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Phytosociology, ecology and plant species diversity of grasslands within nature protection sites near Zurich (Switzerland)

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Abstract: The study covers dry to mesic grasslands and litter meadows which have shown drastic declines in Switzerland, including in the canton of Zurich. The aim is to provide an overview of the hitherto floristically unexplored protected areas of the local nature conservation society Verein Naturnetz Unteramt. The areas of Erliweid and Hofstetterweid were more humid and less alkaline. This contrasts with the drier and more basic areas of Rohmatt, Schleetal, Stückliberg, and Tägerst, with Stückliberg being the least fertile and Rohmatt the most fertile area. A total of 30 vegetation plots (10 m2), i.e. five plots in each of the six different areas, were surveyed. For vegetation classification, I compared several methods used in Switzerland to assign phytosociological syntaxa. Depending on the method used assignments to different phytosociological alliances resulted. In particular, the classification of *Arrhenatherion* instead of *Mesobromion* or *Molinion* leads to different assessment of the importance for protection according to the Federal Ordinance. I also applied a modified TWINSPAN analysis and identified three clearly separated clusters. To compare the areas in terms of diversity and site conditions I used Analysis of Variance. The areas Erliweid and Hofstetterweid, mainly assigned to the alliance of *Molinion caeruleae*, were significantly richer in species. A linear mixed model with random effects showed a negative effect of *Brachypodium pinnatum* cover on species richness. On this basis, an additional second cut at an early or late time, depending on the area and species composition, can be recommended for management at least as an experiment.

Keywords: *Brachypodium pinnatum*; conservation; grassland; management; nature conservation association; syntaxonomy; Switzerland; Stallikon.

Nomenclature: The nomenclature of the vascular plants follows Juillerat et al. (2017).

Abbreviations: ANOVA = analysis of variance; BAFU = Bundesamt für Umwelt, DCA = Detrended Correspondence Analysis; LC = Least Concern, VU=Vulnerable, EN = Endangered; VNU = Verein Naturnetz Unteramt (local nature conservation association).

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Introduction

Dry grasslands, including xeric and meso-xeric grasslands, lost around 95% of their area in Switzerland between 1900 and 2010 (Lachat et al. 2011) and a further fifth of the remaining area in the last 20 years (Urech & Eggenberg 2007 according to BAFU 2017). Even extensively managed mesic grasslands at lower altitudes have declined to 2 to 5% of their original area due to intensification (Bosshard 2015). Peatlands, including some of the litter meadows, lost 82% of their area between 1900 and 2010 (Lachat et al. 2011), with the decline being particularly severe at lower altitudes.

These losses have also had an impact on individual species, with 44% of the 2,700 native plants classified as endangered or potentially endangered in the 2016 Swiss Red List (BAFU 2017). The proportion of habitat-specific species is particularly high in peatlands and dry grasslands at lower altitudes, among other places (BAFU 2017). National biodiversity monitoring also shows that the species composition of vascular plants in grasslands at middle altitudes is becoming increasingly uniform and that forest and nutrient-loving plants are becoming increasingly widespread, especially at middle altitudes.

At present, around 12.5% of Swiss territory is designated for biodiversity conservation. However, protected areas of national importance constitute only 6.2% of the territory, which is a low level by international standards (BAFU 2017). Management is regulated over around 81% of the entire area (BAFU 2019). In the canton of Zurich, peatland occupies around 1,800 ha, of which some 80% is subject to long-term management under a protection ordinance. The area of species-rich dry grasslands is around 600 ha, of which just under half has management secured by a long-term protection ordinance (Baudirektion Kanton Zürich 2021).

The timing and number of cuts depend on the respective habitats and species present, which is why it is important to know the biodiversity and syntaxonomy of the stands. Furthermore, management recommendations for individual stands must be adapted again and again due to, among other things, climate change, nutrient inputs, invasive and spreading species, and new findings in general. The distribution of financial resources means that most protected areas in the canton of Zurich are maintained by farmers (Baudirektion Kanton Zürich 2021). However, especially in the case of protected areas at the communal level, many communal authorities are supported by volunteers who are often organised in nature conservation associations (dialog:umwelt GmbH 2015).

Verein Naturnetz Unteramt (VNU) was founded 90 years ago. It is the local nature conservation association of the municipalities of Bonstetten, Stallikon and Wettswil. In the course of time, the association has leased or purchased 16 parcels in six different areas of the municipality of Stallikon. The association maintains these areas in cooperation with local farmers. The areas are cultivated extensively, i.e. without fertilisation and most of the areas are nature protection zones according to the ordinances of the canton of Zurich whilst one area is a communal protected object. Today's management indicates that the stands are species-rich dry to mesic grasslands and litter meadows.

Previously, some areas managed by VNU were surveyed for specific species groups (e.g. orchids), but to the best of my knowledge and knowledge of the VNU, the areas were never comprehensively floristically surveyed. Therefore, I aimed at classifying the vegetation and investigating the influence of different site conditions and environmental factors. Differences between different classification systems would be noted and their consequences for legal protection discussed. A further objective was to determine biodiversity patterns of different areas and their classified syntaxa.

The aim of this study would is to elucidate the relationships between floristic biodiversity and current management regimes as well as possible changes in management regimes to favour floristic diversity of the sites. In particular, during initial inspections it was noticeable that in many areas there was a dense sward, especially of *Brachypodium pinnatum* so it might be possible to show whether or not it had the negative effects described by some authors (Antognoli et al. 1995 and Maubert & Dutoit 1995 according to Dipner et al. 2010; Hurst & John 1999).

Study area

The six study areas maintained by the VNU, Erliweid, Hofstetterweid, Rohmatt, Schleetal and Stückliberg, are located in the municipality of Stallikon, Zurich in the Reppisch valley (see Fig. 1).

In common with the entire canton of Zurich and also the Swiss Plateau, Stallikon has an Atlantic-type climate (Wohlgemuth et al. 2020). Depending on the altitude, Stallikon has a mean annual temperature of 6 to 10°C (Bundesamt für Meteorologie und Klimatologie MeteoSchweiz 2020a) and the mean annual precipitation is 1,200 to 1,500 mm (Bundesamt für Meteorologie und Klimatologie MeteoSchweiz 2020b).

The Reppischtal is a marginal glacial valley, formed by the deepening of the glacial rivers of the Reuss glacier (Amt für Landschaft und Natur Kanton Zürich year unknown). The bedrock, which can be seen in places as outcrops, consists of mudstone, sandstone, marl or conglomerate. On the steep slopes, landslides and slumping often occur; these are slipped Quaternary unconsolidated rock or slumped and disrupted consolidated Quaternary gravel (Gubler 2009). This is the case in the study areas of Erliweid, Rohmatt, Schleetal, Stückliberg and Tägerst. In places, slopes also contain hanging clay, predominantly composed of layered silty clays mixed with slope debris (Gubler 2009). This is the case in the Hoffstetterweid study area. The valley floor is composed of fine-grained alluvial and lake sediments (Gubler 2009). This is the case in the study areas of Erliweid,

Fig. 1. Left: Location of the municipality of Stallikon in Switzerland. Right: Location of the six study areas in the municipality of Stallikon.

Rohmatt, Schleetal, Stückliberg and Tägerst. In places, slopes also contain hanging clay, predominantly composed of layered silty clays mixed with slope debris (Gubler 2009). This is the case in the Hoffstetterweid study area. The valley floor is then composed of fine-grained flood sediments and lake sediments (Gubler 2009).

In the Reppisch valley near Stallikon, the flat valley floor is predominantly used for arable farming, although the suitability for use is limited by its tendency for it to become waterlogged (Amt für Landschaft und Natur Fachstelle Bodenschutz 2018). The slopes are used as meadow and pasture or are forested. Dry forests as well as dry meadows and pastures can be found in the area, especially on the bordering Uetliberg-Albis chain in exposed southern and southwestern locations (Amt für Landschaft und Natur Fachstelle Naturschutz 2017a; Wohlgemuth et al. 2020). In the more humid southern half of the canton, several smaller wetlands occur in the Stalliker Reppischtal: these are mainly fed by groundwater or run-off from the slopes of the Uetliberg-Albiskette (Amt für Landschaft und Natur Fachstelle Naturschutz 2017b).

The study areas do not differ that much with respect to mean elevation, lying between 550 and 680 m a.s.l. Although the study areas are very heterogeneous in terms of slope, they do not differ much in terms of mean slope, so all areas are clearly sloped. Rohmatt and Stückliberg are primarily exposed to the east, Hofstetterweid is primarily exposed to the west, Schleetal is primarily exposed to the south and southeast and Tägerst is primarily exposed to the south and southwest (see Table 1).

The habitats appear to differ with respect to the exposure according to Amt für Landschaft und Natur Fachstelle Naturschutz (2004, 2017a, 2017b). Thus, Rohmatt, Schleetal and Tägerst show a potential for nutrient-poor, dry grasslands, while Stückliberg has a potential for dry grasslands as well as alternating wet grasslands, and Hofstetterweid shows a potential for wetlands and alternating wet grasslands and is also mapped as a mosaic of litter meadow but also dry grassland.

According to the habitats and productivity, the area management regimes differ. Erliweid, Hofstetterweid, and Rohmatt are cut once a year starting 1 September at the earliest. In Stückliberg, part of the area is cut once a year from 1 August and part from 15 August. In Schleetal, part of the area is cut on 15 July and part on 1 August. In Tägerst, the area is cut on 15 July. In each case, these areas will be mown by the farmer and the cuttings will be collected and removed by the local nature conservation association. The areas have been maintained in this or a similar way by the local nature conservation association in Erliweid since 2009, in Hofstetterweid since 1992, in Rohmatt since 1988, in Schleetal since 1987, in Stückliberg since 2014 and in Tägerst since 1991. This does not mean that the management before the Nature Conservancy took over necessarily differed from the current management. The history of the areas has not been further elaborated, but based on the

Table 1. Results from a GIS analysis of the area, elevation, slope and exposure of the study areas and corresponding subsites with cutting regimes according to the management plan.

Name of the area	Parcel number	Cutting regime (earliest cutting date)	Area m^{-2}	Mean altitude (m a.s.l.)	Minimal altitude (m a.s.l.)	Maximum altitude (m a.s.l.)	Mean slope (°)	Minimum slope (°)	Maximum slope (°)	Mean aspect (°)	Minimum aspect(°)	Maximum aspect (°)
Erliweid	1750	1.9.	10,154	630.2	612.4	640.2	14.0	0.0	25.0	55.0	0.0	120.0
	2231	1.9.	6,456	632.4	605.2	643.0	12.2	0.0	32.0	35.0	0.0	156.0
Hofstetterweid	1066f	1.9.	3,241	679.4	660.1	696.1	20.4	0.9	51.4	275.4	0.0	360.0
Rohmatt	1725a	1.9.	478	564.6	556.4	571.6	21.1	9.6	40.8	103.8	4.3	358.2
Schleetal	1452j	1.8.	474	552.7	550.5	555.3	8.1	0.9	27.1	133.3	6.3	359.0
	1466d	15.7.	3,063	584.5	573.0	591.9	29.6	8.0	49.4	150.7	78.4	205.8
	1452f	1.8.	5,398	570.7	559.7	580.7	19.0	1.0	51.2	143.1	13.0	354.8
	1452e	15.7.	2,684	565.9	554.8	578.0	26.3	0.9	52.2	135.8	31.0	251.5
Stückliberg	1452i	15.8.	2,209	614.0	598.5	627.9	18.5	0.3	39.3	85.1	0.0	360.0
	1452h	1.8.	437	602.6	597.7	605.0	22.7	2.6	43.6	83.2	17.8	189.8
	1452g	15.8.	1,743	611.4	597.7	626.2	28.0	5.5	60.8	88.1	2.6	154.6
	2334	15.8.	2,161	628.9	623.7	638.8	12.0	0.0	51.6	87.0	0.0	360.0
Tägerst	2334	15.7.	283	612.0	607.5	616.5	25.3	15.3	44.6	223.8	198.6	248.1
	2334	15.7.	1,153	608.3	601.0	616.6	25.1	0.4	51.9	221.4	66.8	341.5

suitability for agricultural use, it can be assumed that some areas were traditionally grazed. This would also be suggested by the field names Erliweid and Hofstetterweid (the suffix -weid comes from the German "Weide", meaning pasture).

Methods

Vegetation surveys

In each of the six areas, I collected vegetation and environmental data at five locations, resulting in a total of 30 plots. I stratified the areas according to management regimes (specifically, the earliest cutting date). This means I tried to cover the management regimes with earliest cutting dates on 15 July, 1 August, 15 August, and 1 September with as many plots as possible according to the possibilities of the area (see Table 2). I made no plots in very small but well-defined stands with visibly different site conditions (e.g., stands of rushes or tall perennials along ditches). Otherwise, I randomly selected plot locations in the field.

I visited the plots between 1 June and 14 June 2020 (15 plots) and from 13 July to 21 July 2020 (15 plots). In each case, I collected a complete record of all vascular plants with percent cover estimates using FlorApp for Android, version 2.8 (Info Flora 2018) in a 10 m^2 quadrat (edge length 3.162 m) with a north-south orientation. Species were identified in both generative (Eggenberg et al. 2018; Lauber et al. 2018) and vegetative states (Eggenberg & Möhl 2013) according to the nomenclature of Juillerat et al. (2017). Furthermore, I collected exposure (of the assumed orientation using Compass 360 Pro application, version 3.3.134), slope (of the assumed main fall line using Precise Level application, version unknown), maximum height of vegetation (using double meter), and pH of a soil sample at 10 cm depth (using a colorimetric method).

Statistical analyses

I assigned the plots to phytosociological associations according to reference surveys from Pantke (2008) and the list of species from Delarze et al. (2015), the latter by different methods in Vegedaz (Küchler 2014; WSL 2017): number of common species, Jaccard similarity coefficient and Eggenberg (number of common species and weighted by so called characteristic and accompanying species according to Delarze et al. 2015). I performed TWINSPAN analysis (pseudospecies cut level = 3, values of cut levels = 0, 5, 25, minimum group size = 3, maximum level of divisions = 3) according to Hill (1979) and a modified TWINSPAN classification (same parameters but minimal Sorensen dissimilarity index = 0.3) according to Roleček et al. (2009) to create the synoptic table. For both TWINSPAN analyses I used Juice software, version 7.1.102 (Tichý et al. 2018), and for the GIS analyses, I used QGIS, version 3.16.3 software. I calculated the cover weighted mean indicator values according to Landolt (1977) of the study plots in Vegedaz (Küchler 2014; WSL 2017). I performed all other statistical analyses in R, Version 4.0.2. To perform the Analysis of Variance Model to assess differences in biodiversity and site conditions I used the function 'aov' from the 'stats' package version 4.2.0. I calculated a linear mixed model for all plots with area and cutting regime as random effects to test the influence of Brachypodium pinnatum cover on species richness using the function 'lmer' from the 'lme4' package version 1.1.23. For the results of Analysis of Variance Model, I performed post-hoc Tukey tests using the function 'glht' from the 'multcomp' package, version 1.4.17. For the results of the linear mixed model with random effects, I performed post-hoc Tukey tests using the function 'emmeans' from the 'emmeans' package, version 1.7.0. Furthermore, I performed a DCA using the function 'decorana' and to fit the environmental vectors and factors onto the ordination using the function 'envfit' from the 'vegan' package, version 2.5.7. 'Vegan' was also used to calculate species richness, Eveness H', Shannon index J' and Simpson index.

Table 2. Number of vegetation plots according to different cutting regimes and areas.

	Erliweid	Hofstetterweid	Rohmatt	Schleeta	Stückliberg	Tägerst	Number of plots per cutting regime
1 cut per year from 15 July				2		5	7
1 cut per year from 1 August				3			3
1 cut per year from 15 August:					5		5
– 1 cut per year from 15 August					1		1
– 1 cut per year from 15 August, 1/3 remains standing alternately					4		4
1 cut per year from 1 September	5	5	5				15
Number of plots per area	5	5	5	5	5	5	

Table 3. Overview of the assigned clusters with plot ID, areas, cutting regimes (earliest cutting date), assignment to vegetation units according to the habitats of Switzerland of Delarze et al. (2015) by means of assignment according to number Common, Jaccard (Common / Association) and method Eggenberg. Hey to codes: 2.3.1. = *Molinion*, 2.3.3.= *Filipendulion*, 4.2.3. = *Diplachnion*, 4.2.4. = *Mesobromion*, 4.5.1. = *Arrhenatherion*, 5.3.3.= *Pruno-Rubion*, 5.3.4.= Blackberry Scrub, 4. 5.2. = *Polygono-Trisetion*, 5.1.1. = *Geranion sanguinei*, 5.1.2. = *Trifolion medii*, 4.5.3. = *Cynosurion*, 6.2.1. = *Cephalanthero-Fagenion*, 6.2.3. = *Galio-Fagenion*, 6.3.2. = *Tilion platyphylli*. In addition, the assignment according to Pantke et al. (2008) at the level of alliance and association, and assignment by TWINSPAN analysis (Hill 1979) and Modified TWINSPAN analysis (Roleček et al. 2009) with Sorensen dissimilarity index min. 0.3 (Cluster 2: 0.63, Cluster 3: 0.567).

Cluster ID		Plot ID	Area	Number common	Jaccard	Eggenberg	Alliance	Association	Cutting regime
		5	Rohmatt	4.5.3.	5.3.4.	4.5.3.	*Berberidion vulgaris*	*Evonymo-Sambucetum nigrae*	1 September
		4	Rohmatt	4.5.2.	6.2.3.	2.3.1.	*Trifolion medii*	*Geranio-Astragaletum glyciphylli prov.*	1 September
Custer 1		3	Rohmatt	5.1.2.	5.3.3.	5.1.1.	*Berberidion vulgaris*	*Evonymo-Sambucetum nigrae*	1 September
		2	Rohmatt	6.2.3.	6.2.3.	6.2.1.	*Berberidion vulgaris*	*Evonymo-Sambucetum nigrae*	1 September
		1	Rohmatt	5.1.3.	6.3.2.	6.2.3.	*Fagion sylvaticae*	*Circaeo-Abietetum*	1 September
		4	Hofstetterweid	2.3.1.	2.3.1.	2.3.1.	*Molinion caeruleae*	*Calamagrostio-Solidagonetum*	1 September
		5	Hofstetterweid	2.3.1.	6.4.1.	2.3.1.	*Molinion caeruleae*	*Saturejo-Molinietum arundinaceae*	1 September
		3	Hofstetterweid	2.3.1.	2.3.3.	2.3.1.	*Molinion caeruleae*	*Saturejo-Molinietum arundinaceae*	1 September
		2	Hofstetterweid	2.3.1.	2.3.1.	2.3.1.	*Molinion caeruleae*	*Calamagrostio-Solidagonetum*	1 September
Cluster 2		1	Hofstetterweid	2.3.1.	2.3.3.	2.3.1.	*Molinion caeruleae*	*Saturejo-Molinietum arundinaceae*	1 September
		5	Erliweid	2.3.1.	2.3.1.	2.3.1.	*Molinion caeruleae*	*Saturejo-Molinietum arundinaceae*	1 September
		3	Erliweid	4.5.2.	4.5.1.	4.5.1.	*Trifolion medii*	*Colchico-Brachypodietum*	1 September
		2	Erliweid	4.5.2.	4.5.1.	4.5.1.	*Molinion caeruleae*	*Saturejo-Molinietum arundinaceae*	1 September
		1	Erliweid	2.3.1.	4.5.2.	4.5.1.	*Molinion caeruleae*	*Stachyo-Brometum*	1 September
		2	Stückliberg	4.2.4.	4.2.4.	4.2.4.	*Mesobromion*	*Seselio libanotidis-Mesobrometum*	15 August
		4	Erliweid	4.5.2.	4.5.1.	4.5.1.	*Molinion caeruleae*	*Saturejo-Molinietum arundinaceae*	1 September
		4	Stückliberg	4.2.4.	4.5.1.	4.2.4.	*Mesobromion*	*Coronillo-Mesobrometum*	15 August
	3a	4	Schleetal	4.2.4.	4.5.1.	4.2.4.	*Mesobromion*	*Medicago falcatae-Mesobrometum*	1 August
		5	Stückliberg	4.5.2.	4.5.1.	4.2.4.	*Mesobromion*	*Dauco-Salvio-Mesobrometum*	15 August
		3	Stückliberg	4.2.4.	4.5.1.	4.5.1.	*Mesobromion*	*Coronillo-Mesobrometum*	15 August
		1	Stückliberg	4.2.4.	4.5.2.	4.2.4.	*Arrhenatherion elatioris*	*Centaureo dubiae-Arrhenatheretum*	15 August
Cluster 3		5	Schleetal	4.5.1.	4.5.1.	4.2.4.	*Molinion caeruleae*	*Stachyo-Brometum*	1 August
		3	Schleetal	4.5.1.	4.5.1.	4.5.1.	*Mesobromion*	*Inulo conyzae-Mesobrometum*	1 August
		2	Schleetal	4.5.1.	4.5.1.	4.5.1.	*Arrhenatherion elatioris*	*Centaureo dubiae-Arrhenatheretum*	15 July
		1	Schleetal	4.5.1.	4.5.1.	4.5.1.	*Arrhenatherion elatioris*	*Centaureo dubiae-Arrhenatheretum*	15 July
	3b	3	Tägerst	5.1.2.	5.1.2.	4.5.1.	*Trifolion medii*	*Trifolio medii-Agrimonietum*	15 July
		5	Tägerst	4.5.1.	4.5.1.	4.2.3.	*Trifolion medii*	*Trifolio medii-Agrimonietum*	15 July
		4	Tägerst	4.5.1.	4.5.1.	4.5.1.	*Mesobromion*	*Inulo conyzae-Mesobrometum*	15 July
		2	Tägerst	4.2.4.	4.2.3.	4.5.1.	*Mesobromion*	*Inulo conyzae-Mesobrometum*	15 July
		1	Tägerst	4.5.1.	4.5.1.	4.5.1.	*Mesobromion*	*Inulo conyzae-Mesobrometum*	15 July

Table 4. Diagnostic and dominant species ordered by cluster according to TWINSPAN analysis. Individual records are listed on the left, and frequency for the three clusters is listed on the right. Diagnostic species are ordered by decreasing fidelity (fidelity; phi values) within clusters. Superscripts indicate phi values (phi ≥ 0.50, * phi ≥ 0.25, ° phi > 0.00). Diagnostic and common diagnostic species are indicated with thick border lines. Constant species are shown in black, all other species in grey. Dominant species are shown in bold.**

Cluster ID	Custer 1					Cluster 2									Cluster 3																Freq.	Fid.	Freq.	Fid.	Freq.	Fid.
															Cluster 3a							Cluster 3b														
Area / Plot ID	Rohmatt / 5	Rohmatt / 4	Rohmatt / 3	Rohmatt / 2	Rohmatt / 1	Hofstetterweid /4	Hofstetterweid /5	Hofstetterweid /3	Hofstetterweid /2	Hofstetterweid /1	Erliweid / 5	Erliweid / 3	Erliweid / 2	Erliweid / 1	Stückliberg / 2	Erliweid / 4	Stückliberg / 4	Schleetal / 4	Stückliberg / 5	Stückliberg / 3	Stückliberg / 1	Schleetal / 5	Schleetal / 3	Schleetal / 2	Schleetal / 1	Tägerst / 3	Tägerst / 5	Tägerst / 4	Tägerst / 2	Tägerst / 1	n=5		n=9		n=16	
Diagnostic species Cluster 1																																				
Polygonatum multiflorum	5	1.5	0.4	1	3	.	.	.	1	.	.	.	.	.	.	.	z	.	.	.	.	.	.	.	.	.	.	.	.	.	100	**	11	°	.	°
Viola reichenbachiana	0.5	1	0.6	0.3	0.1	.	.	.	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	100	**	11	°	.	°
Tamus communis	0	0	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	**	.	°	.	°
Glechoma hederacea	0	0	0	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	**	.	°	.	°
Prunus spinosa	0.8	0.1	0	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	**	.	°	.	°
Fragaria vesca	0.5	0.1	0	0.1	0	.	.	.	.	.	0	.	0	0	.	0	.	.	.	.	.	.	0.5	0.5	1	.	0.1	0.1	0.1	0.1	100	*	33	°	50	°
Paris quadrifolia	.	0	0.6	0.1	1.5	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	*	11	°	.	°
Clematis vitalba	0.3	.	1	0.6	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.5	.	.	1	0.5	0.5	1	80	*	.	°	31	°
Fraxinus excelsior	1	0	0	.	0	.	0	.	.	.	0.1	.	0	0.1	.	0.01	.	.	.	.	.	.	0.1	.	0.1	.	.	.	.	.	80	*	44	°	19	°
Phyteuma spicatum	0.3	.	.	0.7	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	*	.	°	.	°
Galium mollugo	0.5	0.6	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	*	.	°	.	°
Taraxacum officinale aggr.	1	0.6	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	.	0.1	60	*	.	°	12	°
Euphorbia stricta	.	.	.	0.01	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	*	.	°	.	°
Aquilegia atrata	.	.	0.8	0.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	*	.	°	.	°
Galium odoratum	.	0.3	.	0.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	*	.	°	.	°
Rubus caesius	4	3	15	15	7.5	1	.	0.1	0	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	100	°	*	°	44	.
Carex tomentosa	6	2	0.5	.	2	.	.	0.6	0.5	0.4	0.2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	°	*	°	56	.
Diagnostic species Cluster 2																																				
Agrostis gigantea	.	.	.	.	.	15	15	23	1	2	.	5	4	12	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	89	**	6	°
Prunella vulgaris	.	.	.	.	.	1.5	.	1	0.3	0.6	3	0.8	1	5	.	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	89	**	6	°
Carex flacca	.	.	.	.	.	1	7	0.5	2	3	1	1	17	2	.	1	0.5	0.1	1	.	0.8	0.5	.	.	.	.	.	0.5	0.1	0.01	.	°	100	*	56	°
Lathyrus pratensis	1	0.6	.	.	.	0	0.1	0	0	0.8	0.8	1	0.3	1.5	.	0.6	.	0.1	.	.	.	0.1	.	.	.	0.3	.	0.1	0.1	.	40	°	100	*	38	°
Filipendula ulmaria	.	.	.	.	.	1	.	0.5	1	.	2	0.5	0.8	0.8	.	7	.	.	.	.	.	.	.	0.1	.	.	.	.	.	.	.	°	78	*	12	°
Potentilla erecta	.	.	0	.	.	0.1	0	0	0.6	0.8	0.5	.	.	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	°	78	*	.	°
Lysimachia vulgaris	.	.	.	.	2	3	0.4	7	15	5	0.1	0.4	.	.	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	°	78	*	6	°
Cirsium oleraceum	.	.	.	0.3	.	0.1	.	.	0.5	0.5	1	1.5	3	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	°	78	*	6	°
Pimpinella major	.	.	.	.	.	.	.	.	1	4.5	5	3	1.5	2.5	0.7	1.5	0.2	.	.	0.5	0.5	.	.	.	.	.	.	.	.	.	.	°	67	*	31	°
Angelica sylvestris	.	.	.	.	.	0.5	0.3	.	5	0.2	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	56	*	.	°
Rhinanthus glacialis	.	.	.	.	.	0.5	0.6	0.5	0.5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	56	*	.	°
Equisetum telmateia	.	.	.	.	.	2	0.4	2	1	1	.	.	.	.	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	56	*	6	°
Geum urbanum	.	.	.	.	.	.	0	.	.	.	0.8	.	0.5	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	44	*	.	°

Table 4. continued

Cluster ID	Custer 1					Cluster 2									Cluster 3																					
															Cluster 3a							Cluster 3b									Freq.	Fid.	Freq.	Fid.	Freq.	Fid.
Area / Plot ID	Rohmatt / 5	Rohmatt / 4	Rohmatt / 3	Rohmatt / 2	Rohmatt / 1	Hofstetterweid /4	Hofstetterweid /5	Hofstetterweid /3	Hofstetterweid /2	Hofstetterweid /1	Erliweid / 5	Erliweid / 3	Erliweid / 2	Erliweid / 1	Stückliberg / 2	Erliweid / 4	Stückliberg / 4	Schleetal / 4	Stückliberg / 5	Stückliberg / 3	Stückliberg / 1	Schleetal / 5	Schleetal / 3	Schleetal / 2	Schleetal / 1	Tägerst / 3	Tägerst / 5	Tägerst / 4	Tägerst / 2	Tägerst / 1	n=5		n=9		n=16	
Carex sylvatica	.	.	.	.	.	2	.	.	0.1	0	.	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	44	*	.	°
Pteridium aquilinum	.	.	.	.	.	1	5	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	44	*	.	°
Euphorbia platyphyllos	.	.	.	.	.	.	0.1	0	.	0	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	44	*	.	°
Colchicum autumnale	.	.	.	.	.	.	.	.	.	.	0.2	0.5	1.5	1	.	.	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	44	*	6	°
Equisetum arvense	.	.	.	.	.	.	.	.	.	.	6	8	7	30	.	0.05	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	44	*	6	°
Molinia arundinacea	.	.	.	.	1	2	20	7	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	°	44	*	.	°
Dactylorhiza maculata	.	0.05	0.01	.	.	0.1	0	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	°	44	*	.	°
Galium boreale	.	.	.	.	.	2	2	.	0.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Hypericum maculatum	.	.	.	.	.	.	.	2	0.05	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Euphorbia cyparissias	.	.	.	.	.	.	0	1	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Carex panicea	.	.	.	.	.	.	.	.	.	0.4	.	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Anthericum ramosum	.	.	.	.	.	.	4	.	1	0.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Linum catharticum	.	.	.	.	.	0	.	.	.	.	0	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Deschampsia cespitosa	.	.	.	.	.	.	.	.	.	1	3	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Gymnadenia conopsea /cf	.	.	.	.	.	.	.	0	.	.	0.4	.	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Succisa pratensis	.	.	.	.	.	.	.	0.1	0.1	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	°	33	*	.	°
Diagnostic species Cluster 3																																				
Knautia arvensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	1	0.5	1	1	1	1	1	0.1	1	.	0.7	.	0.3	.	.	°	.	°	81	**
Bromus erectus	.	.	.	.	.	.	2	5	.	7	.	30	.	.	90	15	85	90	93	90	90	87	80	80	95	75	85	90	85	75	.	°	44	°	100	*
Galium album	.	.	.	0.1	.	0.1	0.4	1	0.3	0	0	0	0.5	1	0.1	0.9	0.1	0.1	0.1	0.3	0.2	0.5	0.1	0.1	0.5	0.5	0.3	0.8	0.1	0.1	20	°	100	°	100	*
Centaurea jacea subsp. jacea	.	.	.	.	.	.	.	.	.	.	.	3.5	5	.	0.5	15	0.7	0.5	1.5	2	2	2	0.5	.	2.5	.	2	2	4	4	.	°	22	°	88	*
Leucanthemum vulgare	.	.	.	.	.	.	.	0.1	.	0.2	0.2	0.3	0.6	1	0.5	0.5	0.5	0.5	0.5	0.6	0.8	0.5	0.1	0.5	0.05	1	0.1	.	0.2	.	.	°	67	°	88	*
Lotus corniculatus	.	.	.	.	.	.	.	.	.	.	.	1	0.7	.	0.1	1	0.5	0.1	0.1	0.1	0.2	0.1	.	.	0.1	.	0.3	0.7	.	0	.	°	22	°	75	*
Scabiosa columbaria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1.5	0.1	0.5	1	2	3	.	.	.	.	5	.	2.5	2	.	°	.	°	62	*
Salvia pratensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.5	.	1	1.5	1	1.5	0.3	1	3	.	.	.	.	.	0.8	.	.	°	.	°	56	*
Poa angustifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	.	0.1	0	0	.	0	.	0.1	0.5	.	°	.	°	50	*
Medicago lupulina	.	.	.	.	.	.	.	.	.	.	.	0.01	.	.	.	0.1	0.1	0	0.1	.	.	0.1	.	.	0	.	0	0.1	.	.	.	°	11	°	50	*
Sanguisorba minor	.	1	.	.	.	.	.	.	.	.	.	0.5	.	.	2	0.9	2	0.8	1	2	3	.	.	.	0.5	.	.	.	.	.	20	°	11	°	50	*
Buphthalmum salicifolium	.	.	.	.	.	2	.	.	.	.	.	.	.	.	1	.	0.8	.	1	1.5	0.8	.	.	.	.	.	.	3	.	5	.	°	11	°	44	*
Anemone nemorosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	0.1	0.1	.	0.1	0.01	0.1	.	°	.	°	38	*
Thymus serpyllum aggr.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	0.2	.	0.5	0.4	2	.	.	.	.	.	.	.	.	.	.	°	.	°	31	*
Diagnostic species Cluster 1 and 2																																				
Knautia dipsacifolia	1	5	0.8	0.5	0.3	7	2	7	4	7	10	3	4	5	.	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	100	*	100	*	6	°
Further relevant species																																				
Brachypodium pinnatum	70	70	70	45	70	45	35	17	25	17	30	10	30	3	1	15	0.5	5	0.5	2	5	1	1	10	0.1	10	1	3	4	2	100	°	100	°	100	°
Molinia caerulea	.	.	.	.	.	.	.	.	3	35	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	°	22	°	12	°

Results

Vegetation classification

The assignment to phytosociological alliances according to Pantke (2008) revealed that most of the study sites can be assigned to *Molinion caeruleae* (litter meadows) and *Mesobromion* (dry or meso-xeric grasslands), with ten and nine study sites respectively. Erliweid and Hofstetterweid were almost exclusively assigned to *Molinion caeruleae*, while Schleetal and Stücklibergseveral were assigned to *Arrhenatherion elatioris* (mesic grasslands). Other single plots in Erliweid, Rohmatt and Tägerst could be assigned to *Trifolion medii* (mesophilous herbaceous margin), *Berberidion vulgaris* (dry warm scrub) or *Fagion* (beech woodland).

However, he assignment to phytosociological alliances according to Delarze et al. (2015) differed fundamentally. Depending on the method, 7 to 14 study plots and thus the clear majority were assigned to *Arrhenatherion*. This alliance was especially characteristic of Schleetal but also occurred in Erliweid, Stückliberg and Tägerst. Using the Jaccard classification, only one plot in Stückliberg could be assigned to *Mesobromion* analogous to the Pantke (2008) classification. With the common number method or Eggenberg method, six plots could be assigned to *Mesobromion*.

The comparison of cutting regimes and alliances according to Pantke (2008) showed that almost all of the plots assigned to *Molinion* are cut late, i.e. at the earliest on 1 September (Table 3). The plots in Rohmatt and Erliweid (which are assigned to forests, shrubs and margins) are also cut late. On the other hand, the plots in Schleetal, Stückliberg and Tägerst, which are assigned to *Mesobromion* as well as *Arrhenatherion elatioris* and *Trifolion medii*, are all cut earlier, i.e. from 15 July, 1 August or 15 August. The only exception was a plot in Schleetal which could be assigned to *Molinion* and is cut on 1 August. According to Delarze et al. (2015), plots assigned to *Arrhenatherion* were detected for all the cutting regimes.

The results of the TWINSPAN analyses are summarised in Table 4. Using a classical TWINSPAN classification, the plots could be divided into four groups. However, a modified TWINSPAN classification showed that only three groups could be identified that exceeded the Sorensen dissimilarity of 0.3 (maximum Sorensen dissimilarity cluster 2: 0.63, cluster 3: 0.567, see Table 3). The first cluster delimited Rohmatt. The second cluster delimited, with one exception, Hofstetterweid (mainly by *Molinion caeruleae* according to Pantke (2008)) and Erliweid (predominantly *Saturejo-Molinietum arundinaceae*). The third cluster included Schleetal, Stückliberg and Tägerst as well as a plot in Erliweid. It contained chiefly *Mesobromion* and *Arrhenatherion elatioris*, but also *Trifolion medii* and *Molinion caeruleae* according to Pantke (2008). This third cluster could be further subdivided by means of the classical TWINSPAN classification into a cluster 3a with mixed associations (found mainly in Stückliberg) and a cluster 3b characterised by *Inulo conyzae-Mesobrometum* (present in Schleetal and Tägerst).

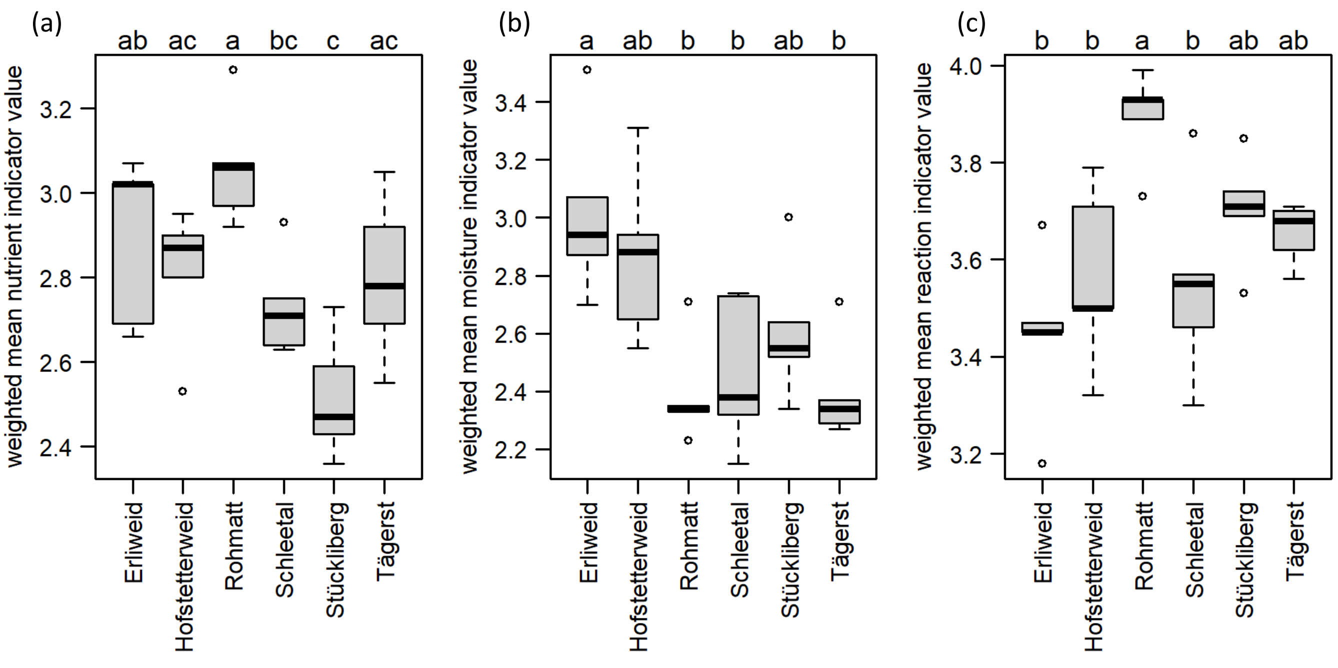


Fig. 2. Box-whisker plots of (a) the indicator weighted means of nutrient value (p < 0.001 *, $F_{5,24}$ = 6.078, r^2 = 0.5587), (b) the indicator weighted means of moisture value (p = 0. 002**, $F5,24$ = 5.292, r^2 = 0.5244), and (c) the indicator weighted means of reaction value (p = 0.003**, $F5,24$ = 5.063, r^2 = 0.5133) of the different study areas. Lowercase letters denote homogeneous groups on p < 0.05 using Tukey's post-hoc test.**

Site conditions

The indicator weighted means of the nutrient value of Erliweid (with 3.0) and Rohmatt (with 3.1) were significantly higher than those of Stückliberg (with 2.5) (p = 0.016*, t = 3.601 and p < 0.001***, t = 5.316, respectively, see Fig. 2a). The indicator weighted means of the moisture value of Erliweid (with 2.9) were also significantly higher than Rohmatt (p = 0.008**, t = 3.914), Schleetal (p = 0.045*, t = 3.142) and Tägerst (p = 0.008*, t =3.889), which all had a mean between 2.3 and 2.5 (see Fig. 2b). For the indicator weighted means of the reaction value significant differences were found between Rohmatt (with 3.9) and Erliweid (p = 0.001**, t = 4.674), Hofstetterweid (p = 0.024*, t = 3.427), and Schleetal (p = 0.026*, t = 3.393) with means of about 3.5 (see Fig. 2c).

Ordination

In the DCA, the 1st and 2nd axes of the DCA could account for most of the species composition (eigenvalues: 0.5980 and 0.1714). The gradient length of the first axis was 2.3411 SD and of the second axis 1.4556 SD. Some of the variables used had significant influence (see Table 5, Fig. 3 above).

Diversity of the areas

A total of 178 species of vascular plants were detected. Fig. 4 shows that the study area plots differed significantly with respect to their species richness (p < 0.001***, $F_{5,24}$ = 18.36, r^2 = 0.7928). Erliweid and Hofstetterweid were significantly richer in species on average with 41.8 and 36.4 species, respectively, than Rohmatt with 26.4 species (p < 0.001***, t = 7.345 and p > 0.001***, t = 4.770), Schleetal with 27.0 species (p < 0. 001***, t = 6.655 and p = 0.004**, t = 9.400), Stückliberg with 29.3 species (p < 0.001***, t = 6.211 and p = 0.019*, t = 7.067) and Tägerst with 26.6 species (p < 0.001***, t = 7.250 and p = 0.001**, t = 9.800) (see Fig. 4). Plots at Erliweid and Rohmatt showed a lower variability of species numbers, both for the minimum and maximum values and the standard deviation. In contrast, plots at Hofstetterweid and Tägerst showed a high variation of species numbers.

Also, for the biodiversity indices evenness (p < 0.001 ***, $F_{5,24}$ = 69.08, r^2 = 0.935), the Shannon index (p < 0.001 ***, $F_{5,24}$ = 89.5, r^2 = 0.9491) and the Simpson index (p < 0.001 ***, $F_{5,24}$ = 69.67, r^2 = 0.9355) significant differences were found between the sites (see Fig. 5a–c). Thus, the more species-rich Erliweid and Hofstetterweid had a significantly higher equal distribution of species (evenness) than the other sites. Rohmatt occupied a middle position in all three biodiversity measures tested and differed significantly from all the other areas.

One Red List species, *Ophrys apifera*, with vulnerable status (VU = vulnerable, see Bornand et al. 2016) was detected in the Schleetal area (see Fig. 6).

Brachypodium pinnatum

A linear mixed model with area and cutting regime as random effects showed that the cover of *Brachypodium pinnatum* had a significant effect on species richness, which decreased by 0.26 species per one percent of *Brachypodium pinnatum* cover (p = 0.011*, t = 7.085, r^2 = 0.35) (see Fig. 7a). The effect was not stronger, but more pronounced, when the model was restricted to study plots with the earliest cutting date of 1 September. Also in this case, species richness decreased significantly by 0.22 species per one percent of *Brachypodium pinnatum* cover with increasing cover of *Brachypodium pinnatum* (p = 0.004**, t = 7.901, r^2 = 0.66) (see Fig. 7b).

Table 5. Results of the DCA: influence of individual variables used on the 1st axis (DCA1) and 2nd axis (DCA2) as well as coefficient of determination (r^2) and significance (p).

		DCA1	DCA2	r^2	p	
N	Slope (°)	0.95237	-0.30494	0.2404	0.029	*
E	Exposure (°)	0.13401	0.99098	0.5424	0.001	***
pH	Soil pH	-0.46636	-0.8846	0.2008	0.042	*
gNZ	Weighted mean values of the nutrient indicator value	0.69452	-0.71947	0.4531	0.001	***
gRZ	Weighted mean values of the reaction indicator value	0.38432	-0.9232	0.0346	0.613	
gFZ	Weighted mean values of the moisture indicator value	0.85288	0.52211	0.0738	0.349	
Bra.pi	Cover of *Brachypodium pinnatum* (%)	0.87215	-0.48924	0.727	0.001	***
Sz	Cutting regime (earliest cutting date):			0.7789	0.001	***
Sz 15.7	From 15. July	-1.0521	0.2555			
Sz 1.8	From 1. August	-1.1631	0.2697			
Sz 15.8	From 15. August	-1.1371	0.2425			
Sz 1.9	From 1. September	1.1852	-0.2727			

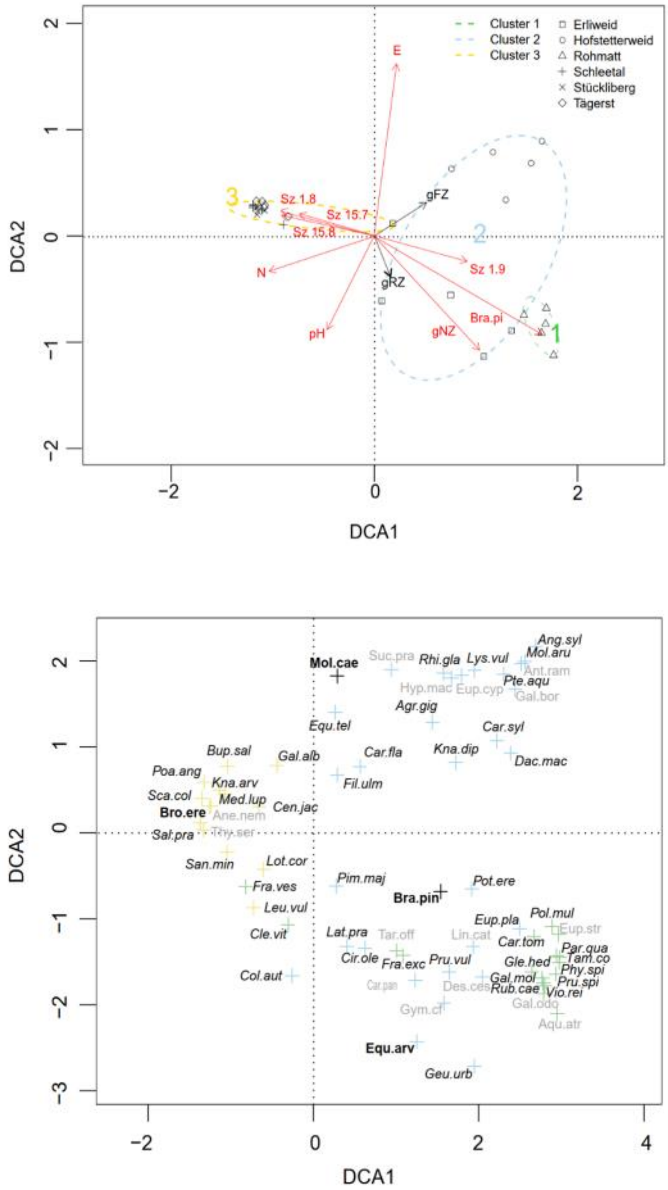


Fig. 3. Top: DCA ordination of 30 vegetation plots in six areas (shown by different symbols). The coloured ellipses indicate the affiliation to the clusters according to TWINSPAN analysis. The correlation with variables between the two ordination axes is shown by arrows (slope (°) (N), aspect (°) (E), soil pH (pH), cutting regime as earliest cutting date (Sz+date), indicator weighted means of nutrient value (gNZ), indicator weighted means of reaction value (gRZ), indicator weighted means of moisture value (gFZ) and cover of *Brachypodium pinnatum* (%) (*Bra. pi*)), with significant variables shown in red (see Table 5). Bottom: Diagnostic species of cluster 1 (+), cluster 2 (+) and cluster 3 (+) according to TWINSPAN analysis. Constant species are shown in italics and black, all other species in grey. Dominant species are shown in bold. The first three letters of genus and species are separated by a dot. The complete species names can be taken from Table 4.

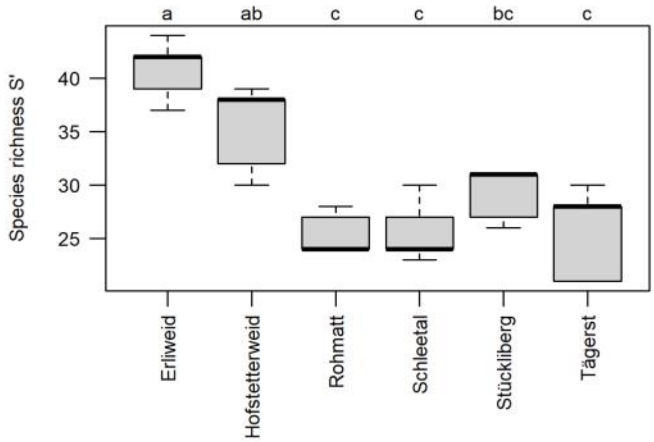


Fig. 4. Box-whisker plots of species richness S' ($p < 0.001$ *, $F_{5,24} = 11.89$, $r^2 = 0.7123$) of the different study sites. Lowercase letters denote homogeneous groups on $p < 0.05$ using Tukey's post-hoc test.**

Discussion

Vegetation classification

Cluster 1, at Rohmatt, is differentiated primarily by the presence of numerous forest species. It is strongly characterised by the forest edge situation and shading, which is why no assignment to a grassland alliance was possible. For clusters 1 and 2, *Knautia dipsacifolia* could also be identified as a diagnostic species, being a characteristic species within the alliance *Trifolion medii* (Oberdorfer & Müller 1977). It clearly shows the influence of the forest edge situation on the corresponding study plots and areas. *Carex tomentosa* should be emphasized as a constant differential species. Koch (1926) described this species as the denominated differential species for the *Molinietum caricetosum tomentosae*, which is distinguished by lower soil moisture within the *Molinietum caeruleae*.

For cluster 2, *Filipendula ulmaria* and *Galium boreale*, among others, could be identified as differential species, which Oberdorfer & Görs (1983) refer to as differential species of the alliance *Molinion caeruleae*. The other differential species *Prunella vulgaris*, *Carex flacca*, *Lathyrus pratensis*, *Potentilla erecta*, *Lysimachia vulgaris*, *Linum catharticum*, *Deschampsia cespitosa*, *Gymnadenia conopsea* and *Succisa pratensis* are described by Klötzli (1969) as common species of litter meadows in the narrow sense.

Bromus erectus, which was recognized as a constant and dominant differential species of cluster 3, is considered a class character species of *Festuco-Brometea*, which includes the alliance *Mesobromion erecti* (Oberdorfer & Korneck 1976). *Scabiosa columbaria* was also identified as a differential species of cluster 3 and is referred to by Oberdorfer & Korneck (1976) as a differential species of the alliance *Mesobromion erecti*. Pictures of some of these diagnostic species are shown in Fig. 8.

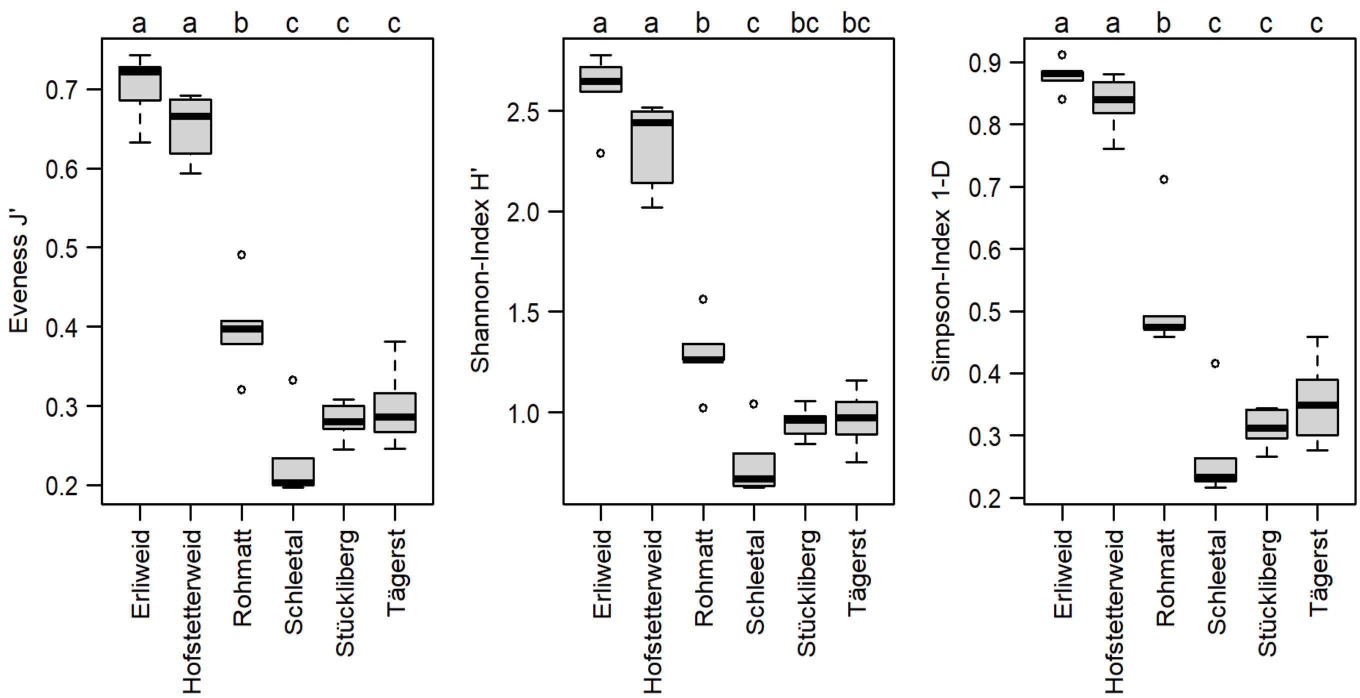


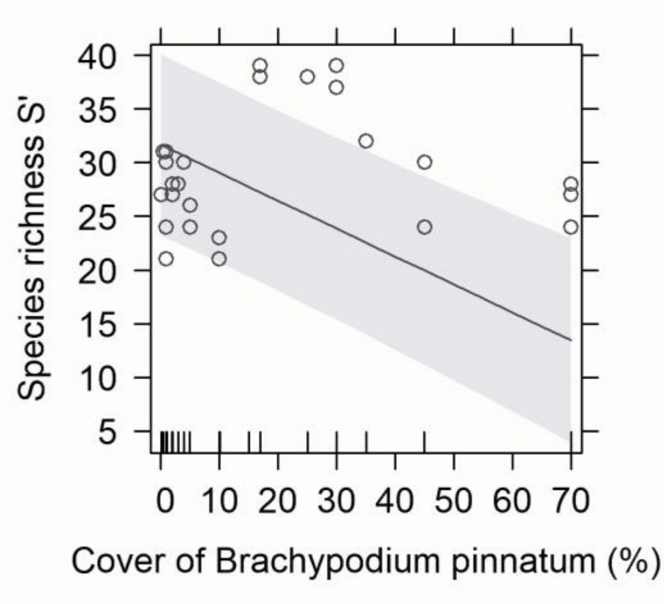
Fig. 5. Box-whisker plots of (a) the equal distribution of species (evenness H') ($p < 0.001$ *, $F_{5,24} = 45.42$, $r^2 = 0.9044$), (b) the Shannon index J' ($p < 0.001$ ***, $F_{5,24} = 46.68$, $r^2 = 0.9068$), and (c) the Simpson index 1 – D of the different sites. Lowercase letters denote homogeneous groups on $p < 0.05$ using Tukey's post-hoc test.**

The alliances *Molinion* and *Mesobromion* assigned according to Pantke (2008) thus seem to be quite justified for Cluster 2 (at Erliweid and Hofstetterweid) and Cluster 3 (with one exception, at Schleetal, Stückliberg and Tägerst), respectively. Interestingly, one plot at Erliweid, which was assigned to *Molinion* according to Pantke (2008) was assigned to cluster 3, which suggests transitions between the areas and syntaxa. The rather low occurrence of indicator species of moistness and wetness, as well as the frequent occurrence of indicator species of moderate dryness, show that the plots of cluster 2 probably belong to a drier to variable formation of the *Molinion*. The frequent assignment to the *Saturejo-Molinietum arundinaceae*, which grows on non-flooded soils and occurs in a dry formation on terrain crests (Klötzli et al. 1973), fits this pattern. It is also evident in the low occurrence of the alternating wetness indicator *Molinia caerulea* but the dominance of the indicator for alternating dryness *Brachypodium pinnatum*. However, this could also be a result of the land use history since Oberdorfer & Korneck (1976) describe at least for the dry meadows that grazing can lead to the displacement of *Bromus erectus* in favour of *Brachypodium pinnatum*. As mentioned in the introduction at least Erliweid and Hofstetterweid may have been grazed for a long time based on their field names. For cluster 3, the frequent assignment to Inulo *conyzae-Mesobrometum* seems quite appropriate. The formation is generally found on steep, dry, south to east facing slopes and was often unused in past decades. This leads to a herb layer rich in grasses and a deep litter layer, which limits the spread of light-demanding species (Keel 1993).

The *Molinion* and *Mesobromion* alliances, assigned according to Pantke (2008) and confirmed by the TWINSPAN analysis, are scarce habitats in Switzerland and are listed as highly endangered (EN) and vulnerable (VU), respectively (Delarze et al. 2016). Both natural habitats are also covered by the Federal Ordinance on the Protection of Nature and Cultural Heritage. Nevertheless, according to Delarze et al. (2015), regardless of the method chosen, assignment to *Arrhenatherion* was more frequent. This habitat type is not

Fig. 6: *Ophrys apifera* in Schleetal. Photo: P. Schmid.

endangered (LC) or vulnerable (VU), depending on its composition, and is not covered by the Federal Ordinance. Thus, the diverging classification of *Mesobromion* or *Molinion* and *Arrhenatherion* could well have consequences, e.g. in expert assessments of habitat protection status in the context of construction projects. In the present case, the results from the Eggenberg method and that using the number of common species are very similar, and apparently more robust than the results from the Jaccard method.



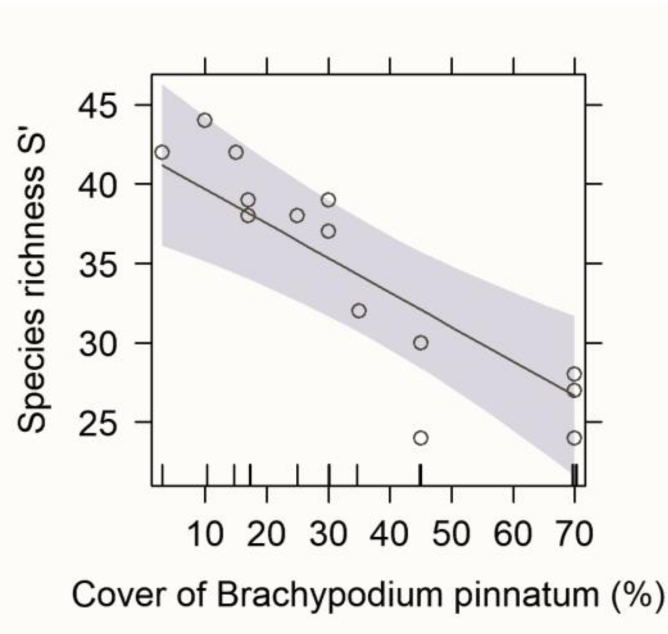


Fig. 7. Partial regression plots showing the regression equation (with 95% confidence interval) of species richness S' and cover of *Brachypodium pinnatum* (%) with the assumption that other factors remain constant for (a) a model across all study plots and (b) a model for the late -cut study plots only.

Site conditions

The vegetation of Erliweid and Hoffstetterweid is mostly assigned to *Molinion caeruleae* according to Pantke (2008). They have weighted means of the nutrient value of 3.0 and 2.9, respectively, which is in agreement with a mean of 3.0 derived from the data of Bergamini et al. (2019) for wet grasslands in the Swiss lowlands. The same is true for the study plots at Rohmatt which have with a mean of 3.1. Schleetal and Tägerst could not be identified as significantly poorer in nutrients, but with a weighted mean nutrient value of 2.7 and 2.8, respectively, they are closer to the 2.7 mean ascribed to the dry grasslands of Swiss lowlands (Bergamini et al. 2019). Stückliberg has a weighted mean nutrient value of 2.5, which is significantly more nutrient-poor than Erliweid and Rohmatt, and is even drier than the dry grasslands in the Swiss lowlands; it is probably more comparable to dry grasslands throughout Switzerland with a mean of 2.5 (Bergamini et al. 2019).

For the weighted means of the moisture level, the drier areas of Rohmatt, Schleetal, Stückliberg and Tägerst with values between 2.3 to 2.5 are similar to the 2.4 mean for dry grasslands according to Bergamini et al. (2019). However, the significantly moister sites of Erliweid with 2.9 and Hoffstetterweid with 2.8 are clearly distinct from the 3.6 mean for wet grasslands in the Swiss lowlands according to Bergamini et al. (2019).

In summary the Erliweid and Hofstetterweid sites are moister and less alkaline. At least for Hofstetterweid this can be traced back to geological conditions due to the hanging clay. They contrast with the drier and more basic sites of Rohmatt, Schleetal, Stückliberg, and Tägerst, with Stückliberg having the lowest nutrient level and Rohmatt the highest.

Ordination

The gradient of the cutting time is clearly visible, which separates Schleetal, Stückliberg and Tägerst in cluster 2 (with an early first cutting date) from Erliweid, Hofstetterweid in cluster 3 and Rohmatt in cluster 1 (with a later first cutting date). Similarly, the weighted mean indicator values of nutrient level and the cover of *Brachypodium pinnatum* increases, while the slope decreases. The exposure and the pH of the soil mainly distinguished Erliweid and Hofstetterweid, although they are combined in cluster 2. The separation of Schleetal, Stückliberg and Tägerst from Erliweid, Hofstetterweid and Rohmatt is clear. Schleetal, Stückliberg and Tägerst cannot then be further differentiated, while Erliweid, Hofstetterweid and Rohmatt are relatively distinct. However, TWINSPAN produced three clusters, though the assignment of just one plot at Erliweid to cluster 1 is surpris-

Table 6. Sample size as well as minimum, 1st quantile, mean, median, 3rd quantile, maximum and standard deviation of number of species of the study plots (10 m^2) at individual sites, and alliances according to Pantke et al. (2008) as well as Swiss reference plots of corresponding associations (Biurrun et al. 2019, 2021; GrassPlot Diversity Explorer 2020a, 2020b, 2020c).

	n	Min	Q1	Mean	Median	Q3	Max	Std.Dev
Area								
Erliweid	5	38.0	40.0	41.8	43.0	43.0	45.0	2.8
Hofstetterweid	5	31.0	33.0	36.4	39.0	39.0	40.0	4.1
Rohmatt	5	25.0	25.0	26.4	25.0	28.0	29.0	1.9
Schleetal	5	24.0	24.8	27.0	26.5	28.8	31.0	3.2
Stückliberg	5	25.0	27.3	29.3	30.0	32.0	32.0	3.1
Tägerst	5	22.0	22.0	26.6	29.0	29.0	31.0	4.3
Alliance								
Arrhenatherion elatioris	3	23.0	24.5	25.3	26.0	26.5	27.0	2.1
Berberidion vulgaris	3	24.0	24.0	25.0	24.0	25.5	27.0	1.7
Fagion sylvaticae	1	24.0	24.0	24.0	24.0	24.0	24.0	NA
Mesobromion	9	24.0	28.0	28.9	30.0	31.0	31.0	2.4
Molinion caeruleae	10	24.0	33.3	36.1	38.0	39.0	42.0	5.7
Trifolion medii	4	21.0	21.0	28.5	24.0	32.0	44.0	10.9
Reference (Biurrun et al. 2019, Biurrun et al. 2021, GrassPlot Diversity Explorer 2020 a, b, c)								
Mesobromion (meso-xeric)		10.0	31.0	38.9	38.0	46.0	68.0	10.9
Arrhenaterion (mesic)		5.0	28.0	36.2	37.0	44.0	73.0	12.5
Molinion (wet)		8.0	22.0	31.3	32.0	40.0	66.0	12.0

ing. The clear separation of the three clusters also reflected the distribution of the diagnostic species for each cluster in the ordination diagram.

Species diversity of the areas

Overall, 10.1% of the core flora of the canton of Zurich (able to survive in nature over several generations without human intervention including extinct and lost species, Wolgemuth et al. 2020) and 4.8% of all wild species known in Switzerland and border areas (Juillerat et al. 2017) occur on the study sites. Table 6 shows that most sites and most of the plots which are assigned to *Mesobromion* are on average less species-rich compared to the Swiss references (Biurrun et al. 2019, 2021; GrassPlot Diversity Explorer 2020a, 2020b, 2020c) for the corresponding most frequently assigned associations. By contrast, the flora of Erliweid and Hofstetterweid, which could be mainly assigned to *Molinion caeruleae*, are on average rather more species-rich than the references. However, none of the sites are particularly species-rich or species-poor. A comparison with the biotopes of national importance in the Swiss lowlands shows that the mean values at 10 m2 for both dry grasslands with 31.9 species and wet meadows with 34.7 species (Bergamini et al. 2019) are higher than in the study sites with the exception of Erliweid and Hofstetterweid. Nevertheless, the mean number of species in the sites is higher than the mean of 24 species determined for herbaceous meadows in dry meadows and pastures of national importance (Bergamini et al. 2019).

Impact of *Brachypodium pinnatum*

The negative effect demonstrated on species diversity of increasing cover of *Brachypodium pinnatum* confirms the results of Antognoli et al. (1995), Maubert & Dutoit (1995, according to Dipner et al. 2010) and Hurst & John (1999). In general, it appears that a later cutting time or the omission of a cut leads to an increase of dominant grass species, such as *Brachypodium pinnatum*, and a corresponding decrease of herbs (Bobbink et al. 1988; Hurst & John 1999; Köhler et al. 2005; Peter et al. 2010).

Recommendations

These results should primarily serve as an overview for the VNU of the floristic diversity of the study sites. In the long term, they could also serve as a basis for monitoring the plant diversity of the sites as well as the effects of possible future changes in management or further measures taken in favour of biodiversity conservation.

However, the results should be treated with caution, as the comparison of different areas, cutting regimes and alliances involves methodological difficulties. Furthermore, a high degree of stratification took place through the selection of areas of the VNU, which are often integrated into larger nature reserves. In terms of ecological gradients, parcel boundaries do not represent meaningful delineations. Accordingly, it would be interesting to extend the study to other areas of the region. Nevertheless, the results can be valuable not only locally but for protection of other grasslands in the region and similar grasslands in adjacent areas. Based on these results and various studies showing that species diversity tends to decrease due to underuse (Köhler 2001; Köhler et al. 2005; Peter et al. 2010), at least as a trial management in terms of cutting regime in certain areas of the region could be adjusted. Thus, Dipner et al. (2010) according to Maubert & Dutoit (1995) recommend intervening when the cover *Brachypodium pinnatum* reaches 50%, as grasses are very difficult to push back once they have become dominant. That threshold is already reached in four plots at the study sites.

For Erliweid, Rohmatt and Hofstetterweid, i.e. clusters 1 and 2, the cutting time could be adjusted to reduce the dominance of *Brachypodium pinnatum* by alternating a cutting date as early as July or a late cutting date in October every two years (Köhler et al. 2005). Since the alliances are stands of Molinion and the cutting date is already in September, it would be more effective to try to mow the areas significantly earlier every two years.

For Schleetal, Stückliberg and Tägerst, i.e. Cluster 3, an additional late cut (not shifting the date of an earlier cut) could reduce the dominance of *Bromus erectus* (Köhler et al. 2005; Peter et al. 2010; Humbert et al. 2012).

In Rohmatt, its location and characteristics at the forest edge should be taken into account when considering management options. In the plots and the wider area, light-demanding species of dry-warm locations such as *Orchis purpurea* and *Cypripedium calceolus* were present. To promote these typical species of open canopy forests, scrub encroachment and litter cover should be reduced. In addition to an additional cut, for *Orchis purpurea* and potentially other typical orchid species, grazing with goats from August onwards could be considered, while for *Cypripedium calceolus*, clearing shrubs and thinning forest stands but no grazing would be effective management options (Sigrist 2020).

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References

Amt für Landschaft und Natur Fachstelle Bodenschutz. 2018. *Landwirtschaftliche Nutzungseignung*. https://maps.zh.ch/

Amt für Landschaft und Natur Fachstelle Naturschutz. 2004. *Lebensraum-Potenziale* (Fechtgebiete, Mager- und Trockenwiesen). https://maps.zh.ch/

Amt für Landschaft und Natur Fachstelle Naturschutz. 2017a. *Übersicht Lebensraumkartierungen – Trockenstandorte 2003* TWW von nationaler Bedeutung gemäss BAFU. https://maps.zh.ch/.

Amt für Landschaft und Natur Fachstelle Naturschutz. 2017b. *Übersicht Lebensraumkartierungen – Feuchtgebietskartierung* 1976/77 gemäss Burnand & Züst. https://maps.zh.ch/.

Amt für Landschaft und Natur Kanton Zürich year unknown. *Inventar der geologischen und geomorphologischen*. Objekte des Kantons Zürich 1975/80.

Antognoli, C., Lörtscher, M., Guggisberg, F., Häfelfinger, S., Stämpfli, A. 1995. Tessiner Magerwiesen im Wandel. *Schriftenreihe Umwelt* 246: 1–135.

BAFU. 2017. *Biodiversität in der Schweiz: Zustand und Entwicklung. Ergebnisse des Überwachungssystems im Bereich Biodiversität, Stand 2016*. Umwelt-Zustand 1630.

BAFU. 2019. *Stand der Umsetzung der Biotopinventare von nationaler Bedeutung. Kantonsumfrage 2018*. Bundesamt für Umwelt, Bern.

Baudirektion Kanton Zürich. 2021. *Naturschutz-Gesamtkonzept: Bilanz 2015 und weitere Umsetzung*.

Bergamini, A., Ginzler, C., Schmidt, B.R., Bedolla, A., Boch, S., Ecker, K., Graf, U., Küchler, H., Küchler, M., Dosch, O. & Holderegger, R. 2019. Zustand und Entwicklung der Biotope von nationaler Bedeutung: Resultate 2011–2017 der Wirkungskontrolle Biotopschutz. Schweiz. *WSL Berichte* 85: 1–104.

Biurrun, I., Burrascano, S., Dembicz, I., Guarino, R., Kapfer, J., Pielech, R., Garcia-Mijangos, I., Wagner, V., Palpurina, S., (…) & Dengler, J. 2019. GrassPlot v. 2.00 – first update on the database of multi-scale plant diversity in Palaearctic grasslands. *Palaearctic Grasslands* 44: 26–47.

Biurrun, I., Pielech, R., Dembicz, I., Gillet, F., Kozub, Ł., Marcenò, C., Reitalu, T., Van Meerbeek, K., Guarino, R., (...) & Dengler, J. 2021. Benchmarking plant diversity of Palaearctic grasslands and other open habitats. *Journal of Vegetation Science* 32: e13050.

Bobbink, R., Bik, L., Willems, J.H. 1988. Effects of nitrogen fertilization on vegetation structure and dominance of *Brachypodium* *pinnatum* (L.) Beauv. in chalk grassland. *Acta Botanica Neerlandica* 37: 231–242.

Bornand, C., Gygax, A., Juillerat, P., Jutzi, M., Möhl, A., Rometsch, S., Sager, L., Santiago, H. & Eggenberg, S. 2016. *Rote Liste Gefässpflanzen. Gefährdete Arten der Schweiz*. Bundesamt für Umwelt, Bern: 178 pp.

Bosshard, A. 2015. Rückgang der Fromentalwiesen und die Auswirkungen auf die Biodiversität. *Agrarforschung Schweiz* 6: 20–27.

Bundesamt für Meteorologie und Klimatologie MeteoSchweiz 2020a. Klimanormwerte Temperatur 1981–2010. https://map.geo.admin.ch

Bundesamt für Meteorologie und Klimatologie MeteoSchweiz 2020b. Klimanormwerte Niederschlag 1981–2010. https://map.geo.admin.ch

Delarze, R., Eggenberg, S., Steiger, P., Bergamini, A., Fivaz, F., Gonseth, Y., Guntern, J., Hofer, G., Sager, L. & Stucki, P. 2016. Rote Liste der Lebensräume der Schweiz. Aktualisierte Kurzfassung zum technischen Bericht 2013 im Auftrag des Bundesamtes für Umwelt (BAFU). BAFU, Bern: 33 pp.

Delarze, R., Gonseth, Y., Eggenberg, S. & Vust, M. 2015. *Lebensräume der Schweiz: Ökologie – Gefährdung – Kennarten*. 3rd ed. Ott, Bern, CH.

Dialog:umwelt GmbH. 2015. *Biodiversitätspolitik in der Schweiz. Neue Grundlagen aus Kantonen, Gemeinden und Gesellschaft sowie Vergleiche mit den Nachbarländern*. 2nd ed. Im Auftrag von MAVA Foundation pour la nature. Bern.

Dipner, M., Volkart, G., Gubser, C., Eggenberg, S., Hedinger, C., Martin, M., Walter, T. & Schmid, W. 2010. *Trockenwiesen und -weiden von nationaler Bedeutung. Vollzugshilfe zur Trockenwiesenverordnung*. Umwelt-Vollzug 1017: 1–83.

Eggenberg, S. & Möhl, A. 2013. *Flora Vegetativa*. 3rd ed. Haupt, Bern, CH.

Eggenberg, S., Bornand, C., Juillerat, P., Jutzi, M., Möhl, A., Nyffeler, R. & Santiago, H. 2018. Flora *Helvetica – Exkursionsführer*. Haupt, Bern, CH.

GrassPlot Diversity Explorer. 2020a. Vegetation type: meso-xeric grassland. Country: CH, query from 15.10.2020 10:15 o'clock. https://edgg.org/databases/GrasslandDiversityExplorer.

GrassPlot Diversity Explorer. 2020b. Vegetation type: mesic grassland. Country: CH, query from 15.10.2020 10:15 o'clock. https://edgg.org/databases/GrasslandDiversityExplorer.

GrassPlot Diversity Explorer. 2020c. Vegetation type: wet grassland. Country: CH, query from15.10.2020 10:15 o'clock. https://edgg.org/databases/GrasslandDiversityExplorer.

Gubler T. 2009. Geologischer Atlas der Schweiz 1:25'000 - Albis (LK 1111).

Hill, M.O. 1979. *TWINSPAN: A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes*. Ithaca, N.Y: Cornell University, Section of Ecology and Systematics.

Humbert, J. Y., Pellet, J., Buri, P. & Arlettaz, R. 2012. Does delaying the first mowing date benefit biodiversity in meadowland? *Environmental Evidence* 1: 9.

Hurst, A. & John, E. 1999. The biotic and abiotic changes associated with *Brachypodium pinnatum* dominance in chalk grassland in south-east England. *Biological Conservation* 88: 75–84.

Info Flora 2018. Das nationale Daten- und Informationszentrum der Schweizer Flora. https://www.infoflora.ch/en/.

Juillerat, P., Bäumler, B., Bornand, C., Gygax, A., Jutzi, M., Möhl, A., Nyffeler, R., Sager, L., Santiago, H. & Eggenberg, S. 2017. *Checklist 2017 der Gefässpflanzenflora der Schweiz*. Info Flora, Bern, CH

Keel, A. 1993. *Vegetationskundlich-ökologische Untersuchungen und Bewirtschaftungsexperimente in Halbtrockenwiesen (Mesobromion) auf dem Schaffhauser Randen*. PhD thesis, Eidgenössischen Technischen Hochschule, Zurich.

Klötzli, F. 1969. *Die Grundwasserbeziehungen der Streu- und Moorwiesen im nördlichen Mittelland. Beiträge zur Geobotanischen Landesaufnahme der Schweiz*. Verlag Hans Huber, Bern.

Klötzli, F., Meyer, M. & Züst S. 1973. Exkursionsführer – Kurzbeschreibung der Exkursionsorte. Ostalpin-Dinarischen Pflanzensoziologischen Arbeitsgemeinschaft: https://www.zobodat.at/pdf/Mitt-ostalpin-dinaris-pflanzensoz-arbeitsg_13_1973_0040-0095.pdf.

Koch, W. 1926. *Die Vegetationseinheiten der Linthebene systematisch-kritische Studie*. PhD thesis, Eidgenössisch Technische Hochschule, Zurich.

Köhler, B. 2001. *Mechanisms and extent of vegetation changes in differently managed limestone grasslands*. PhD thesis, ETH Zurich.

Köhler, B., Gigon, A., Edwards, P.J., Krüsi, B., Langenauer, R., Lüscher, A. & Ryser, P. 2005. Changes in the species composition and conservation value of limestone grasslands in Northern Switzerland after 22 years of contrasting managements. *Perspectives in Plant Ecology, Evolution and Systematics* 7: 51–67.

Küchler, M. 2014. Software VEGEDAZ. Programm für die Erfassung und Auswertung von Vegetationsdaten. Release 2014. Forschungseinheit Biodiversität und Naturschutzbiologie, Eidg. Forschungsanstalt WSL, Birmensdorf.

Lachat, T., Pauli, D., Gonseth, Y., Klaus, G., Scheidegger, C., Vittoz, P. & Walter, T. 2011. *Wandel der Biodiversität in der Schweiz seit 1900. Ist die Talsohle erreicht?* Haupt, Bern: 435 pp.

Landolt, E. 1977. *Ökologische Zeigerwerte zur Schweizer Flora*. Veröffentlichungen des Geobotanischen Instituts der ETH, Stiftung Rubel, Zürich, 64: 1–208.

Lauber, K., Wagner, G. & Gygax, A. 2018. Flora Helvetica. 6th ed. Haupt, Bern, CH.

Maubert, P. & Dutoit, T. 1995. *Connaître et gérer les pelouses calcicoles. Ministère de l'aménagement du territoire et de l'environnement*. Outils de gestion. 65 pp.

Oberdorfer, E. & Görs, S. 1983. Klasse: *Molinio-Arrhenatheretea* Tx. 37. In: Oberdorfer, E. (ed.) *Süddeutsche Pflanzengesellschaften – Teil III: Wirtschaftswiesen und Unkrautgesellschaften*. 2nd ed.: pp. 347-436. Fischer, Stuttgart.

Oberdorfer, E. & Korneck, D. 1976. Klasse: *Festuco-Brometea* Br.-Bl. et Tx. 43. – In: Oberdorfer, E. (ed.) *Süddeutsche Pflanzengesellschaften – Teil II: Sand- und Trockenrasen, Heide und Borstgras-Gesellschaften, alpine Magerrasen, Saum-Gesellschaften, Schlag- und Hochstaudenfluren*. 2nd ed.: pp. 86-248. Fischer, Stuttgart.

Oberdorfer, E. & Müller, T. 1977. Klasse: *Trifolio-Geranietea sanguinei* Th. Müller 61. In: Oberdorfer, E. (ed.) *Süddeutsche Pflanzengesellschaften – Teil II: Sand- und Trockenrasen, Heide und Borstgras-Gesellschaften, alpine Magerrasen, Saum-Gesellschaften, Schlag- und Hochstaudenfluren*. 2nd ed.: pp. 249-298. Fischer, Stuttgart.

Pantke, R. 2008. Pflanzengesellschaften der Schweiz. https://www.wsl.ch/de/services-und-produkte/daten-monitoring-und-inventare/pflanzengesellschaften-der-schweiz.html.

Peter, M., Babbi M. & Kronauer L. 2010. *Trendanalyse der Vertragswiesen mit der Landwirtschaft*. Projekt Bewirtschaftungsverträge Naturnahe Landwirtschaft, Beve. Agrofutura AG & Departement Bau. Verkehr und Umwelt, Sektion Natur und Landschaft, Kt. Aargau.

Roleček, J., Tichý, L., Zelený, D. & Chytrý, M. 2009. Modified TWINSPAN classification in which the hierarchy respects cluster heterogeneity. *Journal of Vegetation Science* 20: 596–602.

Sigrist, S. 2020. *Eignung der Ziegenbeweidung zur Wiederherstellung eines Orchideenwaldes – Erfolgskontrolle Zuckenriet*. Bachelor thesis Umweltingenieurswesen, IUNR, ZHAW, Wädenswil.

Tichý, L., Chytrý, M. & Zelený, D. 2018. Juice Version 7.0.102. URL: http://www.sci.muni.cz/botany/juice/.

Urech, M., Eggenberger, S., pro seco. 2007. *Inventarvergleiche*. Interner Bericht, Bern. Im Auftrag des BAFU.

Wolgemuth, T., Del Fabbro, C., Keel, A., Kessler, M. & Nobis, M. 2020. *Flora des Kantons* Zürich. Haupt Verlag, Bern, CH.

WSL 2017. VEGEDAZ. URL: https://www.wsl.ch/de/services-und-produkte/software-websites-und-apps/vegedaz-version-2017.html.

Fig. 8. From left to right: *Carex tomentosa, Gymnadenia conopsea* and *Scabiosa columbaria* as differential species of clusters 1, 2 and 3. Photos: P. Schmid.