p < 0{,}01$; rot, $p < 0{,}001$. Zahlen am Ende einger Pfeile ersetzen Variablennamen, die aus Platzgründen in die jeweilige Legende geschrieben wurden. Ionen-/Elementgehalte beziehen sich auf trockenen Boden.

Supplement E5. All Red List species found in relevé plots with relevé numbers and their NRW Red list status (LANUV NRW 2010, 2011a, 2011b).

Anhang E5. Alle in den Vegetationsaufnahmen gefundene Rote-Liste-Arten mit Probeflächennummern und ihrem Status in der Roten Liste von NRW (LANUV NRW 2010, 2011a, 2011b).

No.	Species	Relevé number	Red List (RL) status in NRW
1	*Aulacomnium palustre*	18, 19, 21, 22, 23, 27, 32, 33, 40, 42, 43, 45, 51, 52, 54, 56, 58, 59, 62	3
2	*Briza media*	57	3S
3	*Campylium stellatum*	47	2
4	*Carex echinata*	1, 17, 18, 19, 20, 22, 23, 26, 31, 32, 34, 35, 38, 39, 40, 42, 43, 44, 46, 47, 48, 49, 52, 53, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 73	3
5	*Carex flava* agg.	47, 62, 63	2
6	*Carex panicea*	2, 4, 5, 6, 8, 9, 10, 11, 13, 14, 17, 22, 23, 34, 35, 37, 38, 42, 43, 47, 48, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 70, 71, 72, 73	3S
7	*Carex pulicaris*	47	2S
8	*Comarum palustris*	4, 23, 51, 55, 62	3
9	*Dactylorhiza maculata* agg.	34, 46, 47, 49, 55, 61, 62, 66, 68, 70	*S
10	*Dactylorhiza majalis*	5, 17, 43, 49, 57, 60, 62, 64, 65, 67, 68, 71, 73	3S
11	*Danthonia decumbens*	33	3
12	*Dichodontium palustre*	70	3
13	*Equisetum palustre*	4, 6, 31, 37	3
14	*Eriophorum angustifolium*	4, 18, 19, 20, 21, 22, 23, 25, 32, 34, 35, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73	3
15	*Eriophorum vaginatum*	51, 52	3S
16	*Fossombronia* spec.	66	
17	*Geum rivale*	65	3
18	*Hydrocotyle vulgaris*	72	RL Süderbergland: 3
19	*Juncus filiformis*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 22, 23, 24, 26, 27, 28, 29, 30, 31, 33, 36, 37, 38, 39	2S
20	*Juncus squarrosus*	18, 19, 50	3S
21	*Menyanthes trifoliata*	41, 43, 62, 65, 66, 68, 70, 71	3
22	*Montia fontana* subsp. *amporitana*	45	3
23	*Nardus stricta*	5, 19, 35, 42, 50, 59, 61, 68	3
24	*Palustriella commutata*	64	3
25	*Pedicularis sylvatica*	42	3S
26	*Philonotis caespitosa / Ph. fontana*	32, 34, 42, 43, 47, 54, 56, 57, 60, 63, 64, 66, 67, 70, 71	both 3
27	*Plagiomnium elatum*	32, 34, 54, 58, 64, 65, 66	3
28	*Plagiomnium ellipticum*	28, 32, 41, 43, 46, 47, 48, 49, 53, 56, 57, 60, 62, 65, 66, 67, 69, 70, 71, 72, 73	3
29	*Ptychostomum pseudotriquetrum*	32, 34, 43, 47, 62, 66, 73	3
30	*Rhinanthus minor*	9, 12	3S
31	*Rhizomnium pseudopunctatum*	47	2
32	*Riccardia* sp.	68	Not all spp. red-listed
33	*Sarmentypnum exannulatum*	42, 68	2
34	*Sphagnum angustifolium*	52	G
35	*Sphagnum contortum*	62, 66	1
36	*Sphagnum cuspidatum*	20	3
37	*Sphagnum subnitens*	42, 61, 62, 68	3
38	*Sphagnum teres*	49, 54, 61	2
39	*Sphagnum warnstorfii*	58	2
40	*Straminergon stramineum*	18, 21, 22, 40, 43, 44, 45, 52, 61, 68, 71	3
41	*Succisa pratensis*	5, 10, 29, 32, 35, 55, 57, 62, 68, 71	3
42	*Thuidium delicatulum*	42	2
43	*Triglochin palustris*	47, 66	2
44	*Veronica scutellata*	23, 29, 34, 40, 41, 42, 43, 45, 46, 63, 64, 67, 71	3
45	*Viola palustris*	8, 21, 22, 31, 34, 35, 40, 42, 43, 45, 46, 48, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 66, 67, 68, 69, 70	3

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LANUV NRW (Landesamt für Natur, Umwelt und Verbraucherschutz) (Ed.) (2011b): Rote Liste und Artenverzeichnis der Laubmoose – *Bryophyta* in Nordrhein-Westfalen, 3. Fassung, Stand August 2011. – https://www.lanuv.nrw.de/fileadmin/lanuv/natur/arten/rote_liste/pdf/RL-NW11-MOOSE/RL-NW11-2-Laubmoose-Bryophyta-endst.pdf (last accessed 19th Sept. 2022).

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Supplement E6. The classified plant communities characterized by categorial variables (see Supplement E1). Cell-wise arranged according to the number of plots (in parentheses) fulfilling the criteria. Information per community about district, plot shape and time of sampling are also included. Ecoregions: 336-E2, Südsauerländer Bergland; 330, Mittelsieg-Bergland; 331, Siegerland; 332, Ostsauerländer Gebirgsrand, 333, Rothaar Mountains with Hochsauerland; 334, Nordsauerländer Oberland; 335, Innersauerländer Senken; 336, Südsauerländer Bergland; 338, Bergische Hochflächen. Topsoil: (moist) humous topsoil comprises various gleysols or pseudogley. District: OE, Kreis Olpe; MK, Märkischer Kreis; SI, Kreis Siegen-Wittgenstein; HSK, Hochsauerlandkreis.

Anhang E6. Die klassifizierten Pflanzengesellschaften durch kategoriale Variablen charakterisiert (vgl. Anhang E1). Zellweise geordnet nach der Anzahl der Probeflächen (in Klammern), die die Kriterien erfüllen. Weitere Informationen betreffen die Landkreiszugehörigkeit, die Probeflächenform und die Zeiträume der Probenahme. Naturräume: 336-E2, Südsauerländer Bergland; 330, Mittelsieg-Bergland; 331, Siegerland; 332, Ostsauerländer Gebirgsrand, 333, Rothaargebirge mit Hochsauerland; 334, Nordsauerländer Oberland; 335, Innersauerländer Senken; 336, Südsauerländer Bergland; 338, Bergische Hochflächen. *Topsoil* (Oberboden): (feuchter) humoser Oberboden umfasst verschiedene Gleysol-Typen oder Pseudogley. Landkreis: OE, Kreis Olpe; MK, Märkischer Kreis; SI, Kreis Siegen-Wittgenstein; HSK, Hochsauerlandkreis.

Group no.	**1**	**2**	**3**	**4a-c**	**4a**	**4b**	**4c**	**5**
Plant community	***Juncus filiformis* meadows**		**Fen grasslands with *Eriophorum angustifolium***					
	Variant with *Agrostis capillaris*	Variant with *Taraxacum* and *Lysimachia*	Variant with *Carex panicea*	Variants with *Agrostis canina*	Variant with *Juncus acutiflorus*	Variant with *Carex rostrata*	Variant with *Anthoxanthum odoratum*	Variant with Molinia and *Sphagnum*
Number of relevés	17	11	12	22	7	6	9	11
Conservation status	NSG (6), other (5), FFH (5)	FFH (4), other (4), NSG (3)	FFH (6), NSG (4), other (2)	FFH (13), NSG (5), other (4)	FFH (3), NSG (2), other (2)	FFH (4), other (2)	FFH (6), NSG (3)	FFH (8), NSG (2), other (1)
Geology	Holocene (9), Middle Devonian (4), Pleisto-Holocene (2), Early Devonian (2)	Holocene (6), Pleisto-Holocene (1), Late Pleistocene (1), Early Carboniferous (1), Late Devonian (1), Early Devonian (1)	Middle Devonian (7), Holocene (2), Late Devonian (2), Early Devonian (1)	Middle Devonian (12), Holocene (2), Pleisto- Holocene (2), Early Carboniferous (2), Early Devonian (2), Late Carboniferous (1), Late Devonian (1)	Middle Devonian (3), Pleisto-Holocene (1), Late Carboniferous (1), Early Carboniferous (1), Early Devonian (1)	Middle Devonian (4), Holocene (1), Early Devonian (1)	Middle Devonian (5), Holocene (1), Pleisto- Holocene (1), Early Carboniferous (1), Late Devonian (1)	Holocene (4), Early Devonian (3), Middle to Late Devonian (2), Middle Devonian (2)
Ecoregion, *Naturraum*	336-E2 (9), 333 (4), 330 (1), 331 (1), 332 (1), 338 (1)	332 (5), 336-E2 (3), 333 (2), 336-E1 (1)	333 (9), 332 (2), 335 (1)	333 (15), 336-E2 (3), 333 (2), 331 (1), 332 (1)	334 (3), 333 (2), 336-E2 (2)	333 (4), 331 (1), 336-E2 (1)	333 (8), 332 (1)	333 (8), 331 (1), 334 (1), 336-E2 (1)
Agricultural land-use and intensity	Mown (12), Irregularly mown or grazed (3), Grazed (1), None (1)	Mown (9), Irregularly mown or grazed (2)	Grazed (7), Irregularly mown or grazed (3), None (2)	Grazed (12), None (6), Irregularly mown or grazed (3), Mown (1)	Grazed (3), None (3), Irregularly mown or grazed (1)	None (3), Irregularly mown or grazed (2), Mown (1)	Grazed (9)	None (6), Mown (3), Irregularly mown or grazed (2)
Adjacent formation	Grassland (12), Spruce forest (3), Various forest types (2)	Grassland (8), Various forest types (2), Deciduous forest (1)	Spruce forest (4), Grassland (4), Deciduous forest (2), Arable field (1), Various forest types (1)	Spruce forest (9), Grassland (6), Various forest types (4), Deciduous forest (3)	Grassland (3), Spruce forest (3), Various forest types (1)	Grassland (2), Various forest types (2), Deciduous forest (1), Spruce forest (1)	Spruce forest (5), Deciduous forest (2), Grassland (1), Various forest types (1)	Spruce forest (9), Grassland (1), Heath (1)
Soil type	Pseudogley (9), Auengley (3), Braunerde (3), Gley (1), Parabraunerde (1)	Gley (4), Auengley (2), Braunerde (2), Pseudogley (2), Niedermoorgley (1)	Niedermoorgley (3), Pseudogley (3), Kolluvisol (2), Nassgley (2), Braunerde (1), Gley (1)	Gley (6), Braunerde (5), Nassgley (5), Niedermoorgley (3), Pseudogley (3)	Nassgley (2), Pseudogley (2), Braunerde (1), Gley (1), Niedermoorgley (1)	Gley (2), Nassgley (2), Niedermoorgley (2)	Braunerde (4), Gley (3), Nassgley (1), Pseudogley (1)	Niedermoorgley (4), Braunerde (3), Pseudogley (2), Gley (1), Nassgley (1)
Topsoil (as identified in the field)	(moist) humous (Ah/aA) (17)	(moist) humous (Ah/aA) (11)	Fen peat (nH) (6), Bog peat (hH) (5), (moist) humous (Ah/aA) (1)	Bog peat (hH) (11), Fen peat (nH) (9), (moist) humous (Ah/aA) (2)	Bog peat (hH) (5), Fen peat (nH) (2)	Bog peat (hH) (3), Fen peat (nH) (3)	Fen peat (nH) (4), Bog peat (hH) (3), (moist) humous (Ah/aA) (2)	Bog peat (hH) (6), Fen peat (nH) (3), (moist) humous (Ah/aA) (2)
Soil moisture (at the time of sampling; note that summer 2019 was much dryer than usual)	dry (15), very dry (2)	dry (10), slightly moist (1)	almost wet (7), slightly moist (3), wet with above-ground water (1), dry (1)	dry (8), slightly moist (6), almost wet (6), wet with above-ground water (1), very dry (1)	slightly moist (3), almost wet (2), wet with above-ground water (1), dry (1)	dry (3), almost wet (2), slightly moist (1)	dry (4), slightly moist (2), almost wet (2), very dry (1)	dry (4), very dry (2), almost wet (2), wet with above-ground water (2), slightly moist (1)
Shape of the stands	flat, extensive (7), shallow depression (5), linear near ditch (5)	shallow depression (8), flat, extensive (2), linear near ditch (1)	extensive by spring or stream (6), flat, extensive (4), shallow depression (1), linear near ditch (1)	flat, extensive (16), flushes, springs (3), linear near ditch (3)	flat, extensive (4), linear near ditch (2), flushes, springs (1)	flat, extensive (5), linear near ditch (1)	flat, extensive (7), flushes, springs (2)	flat, extensive (6), linear near ditch (3), shallow depression (1), flushes, springs (1)
District, *Landkreis*	OE (8), MK (6), SI (3), HSK (1)	HSK (6), MK (2), OE (2), SI (1)	HSK (9), SI (2), OE (1)	HSK (12), SI (5), MK (2), OE (2), SO (1)	HSK (2), SI (2), MK (1), OE (1), SO (1)	HSK (3), MK (1), OE (1), SI (1)	HSK (7), SI (2)	SI (5), HSK (3), OE (2), MK (1)
Plot shape	Quadrat (9), linear (8)	Quadrat (8), linear (3)	Quadrat (8), linear (4)	Quadrat (19), linear (3)	Quadrat (6), linear (1)	Quadrat (4), linear (2)	Quadrat (9)	Quadrat (7), linear (4)
Sampling period	21.05.-22.06.2019	31.05.-20.06.2019	10.06.-08.08.2019	22.06.-12.08.2019	22.06.-12.08.2019	19.06.-20.07.2019	15.06.-21.07.2019	13.06.-20.07.2019

Supplement E7. All numeric variables with arithmetic means / medians of Ellenberg indicator values (standard deviation in parentheses) and minimum-maximum values in the respective rows below. Highest and lowest mean / median in bold font.

Anhang E7. Alle numerischen Variablen mit arithmetischen Mittelwerten / Medianen der Ellenberg-Indikatorwerte (Standardabweichung in Klammern) und Minimum-Maximum-Werten jeweils in den Zeilen darunter. Höchster und niedrigster Mittelwert / Median in fetter Schrift.

Group number	**1**	**2**	**3**	**4a-c**	**4a**	**4b**	**4c**	**5**
Plant community	***Juncus filiformis* meadows**		**Fen grasslands with *Eriophorum angustifolium***					
	Variant with *Agrostis capillaris*	Variant with *Taraxacum* and *Lysimachia*	Variant with *Carex panicea*	Variants with *Agrostis canina*	Variant with *Juncus acutiflorus*	Variant with *Carex rostrata*	Variant with *Anthoxanthum odoratum*	Variant with *Molinia* and *Sphagnum*
n =	17	11	12	22	7	6	9	11
pH (H_2O)	5 (5.41)	5.12 (5.52)	**5.39 (5.37)**	5.09 (5.14)	5.2 (5.22)	5.01 (4.95)	5.08 (5.41)	**4.34 (4.43)**
	4.66-5.26	4.9-5.61	4.79-6.82	4.48-6.19	4.69-5.8	4.48-6.19	4.82-5.69	3.88-5.57
pH (KCl)	4.12 (4.46)	4.29 (4.63)	**4.81 (4.85)**	4.34 (4.41)	4.49 (4.56)	4.29 (4.25)	4.29 (4.55)	**3.48 (3.58)**
	3.77-4.59	3.99-4.74	4.3-6.48	3.79-5.73	4.04-5.19	3.79-5.73	4.03-5.07	3.03-5.01
C/N (g/g)	11.71 (0.84)	**11.41 (0.94)**	14.28 (1.43)	14.4 (1.23)	14.36 (1.28)	14.9 (0.75)	14.09 (1.34)	**19.46 (4.53)**
	10.45-13.36	10.59-13.89	11.92-17.39	12.47-16.83	12.94-16.65	13.76-15.97	12.47-16.83	13.54-30.32
Base saturation excl. Na (%)	66.82 (12.37)	80.24 (11.72)	**96.89 (3.12)**	89.05 (8.77)	85.52 (11.27)	91.35 (7.56)	90.28 (6.03)	**45.91 (28.65)**
	38.56-87.98	58.03-94.67	87.37-99.58	63.86-98.93	63.86-98.93	77.5-98.69	80.07-97.86	3.7-86.08
C (mg/g)	**108.93 (42.84)**	125.66 (31.23)	182.53 (86.18)	267.04 (107.48)	275.24 (95.19)	354.25 (70.51)	202.51 (92.69)	**367.86 (94.46)**
	58.10-207-52	98.19-213.66	60-83-334.59	108-32-428.38	108.32-409.71	243.67-428.38	133.9-377.54	146.95-464.04
N (mg/g)	**9.2 (3.25)**	10.91 (1.94)	12.74 (5.79)	18.28 (6.73)	19.08 (6.74)	**23.62 (3.84)**	14.11 (5.36)	19.19 (4.87)
	5.35-16.31	8.06-15.36	4.52-21.95	8.15-31.1	8.15-31.1	17.13-28.19	9.2-25.07	10.81-28.09
C_{org} (mg/g)	**108.74 (42.85)**	125.44 (31.21)	182.21 (86.12)	266.83 (107.48)	275.03 (95.16)	354.04 (70.58)	202.32 (92.67)	**367.73 (94.58)**
	57.84-207.34	97.99-213.41	60.66-334.39	108.17-428.27	108.17-409.25	243.45-428.27	133.76-377.45	146.38-463.97
P (µmol$_c$/g)	1.49 (0.63)	2.09 (0.54)	0.95 (0.68)	1.39 (1.24)	1.34 (1.42)	**2.15 (1.48)**	**0.92 (0.36)**	1.33 (1.18)
	0.49-2.79	1.25-3.12	0.11-2.06	0.19-5.37	0.19-4.53	0.83-5.37	0.41-1.68	0.13-3.92
Al^{3+} (µmol$_c$/g)	20.81 (9.18)	14.19 (8.4)	3.35 (5.49)	13.17 (15.79)	18.37 (21.79)	11.26 (16.3)	**10.4 (5.64)**	**37.17 (46.25)**
	4.21-39.54	2.45-32.65	0-20	0.1-60.93	0.66-60.93	0.1-46.26	1-16.79	0.01-178.22
Ca^{2+} (µmol$_c$/g)	**60.67 (24.79)**	107.08 (45.43)	284.74 (130.02)	236.89 (149.97)	247.07 (170.36)	**305.1 (137.45)**	183.49 (117.36)	77.12 (66.83)
	20.97-110.01	50.53-178.79	104.51-591.49	68.5-617.39	72.93-617.39	170.2-570.34	68.5-464.13	8.17-193.25
Fe^{2+} (µmol$_c$/g)	**0.8 (1.08)**	1.14 (1.82)	1.36 (2.3)	1.75 (3.08)	2.19 (4.54)	2.32 (2.95)	1.03 (0.68)	**13.64 (21.66)**
	0.05-3.26	0.09-6.44	0-6.78	0.02-13.28	0.02-13.28	0.07-8.67	0.21-2.67	0.02-80.03
K^{+} (µmol$_c$/g)	5.94 (2.4)	6.47 (1.49)	5.97 (5)	7.92 (4.48)	9.11 (3.7)	**11.52 (4.03)**	**4.59 (2.61)**	6.01 (2.04)
	2.21-9.93	3.76-9.22	1.44-18.73	2.47-19	3.63-13.76	7.42-19	2.47-11.3	1.8-8.92
Mg^{2+} (µmol$_c$/g)	**13.73 (12.07)**	20.38 (8.03)	45.07 (30.47)	51.04 (34.69)	48.05 (22.82)	**82.55 (45.77)**	32.37 (11.06)	21.66 (14.97)
	3.29-55.7	9.93-33.94	11.48-126.36	16.46-174.97	16.46-81.18	41.86-174.97	18.62-57.3	5.33-58.93
Mn^{2+} (µmol$_c$/g)	12.27 (5.62)	10.46 (4.2)	4.04 (2.84)	8.85 (8.76)	**15.82 (10.39)**	9.28 (6.71)	**3.14 (1.76)**	5.29 (8.31)
	3.8-22.66	1.92-14.8	0.94-9.08	1.53-36.79	3.55-36.79	2.44-23.27	1.53-7.38	0.27-28.51
H (µmolc/g)	2.72 (0.85)	2.17 (0.75)	**1 (1.19)**	3.55 (4.94)	2.12 (2.28)	6.68 (8.07)	2.59 (1.75)	**186.97 (502.01)**
	1.54-4.79	0.77-3.12	0-4.06	0.06-23.16	0.07-7.01	0.06-23.16	0.59-6.81	0.34-1771.28
CEC excl. Na (µmol$_c$/g)	**116.95 (35.27)**	161.89 (44.68)	345.52 (146.72)	323.17 (163.78)	342.73 (176.83)	**428.71 (127.76)**	237.61 (123.79)	347.86 (485.1)
	67.44-198.56	109.73-244.21	121.29-644.99	112.49-715.61	112.49-715.61	283.88-665.07	113.25-544.36	65.76-1857.03
Exchangeable base pool (µmol$_c$/g)	**80.34 (34.74)**	133.93 (51.7)	335.78 (146.59)	295.85 (169.39)	304.23 (187.02)	**399.17 (143.68)**	220.44 (127.72)	104.79 (80.21)
	28.51-174.69	67.18-216.65	117.43-642.29	93.02-707.93	93.02-707.93	220.02-656.32	93.02-532.72	18.89-247.46
Soil density (g/cm³)	**0.37 (0.14)**	0.31 (0.09)	0.21 (0.08)	0.18 (0.08)	0.14 (0.03)	**0.12 (0.01)**	0.26 (0.07)	0.16 (0.07)
	0.13-0.63	0.13-0.43	0.11-0.39	0.09-0.37	0.1-0.2	0.1-0.14	0.09-0.37	0.08-0.27
C (mg/cm³)	35.18 (5.07)	36.97 (6.76)	**32.6 (9.34)**	41.93 (13.5)	35.33 (8.78)	40.48 (5.08)	48.04 (17.19)	**54.03 (19.67)**
	25.68-42.58	25.45-49.02	18.93-54.65	21.28-93.07	21.28-48.74	32.79-48.12	31.78-93.07	25.09-82.85
N (mg/cm³)	3.04 (0.6)	3.27 (0.7)	**2.28 (0.62)**	2.94 (0.97)	2.47 (0.66)	2.71 (0.31)	**3.44 (1.2)**	2.95 (1.24)
	1.92-4.07	1.94-4.13	1.37-3.74	1.6-6.18	1.6-3.7	2.31-3.17	1.89-6.18	1.13-5.52
C_{org} (mg/cm³)	35.11 (5.05)	36.9 (6.75)	**32.54 (9.35)**	41.9 (13.5)	35.3 (8.78)	40.46 (5.09)	47.99 (17.2)	**54 (19.68)**
	25.65-42.49	25.41-48.96	18.88-54.62	21.25-93.04	21.25-48.69	32.76-48.1	31.75-93.04	25.07-82.83
P (µmol$_c$/cm³)	0.53 (0.25)	**0.63 (0.21)**	**0.16 (0.11)**	0.22 (0.15)	0.17 (0.17)	0.25 (0.16)	0.24 (0.12)	0.22 (0.2)
	0.12-0.95	0.33-1.14	0.02-0.32	0.04-0.6	0.04-0.54	0.08-0.6	0.06-0.41	0.02-0.58
Al^{3+} (µmol$_c$/cm³)	**7.61 (4.34)**	4.36 (2.86)	**0.64 (0.98)**	2.22 (2.05)	2.15 (2.34)	1.19 (1.63)	2.96 (1.74)	6.09 (8.52)
	0.73-20.74	0.82-9.2	0-3.63	0.01-5.91	0.08-5.91	0.01-4.65	0.09-5.09	0-31.82
Ca^{2+} (µmol$_c$/cm³)	21.14 (8.97)	31.36 (12.8)	**51.31 (12.29)**	36.94 (17.95)	32.75 (20.55)	36.07 (16.76)	40.78 (15.57)	**9.75 (7.81)**
	6-40.35	14.25-59.86	38.41-79.11	8.34-73.45	8.34-73.45	17.11-61.9	19.57-71.61	0.82-27.52
Fe^{2+} (µmol$_c$/cm³)	**0.2 (0.23)**	0.24 (0.27)	0.23 (0.38)	0.26 (0.4)	0.29 (0.61)	0.26 (0.33)	0.24 (0.13)	**2.17 (3.31)**
	0.02-0.72	0.03-0.81	0-1.23	0-1.79	0-1.79	0.01-0.97	0.05-0.53	0-11.72
K^{+} (µmol$_c$/cm³)	1.93 (0.59)	**1.99 (0.71)**	0.98 (0.56)	1.18 (0.46)	1.17 (0.41)	1.35 (0.49)	1.07 (0.43)	**0.93 (0.47)**
	1.17-3.41	0.97-3.42	0.47-2.14	0.7-2.08	0.7-1.82	0.78-2.06	0.7-2.08	0.27-1.71
Mg^{2+} (µmol$_c$/cm³)	4.25 (2.44)	6.13 (2.89)	7.96 (4.98)	7.89 (4.34)	6.1 (2.46)	**9.87 (6.41)**	7.96 (2.96)	**3.09 (2.09)**
	1.31-9.7	2.8-12.44	4.49-23.86	3.23-23.55	3.23-9.86	4.21-23.55	4.94-15.57	0.45-8.62
Mn^{2+} (µmol$_c$/cm³)	**4.16 (1.85)**	3.42 (1.76)	**0.72 (0.4)**	1.29 (1.11)	2.13 (1.37)	1.13 (0.93)	0.74 (0.32)	0.94 (2.01)
	1.15-8.37	0.24-6.31	0.13-1.46	0.27-4.87	0.48-4.87	0.27-3.13	0.36-1.28	0.04-7.18
H (µmol$_c$/cm³)	0.98 (0.42)	0.65 (0.28)	**0.18 (0.2)**	0.58 (0.61)	0.28 (0.3)	0.74 (0.89)	0.7 (0.46)	**27.52 (75.24)**
	0.27-2.25	0.26-1.15	0-0.74	0.01-2.6	0.01-0.94	0.01-2.6	0.05-1.68	0.09-265.28
CEC (µmol$_c$/cm³)	**40.28 (12.21)**	48.16 (13.83)	**62.01 (12.21)**	50.35 (18.13)	44.87 (20.68)	50.6 (17)	54.46 (15.43)	50.49 (72.79)
	22.65-65.76	30.84-78.53	47.43-86.26	22.1-85.14	22.1-85.14	28.54-72.18	32.35-82.9	5.6-278.13
Exchangeable base pool (µmol$_c$/cm³)	27.33 (10.01)	39.48 (15.23)	**60.25 (12.88)**	46.01 (19.44)	40.03 (22.24)	47.28 (18.52)	49.81 (16.33)	**13.77 (9.65)**
	10.47-46.49	18.94-74.35	45.92-85.9	14.94-84.22	14.94-84.22	22.12-71.23	26.57-80.02	1.61-37.44
Open soil (%)	3 (7)	**1 (2)**	**20 (20)**	8 (10)	11 (16)	3 (4)	8 (5)	4 (6)
	0-30	0-5	1-80	0-50	0-50	0-10	2-15	0-20
Litter (cm)	4 (2)	4 (1)	7 (5)	9 (4)	**12 (5)**	10 (3)	8 (4)	10 (6)
	2-10	2-7	0-20	4-20	5-20	4-15	4-15	3-20
Litter (%)	21 (21)	**18 (21)**	29 (34)	40 (32)	53 (34)	**55 (29)**	19 (18)	46 (22)
	2-60	1-60	0-90	2-90	5-85	3-90	2-50	2-80
Bryophyte layer height (cm)	3 (1)	**2 (1)**	4 (2)	5 (1)	4 (1)	5 (1)	5 (1)	**6 (2)**
	2-5	0-3	2-10	2-8	2-5	4-7	3-8	2-10
Bryophyte layer cover (%)	58 (21)	38 (29)	54 (21)	50 (25)	**32 (25)**	56 (20)	59 (21)	**64 (28)**
	30-95	0-85	20-80	3-90	3-70	30-80	25-90	15-95
Herb layer height (cm)	**27 (10)**	29 (8)	38 (11)	48 (16)	**64 (11)**	38 (6)	43 (14)	36 (8)
	15-50	20-45	25-60	25-80	50-80	25-45	30-70	20-50
Herb layer cover (%)	78 (12)	**90 (11)**	69 (13)	74 (16)	83 (12)	**60 (14)**	75 (12)	66 (18)
	50-95	65-100	50-95	40-98	60-98	40-80	60-95	40-97
Shrub layer height (m)	0 (0)	0 (0)	0 (0)	0 (1)	0 (1)	**1 (1)**	0 (0)	0 (0)
	0-0	0-0	0-0	0-3	0-3	0-3	0-0	0-0
Shrub layer cover (%)	0 (0)	0 (0)	1 (4)	1 (1)	0 (1)	1 (2)	0 (1)	0 (0)
	0-0	0-0	0-15	0-5	0-2	0-5	0-3	0-0
Tree layer height (m)	0 (0)	0 (0)	1 (2)	1 (3)	0 (0)	**2 (5)**	0 (0)	1 (2)
	0-0	0-0	0-8	0-13	0-0	0-13	0-0	0-8
Tree layer cover (%)	0 (0)	0 (0)	1 (4)	1 (6)	0 (0)	**5 (11)**	0 (0)	0 (1)
	0-0	0-0	0-15	0-30	0-0	0-30	0-0	0-2
Ellenberg Light (L)	7 (0)	7 (0)	7 (0)	7 (0.2)	7 (0)	7 (0.4)	7 (0)	7 (0.3)
	7-7	7-7	7-7	7-8	7-7	7-8	7-7	7-8
Ellenberg Temperature (T)	5 (0)	5 (0.1)	5 (0.3)	5 (0.4)	5 (0.3)	4 (0.5)	5 (0)	4 (0.5)
	5-5	5-5.5	4-5	4-5	4-5	4-5	5-5	3.5-5
Ellenberg Continentality (C)	3 (0.2)	3 (0.3)	3 (0)	3 (0.6)	3 (0.5)	**3.75 (0.6)**	3 (0)	3 (0.8)
	3-4	3-4	3-3	3-5	3-4.5	3-5	3-3	3-5
Ellenberg Moisture (M)	7 (0.4)	7 (0.5)	8 (0.4)	8 (0.5)	8 (0.5)	7.5 (0.5)	7 (0.5)	7 (0.4)
	6-8	6-8	7-8	7-8	7-8	7-8	7-8	7-8
Ellenberg Soil reaction (R)	5 (0.5)	5 (0.5)	5 (0.4)	4 (0.6)	4 (0.5)	4.25 (0.7)	4 (0.4)	**3 (0.5)**
	4-5	4-5	4-5	3-5	4-5	3-5	4-5	2-4
Ellenberg Nutrients (N)	4 (0.6)	**5 (0.7)**	4 (0.5)	3 (0.7)	4 (0.7)	3 (0.7)	3 (0.5)	**2 (0.4)**
	3-5	3-5	3-4	2-5	3-5	2-4	3-4	2-3
Precipitation (mm/a)	1177 (90)	**1009 (199)**	1070 (158)	1117 (148)	1042 (158)	**1207 (67)**	1116 (146)	1114 (120)
	943-1278	769-1278	742-1267	769-1278	866-1278	1114-1278	769-1267	866-1267
Temperature (°C)	**9 (1)**	7 (1)	7 (1)	7 (1)	8 (1)	7 (1)	**6 (1)**	7 (1)
	6-9	6-9	6-9	6-9	7-9	6-9	6-7	6-9
Elevation (m a.s.l.)	**397 (64)**	415 (78)	548 (75)	544 (123)	455 (74)	579 (171)	**590 (65)**	554 (129)
	278-580	311-569	405-653	359-780	359-572	359-780	448-679	291-810
Inclination (°)	2 (1)	**1 (1)**	**6 (4)**	4 (2)	4 (2)	5 (2)	5 (2)	3 (2)
	0-5	0-3	1-17	1-8	1-8	2-7	1-8	1-8
Aspect (°)	168 (113)	**156 (95)**	**225 (103)**	212 (104)	199 (72)	236 (123)	205 (109)	175 (121)
	23-360	45-315	23-360	45-360	90-315	45-360	68-360	23-360
Topsoil depth (cm)	16 (3)	**14 (3)**	36 (19)	48 (28)	54 (24)	**58 (29)**	37 (26)	44 (30)
	6-21	10-20	10-76	12-100	22-88	12-100	13-100	5-100

Supplement E8. Vegetation table of all investigated plots (no. 1-73) in the region of Süderbergland, NRW. "D/C" = differential or character species of higher groups. "d" = differential species of the communities (groups). "Acc." = Accompanying species.

Anhang E8. Vegetationstabelle aller untersuchten Plots (no. 1-73) in der Region Süderbergland, NRW. "D/C" = Gruppendifferenzialarten oder Charakterarten höherer Gruppen. "d" = Differentialarten der Gesellschaften (Gruppen). "Acc" = Begleitarten.

		Juncetum filiformis, variant with *Agrostis capillaris* (d1)	*Juncetum filiformis*, variant with *Taraxacum* and *Lysimachia* (d2)	*Caricetum nigrae caricetosum paniceae* (d3)	*Caricetum nigrae* variants with *Agrostis canina* (d5) (see Supplement E9)	*Carici echinatae-Sphagnetum* (d4)
	plot no.	29 27 2 8 38 17 1 9 13 28 33 10 39 7 15 14 30	24 36 31 11 26 5 12 16 3 6 37	4 23 72 34 57 70 65 60 47 64 73 43	53 48 21 69 41 40 45 32 49 58 52 68 62 71 35 42 66 54 63 67 46 56	44 22 25 55 20 61 50 51 59 18 19
	coordinates (WGS 84, 32U)	5662052 411965; 5650357 463922; 5644575 420198; 5644222 418893; 5676211 469163; 5662807 402015; 5638995 418822; 5652486 433562; 5671719 416727; 5662037 411374; 5668304 432473; 5651854 434149; 5655759 439961; 5644242 418046; 5661825 407879; 5667866 409551; 5656553 416858	5676843 468667; 5668601 476197; 5667083 399197; 5657453 432167; 5646359 442092; 5673557 480542; 5653850 417812; 5663075 411040; 5678455 479745; 5676532 479214; 5668003 481451	5675190 469970; 5676919 468649; 5682789 446401; 5690846 469555; 5655930 433924; 5672450 465241; 5668764 470940; 5677255 470563; 5671742 459206; 5678505 476427; 5647693 463033; 5638747 457526	5646322 455348; 5651714 413247; 5643011 447217; 5661337 411786; 5698353 466593; 5700987 463872; 5700234 480738; 5649923 432608; 5659231 410459; 5678739 470634; 5655839 446036; 5674018 458984; 5672583 465513; 5674942 466098; 5664914 477482; 5679746 465488; 5677130 471053; 5647873 454678; 5675817 471621; 5673711 461279; 5674802 460543; 5647226 455782	5700758 477800; 5643009 447198; 5642427 432186; 5644273 446572; 5672606 464388; 5655182 443550; 5654671 449946; 5678498 469789; 5648893 448893; 5645415 445415; 5644913 445419
	group no.	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3 3 3 3	4a 4a 4a 4a 4a 4a 4a 4b 4b 4b 4b 4b 4b 4c 4c 4c 4c 4c 4c 4c 4c 4c	5 5 5 5 5 5 5 5 5 5 5
D/C 1	1 *Juncus filiformis*	8 4 18 3 18 8 18 3 3 4 8 4 4 2 18 4 3	38 8 4 38 8 18 18 8 8 8 3	4 8	. . . .	. 4 . . . . 4 .
	2 *Trifolium pratense*	. 2 3 1 2 2 3 3 2 . . 1 . 2 2 3 8	2 2 . 2 . 3 4 4 8 . 2	. . . . 2 . . 2	. . . .	. . . .
	3 *Plantago lanceolata*	. . . . 2 3 3 3 1 . 3 . 2 2 1 4 8	. . 2 . 2 2 3 3 4 2 .	. . . . 1 . 2 .	. . . . 2 . . . . 2 . . .	. . . .
	4 *Carex leporina*	. 2 38 2 . 3 2 4 2 . 3 2 2 2 . . 8	2 3 2 . 2 3 4 . 8 . 4	. . . .	. . . . 3	. . . . . . 18 . . . .
	5 *Alopecurus pratensis*	3 . 2 . . . . . 4 8	. 38 . 3 4 . . 3 8 2 8	. . . .	. . . .	. . . .
	6 *Festuca pratensis*	. . . . 2 . . . . 2 8 2	. 3 . . . . . 3 18 2 8	. . . . 3 .	. . . .	. . . .
D/C 2	7 *Eriophorum angustifolium*	. . . . 2	. . . .	2 2 18 3 3 3 3 8 4 3 3 3	3 4 2 4 3 18 3 3 3 3 4 8 3 3 4 4 3 3 3 3 4 3	8 3 18 18 18 18 38 3 8 4 4
	8 *Carex echinata*	. . . . 1 2 1 . . . . . 3	. . 2 . 3	. 18 . 3 3 8 3 4 8 3 3 3	3 2 . 2 . 2 . 8 3 . 2 3 8 3 2 18 4 3 3 3 3 4	3 2 . 4 2 3 . . . 2 4 4
	9 *Potentilla erecta*	. . . .	. . 4	. . . 1 3 2 1 3 3 . 1 2	1 2 . 3 . . 1 2 . 8 . 8 3 . 2 3 2 . 3 2 . .	. 3 . 3 . 3 3 2 18 . 1
	10 *Epilobium palustre*	. . . . 1	. . . .	. . 3 3 3 2 3 3 3 3 . 1	. 3 3 2 3 3 3 2 2 3 1 3 2 . 2 . 3 3 3 2 2 3	. 2 2 2 . 1 . . 3 . .
	11 *Viola palustris*	. . . 1	. . 4	. . . 2 3 3 . 3 . . . 3	1 3 3 3 . 3 4 . . 3 3 3 3 . 2 4 2 3 3 3 3 3	. 2 . 4 . 1 2 . 8 . .
	12 *Carex nigra*	. 2 2 . . . . 2 . 8 . 3 . .	4 3 4 3	. 3 3 4 . 38 . . 2 38 3 8	18 18 . 8 3 2 . 8 38 18 8 4 8 38 . 18 4 . 8 3 3 3	38 8 . 4 4 . 18 3 38 2 3
	13 *Aulacomnium palustre*	. 3 . . . . 4	. . . .	38	3 . 2 . . 3 2 8 3 3 . 3 . . 3 . 3 . . 3 . 8	. 8 . . . . . 3 8 2 68
	14 *Carex canescens*	8	. . . .	. 4 . 1	. 3 . . 1 1 3 . . . . . 2 . . . 3	38 2 . 4 . . . 18 . . .
	15 *Straminergon stramineum.*	. . . .	. . . .	 3	. 8 . . 3 38 . . 3 3 . 3	4 2 . . . 3 . . . 2 .
d 1	16 *Agrostis capillaris*	. . . 4 . . . 18 38 4 . 2 . 38 18 18 38	. . 2 . . . 18 38 . . .	. 3	. . . .	. . . . . . 8 3 . . .
	17 *Luzula campestris*	. . . . 4 2 . . . . 2 . 2 3 1 2 3	2	2 2 . . 2 2	. . . . . . 2 . . . . . 2 . . . 3 1 . . 3 .	3 . . . . . 1 2 . . .
	18 *Anemone nemorosa*	. . . . 3 2 . 2 3 3 1 1	. . . .	. . . .	. . 2	3 . . . 2 . . . . . .
	19 *Carex pallescens*	. . . . . . 2 . . . . 3 2 . . . 3	. . . .	2	. . . .	. . . .
d 2	20 *Taraxacum* sect. *Taraxacum*	. . . . 1 2 . . . . 2 . . .	. . . . 2 1 1 2 3 2 1	. . 1	. . . .	. . . .
	21 *Lysimachia nummularia*	. . . . 2	. . . 1 . 2 2 . . 3 2	. 1 . . . . . . 4 . . .	. . . . 4 .	. . . .
	22 *Bellis perennis*	. . . . 1 . . . . . . 1 3	. . . . . 2 3 2 . . .	. . . .	. . . .	. . . .
	23 *Equisetum palustre*	. . . .	. 2 . . . . 2 2	2	. . . .	. . . .
	24 *Trifolium campestre*	. . . .	. . . . 2 2 1	 2	. . . .	. . . .
d 3	25 *Carex panicea*	. . 2 8 8 2 . 2 2 . . 3 . . . 3 .	. . . . 1 . 3 . . . 18 8	4 18 8 4 8 2 3 38 4 3 4 8	. 3 . . . . 18 . 8 3 8 18 4 18 . 3 3 . 3	. 3 . . . 4 . . 3 . .
	26 *Crepis paludosa*	. . . . . 2 . . . . . 8 1	. . 2	. . . . 3 3 3 3 3 8 8 3	3 2 . . . . . 3 2 . . . 2 3 . 1 3	. . . 2 . . . .
	27 *Dactylorhiza majalis*	. . . . . 1	. . . . 1 . . .	. . . . 3 . 2 2 . 1 1 1	. . . . 3 . . 2 2 1 . . . . 1 . . .	. . . .
	28 *Glyceria fluitans*	. . . .	. 2 2	. . . . 2 3 3 3 8	. . . . 2	. . . .
	29 *Juncus articulatus*	. . . .	. . . .	. . . . . . 3 . 38 3 . 8	. . . . 3 38 3	. . . .
	30 *Juncus bulbosus*	. . . .	. . . .	. . . . . 4 . . 4 . 3 3	. . . . 8 3 . 3 . 3	. . . 18 . . . .
	31 *Luzula multiflora*	. . . .	. . . .	. . . . 2 3 . 1 2	. . . . 1 . . . . 2	. . . . 2 . . .
	32 *Ptychostomum pseudotriquetrum*	. . . .	. . . .	. . 18 . . . . . 4 . 3 8	. . . . . . 2 . . . . . 3 . . . 2	. . . .
	33 *Equisetum arvense*	. . . .	. . . .	. . . .	2 . . . . 2	. . . .
	34 *Plagiomnium elatum*	. . . .	. . . .	. . 3 . . 2 . . 1 . . .	. . . . 3 . 3 . . . . . . 8 4	. . . .
	35 *Veronica beccabunga*	. . . .	. . . .	. . . 3 . . . 3 . . 3 .	. . . .	. . . .
		. . . .	. . . .	. . . . . 1 . . . . 4 1	. . . .	. . . .
d4	36 *Agrostis canina*	68 8 38 . . 8 18 . 2 . 8 . 4 . 2 . .	. 18 38 68 18 . . . . 18 38	. 8 . . . . . 8 2	4 8 2 8 2 8 38 . 4 4 3 4 2 . 8 3 3 18 8 4 8 8	. 18 8 3 . . . 3 8 3 18
	37 *Brachythecium* spp.	. 18 . . . . 18 . . 2 . . 2	. . . . . 18 2	18 . 3 2 . . . 2 . 3 3 3	2 18 8 38 8 3 3 4 8 18 2 3 3 . . . 3 2 3 . 3 .	. 18 8 . . . . . 8 . .
	38 *Poa trivialis*	. . 2	. . . . 2 2	. . . . . 3 . 2 . . 3 .	3 3 . . 4 . 3 . . 2 . . . . . . 2 8 2 . 3 .	. . . .
	39 *Carex rostrata*	. . . .	. . . .	. . . . . . 2 3	. . . . . 2 . 8 3 3 8 . . . . 8 . . .	. 18 . . . .
	40 *Pellia* sp.	. . . .	. . . .	. . . . . . 2	. . 2 3 . 3 . 2 . . . . 3 . 3 . . .	. . . .
d5	41 *Molinia caerulea*	. . . . 3 . . . . . . 4	. . . . . . 2	. . . .	. . . 2 8 . . 3 . . 2 . 38	. . 3 8 . . 38 . . 38 38
	42 *Deschampsia flexuosa*	. . . .	. . . .	. . . .	. . . .	. . . . . . 2 4 3 18 2
	43 *Galium saxatile*	. . . .	. . . .	. . . .	. . . .	. . . . . 3 3 8 . 2 3
	44 *Polytrichum commune*	. . . .	. . . .	. . . .	. . . . 1	. . . . 4 3 . . 3 3 2
	45 *Amblystegium serpens*	. . . .	. . . .	. . . .	. . 18 . . . . 3 . . . . 3 . . . . 2 .	3 8 2 . . . . . 3 . .
	46 *Nardus stricta*	. . . .	. . . . . . 2	. . . .	. . . . 3 . 2 1	. . . . . 2 2 . 3 . 2
	47 *Pleurozium schreberi*	. . . .	. . . .	. . . .	. . . .	. . . . 18 2 88 4
	48 *Sphagnum fallax*	. . . .	. . . .	. . . .	. . . .	. 3 . 68 38 18
	49 *Festuca ovina* agg.	. . . .	. . . .	. . . .	. . . .	. . . . 3 2 3
	50 *Juncus squarrosus*	. . . .	. . . .	. . . .	. . . .	. . . . 1 . 8 8
D/C 3	51 *Cirsium palustre*	3 . 2 1 . . 2 . . 2 . 2 2 1 2 . 2	2 . . . . 2 . . . 1 .	2 2 8 2 3 2 3 3 2 3 3 3	. 3 3 3 3 2 3 3 3 3 3 3 3 1 2 1 3 3 8 3 3 3	. 3 . 2 . 3 . . 1 . .
	52 *Galium uliginosum*	. . 2 . . . 2	. . . . . 2	3 2 . 3 3 2 3 3 4 3 3 3	3 4 . 3 3 . . . 8 4 . 3 2 2 3 3 3 3 3 3 4 3	. . . .
	53 *Climacium dendroides*	. . . 4 . . . . 2	. . . .	. 18 3 . 38 3 8 4 3 8 3 18	. 2 . . . . 8 . . . . 3 3 . . . 3 3 . 18 3 2	. . . .
	54 *Equisetum fluviatile*	. 1 . . 1 . . . . . . 1	. . . .	. 1 . 3 2 3 3 2 . 38 2 2	. 8 2 . 3 . . 2 . 1 . 3 . 2 . . . 2 2 . 4 .	. 1 . . . . 2 .
	55 *Juncus acutiflorus*	2 . . . . 18 3 . . 8 2 2 . . 3 . 8	. 2 8 . . . 3 8 . 2 .	. 3 3 38 18 . 8 . 8 68 8 68	8 38 68 18 68 . 3 18 . . . . 3 3 38 38 3 .	. 4 . 18 . . . .
	56 *Valeriana dioica*	. . . .	. . . .	3 2 . 8 8 8 4 . 3 4 3 .	. 4 . 3 . . . . . 8 . 4 3 4 4 8 3 3 . 3 18 3	. . . .
	57 *Plagiomnium ellipticum*	. . . . 2	. . . .	. . 38 . 18 3 8 3 18 . 18 8	3 8 . 3 2 . . 3 3 . . . 3 2 . . 8 . . 3 8 3	. . . .
	58 *Philonotis caespitosa / Ph. fontana*	. . . .	. . . .	. . . 3 4 4 . 4 18 3 . 4	. . . . 2 . . . . . . 3 . 3 3 3 8 3 . 3	. . . .
	59 *Plagiomnium undulatum*	. . . .	. . . .	. . 1 . 3 3 3 . 3 . 3 3	. . . . 2 . . 2 2 . . . . 2 3 . . .	. . . .
	60 *Mentha arvensis*	. . . . . . 1	. . . . 1 . . 1	. . . 3 3 2 . 3 . 2 . 3 8	38 . 3 . . . . 2 2 . 3 4 . 3 3 3 .	. . . .
	61 *Carex demissa*	. . . .	. . . . 1	. . . 3 . 1 . 3 . . . 3	. . . . 2 . . . 2 3 . . . 3 3 .	. . . . 2 . . . . . .
	62 *Dactylorhiza maculata* agg.	. . . .	. . . .	. . . 2 . 2 . . 3 . . .	. . . . 1 . 3 3 . . . 2 . . . 1 .	. . 2 . 1 . . . . . .
	63 *Menyanthes trifoliata*	. . . .	. . . .	. . . . . 18 3 18	. . . . 8 . . . . . . 3 38 8 . . 2	. . . .
	64 *Lophocolea bidentata*	. . . .	. . . .	. . . 3 . 3 . 3 . . 3 .	. . . 2 3 . 2 . 2 8 3 4 . . . . . 3 3 3 3 .	. . . . . . 3 . . 8 .
	65 *Chiloscyphus pallescens / Ch. polyanthos*	. . . .	. . . .	. . . 1 . . 3 . . 3 3 3	. 3 . 8 . . . . . 3 3 4 3 3 . 3 . 3 . 3 . .	. . . . . . 3 . . 4 .
	66 *Veronica scutellata*	2	. . . .	. 2 . 3 . . . . . 3 . 3	. . . . . . 1 2 3 . . . . . . 1 . 3 . 2 3 3	. . . . . . 3 . . . .
	67 *Sphagnum squarrosum*	. . . .	. . . .	. 3 . . 2 . . . . . 3 .	. . . . 3 . . . . . 2 . . 2 . . 8 . . . 3 3	. . . . . . 3 . . . .
D/C 4	68 *Sphagnum palustre*	. . . .	. . . .	. . . .	. . . . 3 8 18 . 2 . . 8 . . 3	. 4 . . 2 . . . . 18 18
	69 *Sphagnum flexuosum*	. . . .	. . . .	. . . .	. . . . . . 3 . . . 3 8 . 3 . 3	68 . . . . 38 . . . 8 .
D/C 5	70 *Trifolium repens*	. 3 3 . 2 . 4 . . . 3 . . . 2 3 .	4 2 . . 2 2 2 2 . 2 .	. . . . 3 . . 1 . 3 1 .	. . . . 2 . . 3 .	. . . .
D/C 6	71 *Caltha palustris*	. . . . . 3 . . . . . . 2	. . . . . 2 2 . . 2 1	3 2 2 8 . 2 3 1 2 8 2 3	2 2 2 . 3 . . 2 3 . 8 . . 3 . . . 8 . 1 1 1	. . . .
	72 *Stellaria alsine*	 2	2 . . . . 1 1 2	1 2 . 2 2 . 2 . 3 . 2 3	2 3 . . . 2 4 2 . . . . 1 . 3 2 . . .	. . . .
D/C 7	73 *Juncus conglomeratus*	. . 1 . . . . 1 2 . 2 . . 2	. . . . 2	3 2 1 . 2 . . . . . 2 .	. . . . 2 . . 2 . 2 . . . . 2	. . . .
	74 *Anthoxanthum odoratum*	. 3 8 4 18 38 8 18 18 38 8 18 . 8 8 3 18	. 3 4 . 3 3 18 8 3 4 4 3	. . 3 2 . 4 3 2 4 3 3	. . . . 3 . 8 . . . 4 3 3 3 3 18 3 8 38	. . . . . . 8 . . 4 .
	75 *Ajuga reptans*	. . 2 2 2 2 2 2 2 2 . 2 3 2 2 1 1 2 2	. 2 . 2 2 1 2 . 2 . 2	3 2 3 . 2 4 3 . 2 . . .	. . 2 3 . . . . 2 8 3 3 . . 2 . . 3 3 . 3 3 2	2 . . 3 . . . .
	76 *Vicia cracca*	. . . . . . 1 3 . . 2 1 . . 1 . 2	. . . . . 2 . 1 2 . 2	. 2 . . . . . 1 1 . . 1	. . . . 1 . . . . . . 2 . . . . 3 .	. . . .
	77 *Festuca rubra* agg.	2 68 18 18 8 4 8 3 2 8 38 8 8 38 8 38	. . 8 . . 8 . 4 3 8 2 4 4	. 4 4 . 3 3 8 2 3 3 3 2 3	2 3 4 . 3 . 4 4 2 3 . 3 . 3 18 3 3 4 3 3 8 .	. 38 4 . . . . . 3 . .
	78 *Lathyrus pratensis*	. 4 . . . 1 1	. . 2 . . . . 3 2 3	. . 2 3 . . 3 3 . 1 3 1	. . . . 3 3 . . . . . . 2 . . . 2 .	. . . .
	79 *Rumex acetosa*	. . 2 1 . 1 2 2 1 2 2 2 . 2 1 2 2 3	. . 2 . . 1 3 3 2 1 3 3	2 1 3 2 . 2 2 . 3 . 3 3	2 3 4 3 3 3 2 3 2 3 . 2 . 3 . 3 3 2 3 1 3 2	2 3 . . . .
	80 *Holcus lanatus*	3 4 4 3 3 8 3 3 3 4 4 3 . 4 4 2 18	. 4 . 18 3 4 8 2 18 . 8	. 2 4 2 3 3 3 4 3 3 4 3	4 4 4 3 3 3 3 4 . . . . 3 3 2 2 8 18 3 8 2 18	2 . 2 . . . .
	81 *Ranunculus acris*	. 3 8 2 3 2 3 3 4 2 3 2 2 2 4 3 . 4	. 3 . 8 . 4 4 18 3 2 3 3	2 . 2 3 . . 3 . . . 1 3	. . . 3 . . . . 2 . 1 . . . 2 2 2 . 3 3 2 . 3	. . . .
	82 *Cardamine pratensis*	. 2 2 . . 2 2 2 2 . 1 2 . 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2	2 2 1 2 2 2 . 2 2 3 . 2 3	. 3 1 3 . 2 . . 2 . . 3 3 2 2 3 2 2 2 . 3	. . . .
	83 *Lychnis flos cuculi*	. 2 2 . 3 1 3 2 2 . 2 2 2 . 3 2 2 2	1 . 3 2 2 2 2 . 2 . . 2	2 3 . 3 1 2 3 3 3 3 . 3	. 3 1 3 . 2 1 . . . . . 2 3 . . 3 . 3 3 . .	2 . . . .
	84 *Ranunculus repens*	. . 2 . . . 2 2 2 . . . 2 1 2 4 .	38 . 8 3 8 2 4 2 2 4	. 2 . 2 . . 3 . 1 3 2 . 3	3 . . . . 1 2 2 3 3 2	. . . .
	85 *Scirpus sylvaticus*	2 18 . 8 3 3 . . 38 1 . . 4 . 2 . 2	2 3 3 3 2 1 . 18 . 3 2	. 3 . . 2 . 18 . . 3 3 2	. . . . 3 4 . . . . 3 . . 1 . 3 3 .	. . . .
	86 *Achillea ptarmica*	. 2 2 . 2 . 8 . . 3 2 . 2 8 3 2 2 3	. 3 . . 2 2 3 3 2 3 2 3	2 2 . 2 . 1 3	. 2 2 . 3 . . 1 . . . . . 2 2 . 1 . . . 3 .	. . . .
	87 *Ranunculus flammula*	3 . . . . 2 2 2 2 . . 2 2	. 4 2 3 3 2 3 . . 4 2	. . 3 4 . 3 3 3 3 4 8	. . 1 3 1 2 2 . . . . . . 2 2 2 2 2 3 2 3 4 3	. . . .
	88 *Lotus pedunculatus*	. 4 8 2 2 2 2 1 4 2 3 3 3 3 3 3 1 3 3 8	. 3 . 8 . 4 38 38 3 . 2	3 3 3 2 4 2 18 3 3 3 2 3	3 3 . 3 . . 4 3 4 3 3 . . 3 3 2 4 3 8 3 3 8 4	. . . . . . 3 . . . .
	89 *Calliergonella cuspidata*	3 3 . 3 18 . 18 3 18 3 18 8 18 3 8 38	. 38 68 88 38 18 38 38 . 8 .	38 18 38 4 68 18 8 18 68 38 38 8	. . 3 4 . . 18 18 8 38 8 68 3 3 4 38 18 38 8 18	. . . .
	90 *Filipendula ulmaria*	. 3 . . . 1 . 3 . 1 3 . . 2 . 1 2 2 2 2	. 2 2 38 1 . . 3 3 2 18 8	. 3 3 1 3 3 2 3 2 8 3 3	. . . 38 . 4 . . 38 8 . . . . . . 2 . 3 2 . 2 3	. . . .
	91 *Cerastium holosteoides* subsp. *triviale*	1 . . 1 . . . . 1 . 2 2 2 2 2	. 2 . . . 2 2 2 2 . 2 2 2	. 2 2 . 2 2 2 2 3 3 2	. 2 . 1 2 3 . . . . 2 . 2 . . 3 2 1 2	. . . .
	92 *Myosotis nemorosa*	. . 2 . . 2 3 2 2 2 . 2 . . 3 2 2 4	2 . 2 . 2 2 3 3 2 2 . 2	3 1 2 3 . 2 . 2 3 3 3 3	3 3 3 3 3 . . 2 3 3 3 . . 2 2 3 2 2 3 . 3 3	. . . .
Acc.	93 *Achillea millefolium*	. . . .	. . . . . 1	. . . .	. . . . 2	. . . .
	94 *Agrostis gigantea*	. . . .	18	. . . .	. 2	. . . .
	95 *Agrostis stolonifera*	. . . 38 4 . 2 . . . 3 8 . . . 2 2	. 4 . . 8 8 8 . . 18 .	38 8 . . . . 3 2	. 4 3 4 . 8 2 . 3 3 3 3 4 4 . . 8 3 3 8 .	2 . . . 3 . . . 8 . 18
	96 *Alchemilla glabra*	. . . .	. . . .	. . . . 1 . . .	. . . .	. . . .
	97 *Alchemilla monticola*	 2	. . . . 2 . .	. . . .	. . . .	. . . .
	98 *Aneura pinguis*	. . . .	. . . .	. . . . . . 3	. . . . 2 3	2 3 . . . .
	99 *Angelica sylvestris*	. . . . 1 1	1 . . . 1	2 2	1 . . 2 . . 1 1 3 3 . 2 . . . . . 1	. . 1 . . . .
	100 *Bistorta officinalis*	2 3 2 2 2 . 8 . 2 38 3 8 38 18 18 8 4	8 . 4 8 2 . 1 18 3 8 2	8 8 3 . 3 . 3 3 . . 3 .	3 . 8 . 4 . . 18 8 3 8 2 . 2 . . 3 3 . . 3 .	. 8 . 1 . . 3 8 . . .
	101 *Campylopus pyriformis*	. . . .	. . . .	. . . .	. . . .	4 . . . . 3 . . . . .
	102 *Carex flava* agg.	. . . .	. . . .	. . . . 3 . . .	. . . . 2 . . . . 1	. . . .
	103 *Carex flava* s. str.	. . . .	. . . .	. . . . . 8	. . . . 1	. . . .
	104 *Carex hirta*	. . . .	. . . . 3 . . .	. 3	. . . .	. . . .
	105 *Chaerophyllum hirsutum*	. . . .	. . . .	. . . .	2 . . . . 2	. . . .
	106 *Cirriphyllum piliferum*	. . . .	. . . .	. . . . 3 .	. . . .	. . . 8 . . . .
	107 *Comarum palustre*	. . . .	. . . .	2 2 . . . 3	. . . . 3	. . . . . 8 . . 3 . .
	108 *Cynosurus cristatus*	. . . .	. 2	. . . . 2 . . 2	. . . . 3 3 3 3 . .	. . . .
	109 *Deschampsia cespitosa*	1 3 2 . . . . 2 . 8 . 1 . .	. . 3 4 2 . . . . . 18 2	. 18 . . . 1 . . . 2 . .	1 . 1 . . . . 3 . . . . 3	2 . . . .
	110 *Dicranella schreberiana*	. . . .	. . . .	. . . . 3 4 .	. . . .	. . . .
	111 *Dryopteris carthusiana* agg.	. . . .	. . . .	. . . .	. . . . 1	2 . . . . . . 3 . . .
	112 *Epilobium ciliatum* subsp. *adenocaulon*	. . . .	. . . .	. . 3	. . . . 2 . 3	. . . .
	113 *Epilobium hirsutum*	. . . .	. . . .	. . 3 . . . . 3 .	. . . . 1	. . . .
	114 *Epilobium obscurum*	. . . .	. . . .	. . . .	2 2	. . . .
	115 *Epilobium sp.*	. 1 . . . . . 1	. . . .	1	. . . .	. . . .
	116 *Epilobium tetragonum*	. . . .	. . . .	. . . . . . 1	. . . . . . 3	. . . .
	117 *Equisetum sylvaticum*	. . . . 1	. . . .	. . . . 2	. . . .	. . . . . 3 . . . . .
	118 *Eriophorum vaginatum*	. . . .	. . . .	. . . .	. . . . 2	. . . . 2 . . .
	119 *Festuca arundinacea*	. . . . 2 .	. . . .	. 18	. . . .	. . . .
	120 *Galeopsis sp.*	. . . .	. . . .	. . . .	. 2 . . 2	. . . .
	121 *Galium aparine*	. . . .	. . . . 1 .	. 1	. . . . 1 . . . . 1	. . . .
	122 *Galium palustre*	3 . 2 . . 1 2 . . . 4 . 2 . . . 1	2 2 . 2 2 2 . 2 . 2 3 2	2 4 2 2 2 2 2 3 2 4 3 2	3 3 4 2 2 3 4 2 . 1 3 3 2 3 2 3 2 3 2 3 . 3	. 3 2 . 2 . . 3 3 . .
	123 *Holcus mollis*	. . . . 8	. . . .	. . . . . . 3	. . . . 2 . . . . 3	. . . . . . 3 3 . . .
	124 *Hypericum perforatum*	. . . . 2 . .	. . . .	. . . . . 1	. . . .	. . . .
	125 *Hypochaeris radicata*	. . . .	. . . .	. . . . 1 .	. . . . 1	. . . .
	126 *Juncus effusus*	3 3 3 3 3 . . 4 4 2 . . 18 . . . 3	4 . 2 . 3 2 . 2 . 8 .	8 . 3 18 . 2 3 3 8 2 3 2	3 . . 4 . 38 8 2 . . . 4 38 38 8 . 18 18 18 8 4	. 8 . 3 3 8 . . . . .
	127 *Kindbergia praelonga*	. . . .	. . . .	. 3	. . 38 . 2	. . . .
	128 *Leucanthemum vulgare* agg.	. . . . . . 1	. 1	. . . .	. . . .	. . . .
	129 *Lolium perenne*	. . . .	. . . . 2 . . 2 . . .	. . . .	. . . .	. . . .
	130 *Luzula congesta*	. . . .	. . . .	. . . .	. . . . 1 1	. . . .
	131 *Lycopus europaeus*	. . . .	. . . .	. . . .	. . . 3 3 2	. . . .
	132 *Lysimachia nemorum*	. . . .	. . . .	. . . .	. . . .	. . . . . 1 . . . . .
	133 *Lysimachia vulgaris*	1 . . . . 2	. . . .	. . . .	. . . 38 8	. . . .
	134 *Phalaris arundinacea*	8	. . 8	. . . .	2	. . . .
	135 *Phleum pratense*	. . . . 2 2	. . . 2	. . . .	. . . .	. . . .
	136 *Plagiothecium denticulatum* var. *denticulatum*	. . . .	. . . .	. . . .	. 18 . . . . 18 . 3	4 3 . . . .
	137 *Poa annua*	. . . . 1 . . 1 . .	. . . .	4 . 2	. . . . . . 4 . . . . 3	2 . . . .
	138 *Poa pratensis*	. . 3 . . . . 2 . .	 2	. . . .	. . . . 2 . . 2	. . . .
	139 *Polytrichum formosum*	. . . .	. . . .	. . . .	. . . . 2 2	3 . . . . 3 . . . . .
	140 *Prunella vulgaris*	. . . . . 2 . . . . 3 3 .	. . . .	. . . .	2 . . . . 2 . . 2	. . . .
	141 *Pseudoscleropodium purum*	. . . .	. . . .	. . . .	. . . . 3	. . . .
	142 *Rhinanthus minor*	. . . . . . 2	. . . .	. . . .	3 . . 3 . . . . 18 3	. . . .
	143 *Rhytidiadelphus squarrosus*	38 38 68 38 68 38 68 68 38 38 68 38 38 38 38 38 68	. 38 . 3 8 4 3	. 3 . 4 8 3 . 4 . 4 8 8	. 2 3 . 3 3 8 2 3 . 3 8 18 18 4 38 38 38 8 8 38	. 38 8 . . 18 18 68 3 2 .
	144 *Rumex obtusifolius*	. . . .	. . . .	. . . . 1 .	. . . . 1	. . . .
	145 *Sanguisorba officinalis*	. . . .	1 . . . . 8 .	. . . . . . 1	. . . .	. . . .
	146 *Sarmentypnum exannulatum*	. . . .	. . . .	. . . .	. . . . 3 . . . 2	. . . .
	147 *Scorzoneroides autumnalis*	. . . . . . 38 . . . . 2	. . 3 . . . 1	. . . .	. . . .	. . . .
	148 *Scutellaria galericulata*	. . . .	. . . .	. . . .	. . 2 . 3 4 3	. . . .
	149 *Sphagnum contortum*	. . . .	. . . .	. . . .	. . . . 8 . . 3	. . . .
	150 *Sphagnum fimbriatum*	. . . .	. . . .	. . . .	. . . .	. . . . 18 . . 3 . . .
	151 *Sphagnum subnitens*	. . . .	. . . .	. . . .	. . . . 18 3 . . 68	. . . . . . 3 . . . .
	152 *Sphagnum teres*	. . . .	. . . .	. . . .	. . . . 18 . . . . 3	. . . . . 38 . . . . .
	153 *Succisa pratensis*	1 . . . . 2	. . . 3	. . . 3	. . . . 2 . . 18 3 2 4	. . . .
	154 *Taraxacum sp.*	. . . .	. . . .	. . . .	. . . . 2 2	. . . .
	155 *Trientalis europaea*	. . . .	. . . .	. . . .	. . . . 4	. . . 3 . . . .
	156 *Triglochin palustris*	. . . .	. . . .	. . . . 3 . . .	. . . . 1	. . . .
	157 *Veronica arvensis*	. . . .	. . . . 1 2 .	. . . .	. . . .	. . . .
	158 *Veronica chamaedrys*	. . . . 3 . 1 2	. . . .	. . . .	. . . . 2 . 3 . . 3 . . .	. . . .
	159 *Veronica filiformis*	. . . .	. . . 1 . . . 1 . . .	. . . .	. . . .	. . . .

Furthermore in 1 plot in no.: 2: *Ficaria verna* 1; 3: *Bromus hordeaceus* ssp. *hordeaceus* 3, *Trisetum flavescens* 3; 5: *Cardamine amara* 2, *Pohlia wahlenbergii* 2; 7: *Hypericum desentangsii* 4; 8: *Galeopsis tetrahit* 1; 16: *Alchemilla* sp. 1; 18: *Sphagnum russowii* 2, *Vaccinium myrtillus* 2; 20: *Sphagnum cuspidatum* 8; 22: *Galium mollugo* 4; 24: *Epilobium montanum* 1; 25: *Dryopteris* sp. 1; 30: *Convolvulus arvensis* 2, *Vicia sepium* 1; 32: *Hypericum maculatum* ssp. *maculatum* 2; 33: *Danthonia decumbens* 2; 36: *Alopecurus geniculatus* 4; 40: *Sphagnum inundatum* 3; 42: *Dicranella* sp. 3, *Pedicularis sylvatica* 3, *Thuidium delicatulum* 3; 43: *Marchantia polymorpha* 1; 44: *Epilobium angustifolium* 3; 45: *Juncus bufonius* 2, *Montia fontana* ssp. *amporitana* 8; 46: *Atrichum undulatum* 3; 47: *Campylium stellatum* 3, *Carex pulicaris* 8, *Linum catharticum* 3, *Rhizomnium pseudopunctatum* 3; 48: *Anthriscus sylvestris* 2, *Chaerophyllum* sp. 1, *Eleocharis palustris* 3, *Rubus fruticosus* agg. 2; 49: *Ranunculus aconitifolius* 8, *Stellaria graminea* 2, *Valeriana excelsa* ssp. *excelsa* 4; 52: *Dryopteris dilatata* 1, *Sphagnum angustifolium* 3; 53: *Senecio ovatus* 1; 56: *Plantago major* 1; 57: *Briza media* 4; 58: *Sphagnum warnstorfii* 3; 60: *Sphagnum* sect. Subsecunda 1; 61: *Luzula sylvatica* 38, *Rubus idaeus* 1; 64: *Palustriella commutata* 2; 65: *Chrysosplenium oppositifolium* 1, *Geum rivale* 2; 66: *Fossombronia* sp. 1; 67: *Stellaria holostea* 1, *Thuidium tamariscinum* 3; 68: *Riccardia* sp. 2; 69: *Athyrium filix femina* 1, *Eurhynchium striatum* 3; 70: *Carex flacca* 8, *Dichodontium palustre* 2, *Dicranella staphylina* 2; 72: *Hydrocotyle vulgaris* 2

Supplement E9. Vegetation table of the plots of communities 4a-4c in the region of Süderbergland, NRW. "D/C" = differential or character species of higher groups. "d" = differential species of the communities (groups). "Acc." = Accompanying species.

Anhang E9. Vegetationstabelle der Plots der Gesellschaften 4a-4c in der Region Süderbergland, NRW. "D/C" = Gruppendifferenzialarten oder Charakterarten höherer Gruppen. "d" = Differentialarten der Gesellschaften (Gruppen). "Acc" = Begleitarten.

			Caricetum nigrae, variants with *Agrostis canina* (see Supplement E8)																					
			variant with *Juncus acutiflorus* (d1)							variant with *Carex rostrata* (d2)						variant with *Anthoxanthum odoratum* (d3)								
		plot no.	**53**	**48**	**21**	**69**	**41**	**40**	**45**	**32**	**49**	**58**	**52**	**68**	**62**	**71**	**35**	**42**	**66**	**54**	**63**	**67**	**46**	**56**
		coordinates (WGS 84, 32U)	455348	413247	447217	411786	469361	463872	480738	432608	410459	470634	446036	458984	465513	466098	477482	465488	471053	454678	471621	461279	460543	455782
			5646322	5651714	5643011	5661337	5698353	5700987	5700234	5649923	5659231	5678739	5655839	5674018	5674942	5672583	5664914	5679746	5677130	5647873	5675817	5673711	5674802	5647226
		group no.	4a	4a	4a	4a	4a	4a	4a	4b	4b	4b	4b	4b	4b	4c	4c	4c	4c	4c	4c	4c	4c	4c
d 1	1	*Juncus acutiflorus*	68	8	38	68	18	68	.	3	18	.	.	.	.	.	.	.	3	3	38	38	3	.
	2	*Poa trivialis*	3	3	.	.	4	.	3	.	.	.	2	.	.	.	.	.	2	8	2	.	3	.
	3	*Scutellaria galericulata*	.	.	2	.	3	4	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	4	*Deschampsia cespitosa*	1	.	1	.	.	.	3	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.
	5	*Lycopus europaeus*	.	.	.	.	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	6	*Straminergon stramineum.*	.	.	8	.	.	3	38	.	.	.	3	3	.	3	.	.	.	.	.	.	.	.
	7	*Epilobium ciliatum* subsp. *adenocaulon*	.	.	.	2	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	8	*Galeopsis* sp.	.	2	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	9	*Kindbergia praelonga*	.	.	.	38	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	10	*Lysimachia vulgaris*	.	.	.	.	38	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
d 2	11	*Chiloscyphus pallescens / Ch. polyanthos*	3	.	8	.	.	.	.	3	3	.	4	3	3	.	.	3	.	3	.	3	.	.
	12	*Angelica sylvestris*	1	.	.	.	2	.	.	1	1	3	3	.	.	2	.	.	.	.	.	1	.	.
	13	*Carex rostrata*	.	.	.	.	.	2	.	8	3	3	8	.	.	.	.	.	.	8	.	.	.	.
	14	*Sphagnum palustre*	.	.	.	.	.	.	.	.	3	8	18	.	2	.	.	8	.	.	3	.	.	.
	15	*Aneura pinguis*	.	.	.	.	.	.	.	.	.	.	.	2	3	.	.	.	.	.	.	.	.	2
	16	*Luzula congesta*	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.
	17	*Luzula multiflora*	.	.	.	.	.	.	.	.	1	.	.	.	2	.	.	.	.	.	.	.	.	.
	18	*Plagiothecium denticulatum* var. *denticulatum*	.	.	18	.	.	.	.	.	.	.	18	.	3	.	.	.	.	.	.	.	.	.
	19	*Ptychostomum pseudotriquetrum*	.	.	.	.	.	.	.	2	.	.	.	.	3	.	.	.	2	.	.	.	.	.
	20	*Sphagnum subnitens*	.	.	.	.	.	.	.	.	.	.	.	18	3	.	.	68	.	.	.	.	.	.
d 3	21	*Anthoxanthum odoratum*	3	.	.	.	.	.	.	3	.	8	.	.	.	4	3	3	3	3	18	3	8	38
	22	*Ranunculus flammula*	8	.	.	1	3	1	2	2	.	.	.	.	2	2	2	2	3	2	3	3	4	3
	23	*Philonotis caespitosa / Ph. fontana*	.	.	.	.	.	.	.	2	.	.	.	.	.	3	.	3	3	3	8	3	.	3
	24	*Ranunculus acris*	.	.	.	3	.	.	.	2	.	1	.	.	.	2	2	2	.	3	3	2	.	3
	25	*Climacium dendroides*	.	.	2	.	.	.	.	8	.	.	.	.	3	3	.	.	3	3	.	18	3	2
	26	*Ranunculus repens*	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	2	3	3	2
	27	*Carex demissa*	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	2	3	.	.	3	.	3
	28	*Cynosurus cristatus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	3	3
	29	*Juncus bulbosus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8	3	.	.	3	.	3
	30	*Luzula campestris*	.	.	.	.	.	.	.	2	.	.	.	.	.	2	.	.	.	3	1	.	.	3
	31	*Veronica chamaedrys*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	3	.	.	.	3	.
	32	*Juncus articulatus*	.	.	.	.	.	.	.	.	.	.	.	.	3	38	.	.	.	.	.	.	.	3
	33	*Nardus stricta*	.	.	.	.	.	.	.	.	.	.	.	3	.	.	2	1	.	.	.	.	.	.
	34	*Poa pratensis*	.	.	.	.	.	.	.	.	.	2	.	.	.	.	2	.	.	.	.	.	.	3
	35	*Prunella vulgaris*	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	3	.
	36	*Taraxacum* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	2
	37	*Trifolium repens*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	3
	38	*Vicia cracca*	.	.	.	.	.	.	.	1	.	.	.	.	.	.	2	.	.	.	.	.	3	.
D/C 1	39	*Molinia caerulea*	.	.	.	2	8	.	.	3	.	.	2	.	38	.	.	.	.	.	.	.	.	.
D/C 2	40	*Carex panicea*	.	3	.	.	.	.	.	.	.	18	.	8	3	8	18	4	18	.	3	3	.	3
	41	*Dactylorhiza maculata* agg.	.	.	.	.	.	.	.	.	1	.	.	3	3	.	.	.	2	.	.	.	1	.
	42	*Plagiomnium elatum*	.	.	.	.	.	.	.	3	.	3	.	.	.	.	.	.	8	4	.	.	.	.
	43	*Scirpus sylvaticus*	.	.	.	.	.	.	.	3	4	.	.	.	.	3	.	.	1	.	.	3	3	.
D/C 3	44	*Holcus lanatus*	8	4	4	3	3	3	3	4	.	.	.	.	3	3	2	2	8	18	3	8	2	18
	45	*Rumex acetosa*	2	3	4	3	3	2	3	2	3	.	.	.	.	.	3	3	2	3	1	3	3	2
	46	*Lychnis flos cuculi*	3	.	3	1	3	.	2	1	.	.	.	.	.	2	3	.	.	3	.	3	3	.
	47	*Cardamine pratensis*	3	.	3	1	3	.	2	.	.	.	2	.	.	3	3	2	2	3	2	2	.	3
	48	*Cerastium holosteoides* subsp. *triviale*	.	2	.	.	1	2	3	.	.	.	.	.	.	2	.	2	.	.	3	2	1	2
	49	*Carex canescens*	.	3	.	.	1	1	3	.	.	.	.	.	.	2	.	.	.	3	.	.	.	.
	50	*Mentha arvensis*	8	38	.	3	.	.	.	.	.	.	.	.	.	2	2	.	3	4	.	3	3	3
	51	*Veronica scutellata*	.	.	.	.	1	2	3	.	.	.	.	.	.	1	.	3	.	.	2	3	3	.
	52	*Achillea ptarmica*	.	2	2	.	3	.	.	1	.	.	.	.	.	2	2	.	1	.	.	.	3	.
	53	*Agrostis canina*	4	8	2	8	2	8	38	.	4	4	3	4	2	.	8	3	3	18	8	4	8	8
	54	*Agrostis stolonifera*	.	.	4	3	4	.	8	2	.	3	3	3	3	4	4	.	.	.	8	3	3	8
	55	*Ajuga reptans*	.	.	2	3	.	.	.	2	8	3	3	.	.	2	.	.	3	3	.	3	3	2
	56	*Amblystegium serpens*	.	.	18	.	.	.	.	.	.	.	3	.	.	.	.	3	.	.	.	.	.	.
	57	*Aulacomnium palustre*	.	.	2	.	.	3	2	8	.	3	3	.	3	.	.	3	.	3	.	.	.	8
	58	*Bistorta officinalis*	3	.	8	.	4	.	.	18	8	3	8	2	.	2	.	.	3	3	.	.	3	.
	59	*Brachythecium* spp.	2	18	8	38	8	3	3	4	8	18	2	3	3	.	.	.	3	2	3	.	3	.
	60	*Calliergonella cuspidata*	8	.	.	3	4	.	.	18	18	8	38	8	68	3	3	4	38	18	38	8	8	18
	61	*Caltha palustris*	2	2	2	.	3	.	.	2	3	.	8	.	.	3	.	.	.	8	.	1	1	1
	62	*Carex echinata*	3	2	.	2	.	2	.	8	3	.	2	3	8	3	2	18	4	3	3	3	3	4
	63	*Carex flava* s. str.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	1	.	.	.
	64	*Carex nigra*	8	18	18	.	8	3	2	.	8	38	18	8	4	8	38	.	18	4	.	8	3	3
	65	*Chaerophyllum hirsutum*	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.
	66	*Cirsium palustre*	.	3	3	3	3	2	3	3	3	3	3	3	1	2	1	3	3	8	3	3	3	3
	67	*Crepis paludosa*	3	2	.	.	.	.	.	3	2	.	.	.	2	3	.	1	3	.	.	.	.	.
	68	*Dactylorhiza majalis*	.	.	.	.	.	.	.	.	3	.	.	2	2	1	.	.	.	.	.	1	.	.
	69	*Epilobium obscurum*	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
	70	*Epilobium palustre*	3	3	2	3	3	3	2	2	3	1	3	2	.	2	.	3	3	3	2	2	3	.
	71	*Equisetum arvense*	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.
	72	*Equisetum fluviatile*	.	8	2	.	3	.	.	2	.	1	.	3	.	2	.	.	2	2	.	4	.	.
	73	*Eriophorum angustifolium*	3	4	2	4	3	18	3	3	3	3	4	8	3	3	4	4	3	3	3	3	4	3
	74	*Festuca rubra* agg.	2	3	4	.	3	.	4	4	2	3	.	3	.	3	18	3	3	4	3	3	8	.
	75	*Filipendula ulmaria*	.	.	38	.	4	.	.	38	8	.	.	.	.	2	.	.	3	2	.	2	3	.
	76	*Galium aparine*	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
	77	*Galium palustre*	3	3	4	2	2	3	4	2	.	1	3	3	2	3	2	2	3	3	2	3	3	3
	78	*Galium uliginosum*	3	4	.	3	3	.	.	.	8	4	.	.	3	2	2	3	3	3	3	3	4	3
	79	*Holcus mollis*	.	.	.	.	.	.	.	.	**2**	.	.	.	.	.	.	.	.	**3**	.	.	.	.
	80	*Juncus conglomeratus*	.	.	.	.	2	.	.	2	.	2	.	.	.	.	2	.	.	.	.	.	.	.
	81	*Juncus effusus*	2	3	.	.	4	.	38	8	2	.	.	.	.	.	4	38	38	8	.	18	18	18
	82	*Lathyrus pratensis*	1	.	.	.	.	.	.	3	3	.	.	.	.	.	2	.	.	.	.	.	2	.
	83	*Lophocolea bidentata*	.	.	2	3	.	2	.	2	8	3	4	.	.	.	.	.	3	3	3	3	.	.
	84	*Lotus pedunculatus*	3	3	.	3	.	4	3	4	3	3	.	.	3	3	2	4	3	8	3	3	8	4
	85	*Menyanthes trifoliata*	.	.	.	.	8	.	.	.	.	.	.	3	38	8	.	.	2	.	.	.	.	.
	86	*Myosotis nemorosa*	3	3	3	3	3	.	.	2	3	3	3	.	.	2	2	3	2	3	2	.	3	3
	87	*Pellia* sp.	.	.	2	3	.	3	.	.	2	.	.	.	.	.	.	3	.	3	.	.	.	.
	88	*Plagiomnium ellipticum*	3	8	.	3	2	.	.	3	3	.	.	.	3	2	.	.	8	.	.	3	8	3
	89	*Plagiomnium undulatum*	.	.	.	2	.	.	.	2	2	.	.	.	.	.	.	.	2	3	.	.	.	.
	90	*Plantago lanceolata*	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2	.	.	.
	91	*Poa annua*	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.
	92	*Polytrichum formosum*	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.
	93	*Potentilla erecta*	1	2	.	3	.	.	1	2	.	8	.	8	3	.	2	3	2	.	3	2	.	.
	94	*Pseudoscleropodium purum*	.	.	.	3	.	.	.	.	.	3	.	.	.	.	18	3	.	.	.	.	.	.
	95	*Rhytidiadelphus squarrosus*	8	.	2	3	.	3	3	8	2	3	.	3	8	18	18	4	38	38	38	8	8	38
	96	*Sarmentypnum exannulatum*	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	2	.	.	.	.	.	.
	97	*Sphagnum contortum*	.	.	.	.	.	.	.	.	.	.	.	.	8	.	.	.	3	.	.	.	.	.
	98	*Sphagnum flexuosum*	.	.	.	.	.	3	.	.	.	.	3	8	.	3	.	3	.	.	.	.	.	.
	99	*Sphagnum squarrosum*	.	.	.	3	.	.	.	.	.	2	.	.	2	.	.	8	.	.	.	3	.	3
	100	*Sphagnum teres*	.	.	.	.	.	.	.	.	18	.	.	.	.	.	.	.	.	3	.	.	.	.
	101	*Stellaria alsine*	.	3	.	.	.	2	4	.	2	.	.	.	.	.	.	1	.	3	2	.	.	.
	102	*Succisa pratensis*	.	.	.	.	.	.	.	2	.	.	.	18	3	2	4	.	.	.	.	.	.	.
	103	*Valeriana dioica*	.	4	.	3	3	.	.	.	.	8	.	4	3	4	4	8	3	3	.	3	18	3
	104	*Viola palustris*	3	3	3	3	.	3	4	.	.	3	3	3	3	.	2	4	2	3	3	3	3	3

Furthermore in 1 plot, in no.: 21 *Anemone nemorosa* 2; *Phalaris arundinacea* 2; 32 *Epilobium hirsutum* 1; Hypericum *maculatum* ssp. *maculatum* 2; 35 *Achillea millefolium* 2; *Carex flava* agg. 1; *Carex leporina* 1; 40 *Sphagnum inundatum* 3; 42 *Dicranella* sp. 3; *Pedicularis sylvatica* 3; *Thuidium delicatulum* 3; 45 *Epilobium tetragonum* 3; *Juncus bufonius* 2; *Montia fontana* subsp. *amporitana* 8; 46 *Atrichum undulatum* 3; *Lysimachia nummularia* 4; *Rumex obtusifolius* 1; 48 *Agrostis* gigantea 2; *Anthriscus sylvestris* 2; *Chaerophyllum* sp. 1; *Eleocharis palustris* 3; *Rubus fruticosus* agg. 2; 49 *Ranunculus aconitifolius* 8; *Stellaria graminea* 2; 49 *Valeriana excelsa* subsp. *excelsa* 4; 52 *Dryopteris carthusiana* 1; *Dryopteris dilatata* 1; *Eriophorum vaginatum* 2; *Galium saxatile* 1; *Sphagnum angustifolium* 3; *Trientalis europaea* 4; 53 *Senecio ovatus* 1; 54 *Glyceria fluitans* 2; *Polytrichum commune* 2; 56 *Plantago major* 1; 58 *Sphagnum warnstorfii* 3; 62 *Comarum palustre* 3; 66 *Fossombronia* sp. 1; *Sanguisorba officinalis* 2; *Triglochin palustris* 1; 67 *Stellaria holostea* 1; *Thuidium tamariscinum* 3; 68 *Riccardia* sp. 2; 69 *Athyrium filix femina* 1; *Eurhynchium striatum* 3; 71 *Hypochaeris radicata* 1