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Effects of grazing versus mowing on the vegetation of wet grasslands in the northern Pre-Alps, Switzerland

Pascal Reutimann[1] | Regula Billeter[1] | Jürgen Dengler[1,2]

[1]Vegetation Ecology Research Group, Institute of Natural Resource Sciences (IUNR), Zurich University of Applied Sciences (ZHAW), Wädenswil, Switzerland

[2]Plant Ecology, Bayreuth Center of Ecology and Environmental Research (BayCEER), University of Bayreuth, Bayreuth, Germany

Correspondence
Jürgen Dengler, Vegetation Ecology Research Group, Institute of Natural Resource Sciences (IUNR), Zurich University of Applied Sciences (ZHAW), Wädenswil, Switzerland.
Email: juergen.dengler@zhaw.ch

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Abstract

Question: Wet grasslands are among the most threatened habitats in Central Europe and are subject to loss of their unique species assemblages. Grazing and mowing are important conservation management tools for such semi-natural habitats. The aim of this study was to investigate and compare the influence of grazing and mowing on the diversity and species composition of wet grassland vegetation.

Location: Montane wet grasslands in the Gantrisch Nature Park, Switzerland.

Methods: We sampled 18 pairs of vegetation plots along land-use borders between grazing and mowing (fence-line contrasts), distributed over six fens, mostly belonging to the phytosociological alliance *Calthion palustris*. We tested for differences in structural parameters, biodiversity indices, mean ecological indicator values and the frequency of individual species. In addition, a detrended correspondence analysis was carried out.

Results: Management type had no influence on species richness, Shannon index or Shannon evenness. Maximum microrelief, vegetation height, mean nutrient indicator value and mean competitive strategy were significantly higher with grazing, whereas the mean aeration indicator value and the mean ruderal strategy were significantly higher with mowing. *Cirsium oleraceum*, *Filipendula ulmaria*, *Geum rivale* and *Juncus effusus*, species of nutrient-rich wet meadows, were more frequent under grazing, whereas mowing favoured grassland species with wide ecological amplitude, such as *Plantago lanceolata* and *Trifolium pratense*.

Conclusions: At the plot scale, vascular plant diversity did not differ between these management regimes. Thus, from the conservation point of view, in the study region, there is no clear preference for either management type, and both should be eligible for subsidies. At the landscape scale, it is beneficial to have both management types present to ensure high gamma-diversity, as they favour different species.

KEYWORDS
biodiversity conservation, *Calthion palustris*, ecological indicator value, fen, fence-line contrast, grazing, mowing, semi-natural grassland, Switzerland, wet grassland

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1 | INTRODUCTION

Mires are unique habitats, home to many rare plants and animals. Across Europe, most mire habitat types are endangered (Janssen et al., 2016). The underlying causes are various: hydrological changes (Schrautzer et al., 2019), eutrophication (Hájek et al., 2015), global climate change (Essl et al., 2012; Herrera-Pantoja et al., 2012; Swindles et al., 2019) and the abandonment of extensive management (Diemer et al., 2001; Opdekamp et al., 2012; Joyce, 2014).

Owing to peat extraction and the intensification of agriculture, approximately 85% of Swiss mires have disappeared during the past century (Lachat et al., 2010), making them one of the most threatened habitats (Delarze et al., 2016). Mires are habitats for a large proportion of Switzerland's endangered plant species (Klaus et al., 2007; Bornand et al., 2016). In Switzerland, representative parts of mires *sensu lato*, including both peat-forming bogs and fens as well as non-peat-forming wet grassland types derived from these, are currently protected as habitats of national importance (overview by Bergamini et al., 2019). Although the decrease in mire areas in Switzerland could be slowed through conservation measures, the quality of these areas continues to decline (Klaus et al., 2007; Küchler et al., 2018). The main reasons for the continuing negative development of Swiss mires are an increase in nutrients, desiccation and deteriorating light conditions through the encroachment of woody species (Graf et al., 2010; Bergamini et al., 2019). Across Switzerland, the area of peat-forming fens is decreasing in favour of non-peat-forming fens (Klaus et al., 2007), commonly referred to as wet grasslands or fen grasslands. Regarding fen habitats, an increase in woody vegetation cover in particular, as well as a disturbed water balance has led to a decrease in moisture, light and corresponding habitat specialists (Bergamini et al., 2019). In the natural landscape below the forest line, the majority of the now-protected fen habitats (e.g., *Caricion davallianae*) were once forested (Egloff et al., 2002). Keeping these habitats that were created by anthropogenic use open and thus promoting small-scale biodiversity in the cultural landscape aligns with today's conservation goals (but see Kozub et al., 2019 who found in Northern Poland that near natural fens are negatively affected by mowing, whereas managed fen habitats profit from the maintenance of low-intensity land use). Therefore, extensive agricultural management is desirable in Switzerland's fens.

Grassland management has different impacts on species richness and plant composition, depending on land-use type and region (Socher et al., 2013). For example, in urban areas, nutrient changes in grassland seem more likely to be affected by changes in management (Kummli et al., 2021), whereas in rural areas, nutrient ratios in grassland are influenced by the surrounding intensively used agricultural land (Charmillot et al., 2021). In grassland management, the question often arises whether grazing or mowing has a higher nature conservation benefit (see Tälle et al., 2016). This issue is particularly relevant for the management of fens, a term that we use both for peat-forming fens (e.g., *Caricion davallianae*, *Caricion nigrae*) and for non-peat-forming wet grasslands often derived from the former (e.g., *Molinion*, *Calthion*, *Filipendulion*; typology according to Delarze et al., 2015, 2016; similarly in the European typology by Mucina et al., 2016).

The hydrological conditions, chemical properties and characteristic biota of degraded mires can be improved by mowing or extensive grazing (Rowland et al., 2021). Various studies show that mowing is an effective method to restore typical plant communities in fens even after a long period of abandonment (Peintinger & Bergamini, 2006; Billeter et al., 2007; Galvánek et al., 2015; Horák & Šafářová, 2015). Mowing can lead to a higher abundance of fen-typical vascular plant species (Sundberg, 2012), and the species richness of mire vegetation is generally increased by mowing (Menichino et al., 2016). Grazing can also counteract reed and shrub expansion in wetlands (Mirski, 2022). Abandonment of grazing leads to a decline in floristic quality and a decrease in specialized and rare fen species (Bart, 2021).

Both management methods shape the landscape in different ways. Whereas mowing creates homogeneous vegetation, grazing leads to a heterogenous vegetation structure (Rūsiņa, 2017). Traditionally, mowing was recommended over grazing in fen management (Klaus et al., 2007; Hájková et al., 2022), but this view has been questioned (Voss, 2001). When comparing mown and grazed fen areas, in some studies species richness was higher in meadows (Stammel et al., 2003), whereas in other cases it was higher in pastures (Voss, 2001). One advantage of grazing is that cattle prefer nutrient-rich plant species of the mesic grassland and, with this selective feeding behaviour, spare fen species with a lower forage value (Voss, 2001). However, if nutrient-rich species show poor regeneration or if grazing is too intensive, this may force cattle to graze nutrient-poor fen vegetation nevertheless (Güsewell et al., 2007). Furthermore, it is possible that grazing leads to higher nutrient levels in mires (Küchler et al., 2009), or initiates the loss of typical fen species (Sienkiewicz-Paderewska et al., 2020). Another controversy is whether cattle trampling is beneficial or damaging to mire vegetation. Spitale (2021), observed that moss communities and rare bryophyte species decreased because of cattle trampling. Intensive grazing can furthermore lead to soil degradation due to trampling damage (Middleton et al., 2006). On the other hand, hoof print gaps can in turn be a potential habitat for colonizers of disturbed sites, such as *Carex echinata* (Voss, 2001). Generally, understanding of the differential effects of mowing vs grazing in fen grasslands is limited because, with very few exceptions, most studies either analysed mowing or grazing and did not conduct a comparison.

Despite extensive management, the condition of mires in Switzerland continues to deteriorate (Bergamini et al., 2009, 2019). It is therefore important to understand the influence of different management types on the condition of mire vegetation so that appropriate measures can be implemented. We aimed to investigate how grazing and mowing affect the local vegetation in fen grasslands. For this purpose, we recorded the vascular plants of mown and grazed fens in a mire landscape in the Swiss Pre-Alps in 18 pairs of vegetation plots. The study sites belong to the phytosociological alliance *Calthion palustris*, with some share of typical fen species of the alliance *Caricion davallianae* (typology according to Delarze et al., 2015 and Mucina et al., 2016). In the refined EUNIS habitat typology, they belong to "R35 – Moist or wet mesotrophic to eutrophic hay meadows" and "R36 – Moist or wet mesotrophic to eutrophic pasture" (Chytrý et al., 2020; see also the European Red List of habitats by Janssen et al., 2016). We tested the collected data for differences in diversity indices, ecological indicator values and functional traits between mowing and grazing.

2 | METHODS

2.1 | Study area

The six studied sites are part of one of the largest Swiss mire landscapes: Gantrisch Nature Park in the canton of Bern (Figure 1). The study area covers a north–south extension of 1 km (46.759–46.749°N) and an east–west extension of 7 km (7.355–7.443°E). The sites are located between 1,100 and 1,350 m a.s.l. in the northern Pre-Alps in the upper montane belt.

The study area belongs to the tectonic unit of the Gurnigel nappes, adjacent to the subalpine molasse (Swiss Geoportal, 2021). The Gurnigel nappes are characterized by flysch (sandstone and marlstone) (Gnägi & Labhart, 2017). This substrate is water-impermeable and thus promotes mire formation (Steiner et al., 2002). Owing to the soft, flysch bedrock and the steep terrain, there are also some landslide areas (Swiss Geoportal, 2021).

The climate is Atlantic with an annual precipitation total of 1,151 mm and a mean annual temperature of 8°C (10-year averages from 2011 to 2020), measured at the weather station at Plaffeien, 10 km distant at 1,042 m a.s.l. (MeteoSwiss, 2021). The mire landscape is mosaic-like, consisting of forest and open land, the latter being dominated by fens. According to cantonal geodata, the investigated sites 1 and 6 as well as the meadow part of site 4 are considered small sedge fens (i.e., *Caricion davallianae*) and the other sites are considered nutrient-rich wet grasslands (i.e., *Calthion palustris*) (pers. comm. Heidi Schlosser, Office for Agriculture and Nature of the Canton of Bern).

The fens of the mire landscape are subject to nature conservation agreements with the farmers and are either grazed or used as hay meadows or litter meadows. The earliest time for cutting the meadows is 15 July. The pastures are extensively grazed from May/June until autumn by rearing cattle, suckler cows and dairy cows of various breeds (Simmental, Swiss-Fleckvieh, Limousin). Site 4 was grazed with sheep (rotational pasture) for the first time in 2021. Grazing normally takes place for only part of the year, mostly June to September, and during this period the stocking rate of the various pastures is between 1.6 and 6.7 livestock units per hectare, but the situation in each pasture varies from year to year. In addition to grazing, the grazed areas of sites 1–3 are additionally subject to a management cut. On sites 2, 3, 5 and the pasture of site 4, light fertilization with manure was permitted until 2018. Information on the management contracts was provided by Heidi Schlosser, Inventory and Contracts Officer, Nature Promotion Division, Office for Agriculture and Nature of the Canton of Bern. More specific information on management was obtained directly from the landowners.

2.2 | Field sampling

To exclude other aspects not relevant for the study, we selected the studied sites according to the following criteria: (a) the sites are located within the perimeter of the fens of national importance; (b) the

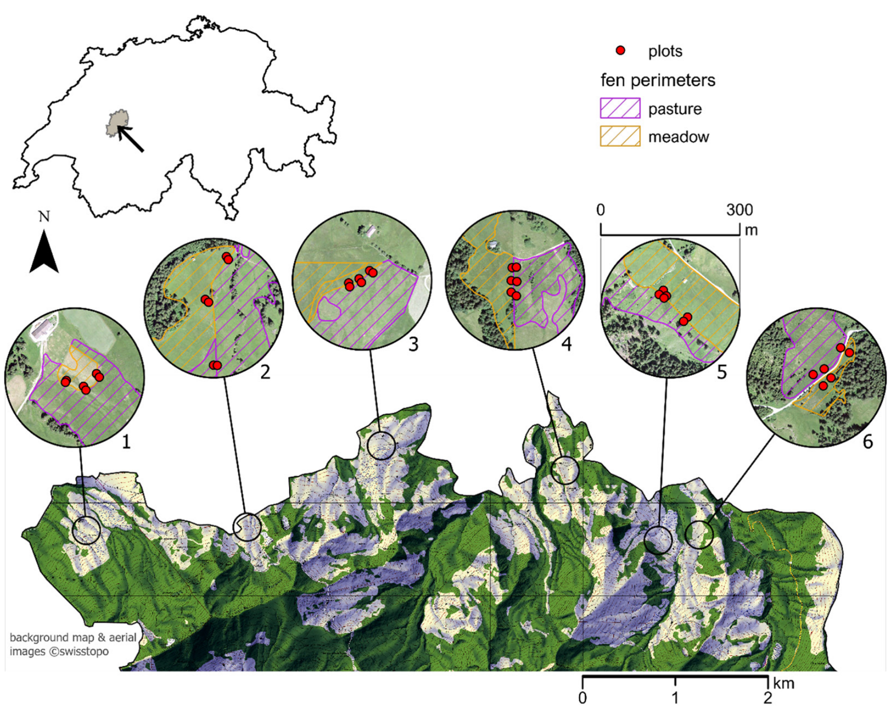

FIGURE 1 Map showing the study area. (Upper) Location of the mire landscape within the Gantrisch Nature Park (grey area) in Switzerland. (Lower) Location of the six sites within the mire landscape that are of national importance. (Middle) Positioning of the pairs of plots within the fens. Maps and aerial images © swisstopo

sites share a land-use boundary between mown and grazed fens; and (c) the current management has been in place for at least 10 years. According to these criteria, we identified six suitable sites, and at each of which we surveyed three meadow–pasture pairs (six plots); i.e., a total of 18 pairs (36 plots) (Figures 1 and 2).

The distance between a plot and the land-use boundary was set at 5 m. To cover the diversity in the fen, plots were distributed as evenly as possible along the boundary using aerial images. In the case of atypical conditions found on site (e.g., trees, topographically distinct elevation without bog vegetation), the plots were shifted along the boundary according to the following criteria: at least 5 m or a maximum 10 m distance to the boundary, at least 20 m lateral distance between the pairs of plots, at least 5 m from the edge of the meadow/pasture and at least 5 m from obstacles (woodlands, open rocky areas, water bodies).

We carried out the vegetation surveys from 11 to 20 June 2021, which approximately corresponds to peak standing crop. The 10-m^2 plots were aligned parallel to the land-use boundary, and their geographical coordinates were recorded (Galaxy Tab S4, accuracy ± 3 m) and permanently marked with a buried magnet for future surveys (corner on the side of the land-use boundary distant from the start or lowest plot ID).

Within the plots, we determined all vascular plants, and estimated their per cent cover on a continuous scale. Furthermore, we recorded environmental parameters (altitude, aspect, inclination, pH, maximum microrelief, standardized soil depth and pH) and some structural parameters (maximum and standardized vegetation height and the cover of different vegetation layers) for each plot (for details see Dengler et al., 2016). Maximum microrelief was defined as the maximum perpendicular deviation of the soil surface from an approximately 1-m long straight metal stick laid on the ground (Dengler et al., 2016). In addition, mixed soil samples of the uppermost 10 cm were taken at five locations within the plot and subsequently air-dried. The pH of the mixed soil mixture was later measured using a multiprobe (Hanna Instruments, type HI-991300) in distilled water (soil/water mass ratio of 10:25).

All data collected in the field were digitally recorded using the application FlorApp (Android, version 2.6.1) from Info Flora (Info Flora, 2021). The species were identified using the reference works from Eggenberg et al. (2018), Lauber et al. (2018) and Eggenberg and Möhl (2020). Taxonomy and nomenclature follow the Swiss checklist (Juillerat et al., 2017). The plot data are available in Appendices S1 and S2 and have also been contributed to the GrassPlot database (Dengler et al., 2018).

2.3 | Statistical analyses

We used R (version 4.1.0; R Core Team, R Foundation for Statistical Computing, Vienna, AT) for all statistical analyses.

The following environmental parameters collected in the field were used to exclude the influence of factors other than management: elevation, inclination, south component of aspect, pH, mean soil depth and variation in soil depth. Consequently, we expected no significant differences in these parameters between the mown and grazed plots.

We calculated species richness, Shannon index and Shannon evenness using the functions "specnumber" and "diversity" (*vegan* package, R version 2.6-2; R Core Team, R Foundation for Statistical Computing, Vienna, AT). Using the program VEGEDAZ (version October 2019, WSL, Birmensdorf, Switzerland), the square root of cover weighted means of ecological indicator values (soil variables and mowing tolerance) and Competitor, stress-tolerator, ruderal (CSR) strategy types sensu Grime (2001) (Table 1) from Landolt et al. (2010) were calculated for each plot (Table 1). Instead of analysing the nine different CSR strategies distinguished by Landolt et al. (2010) (ccc, ccr, ccs, crr, css, crs,...), we used the numerical implementation in VEGEDAZ, where these nine categories are translated into ordinal values ranging from 0 to 3 for each of the three strategy dimensions competitiveness, ruderality and stress tolerance, with the three scores of each species summing up to 3. Each score corresponds to the number of the respective letter in the strategy category. This form of coding allows us to handle the three strategy dimensions mathematically in the same manner as ecological indicator values.

We conducted a detrended correspondence analysis to visualize the similarity relationships among the plots and the species using the function "decorana" (*vegan* package, with default settings; R version 4.2.2, R Core Team, R Foundation for Statistical Computing, Vienna, AT). To identify potential underlying factors, the indicator values and strategy types were correlated with the ordination axes using the function "envfit" (*vegan* package, with default settings; R version 4.2.2, R Core Team, R Foundation for Statistical Computing, Vienna, AT), and the significant correlations (p.max = 0.001) were added post hoc to the ordination graph.

We used a mixed effect model to for differences in environmental parameters, biodiversity, indicator values and strategy types between mowing and grazing. Owing to the fully balanced design, we did this with an analysis of variance (command *aov*), applying as *Error* term pair nested in site. A sign test was used to examine which species occur more frequently under which management type.

3 | RESULTS

3.1 | Measured parameters

The parameters elevation, inclination, south component of aspect, pH, mean soil depth and variation in soil depth showed no significant differences between mowing and grazing (Appendix S3).

Among the parameters measured in the field, maximum microrelief, vegetation height variation and mean vegetation height had significantly higher values under grazing than under mowing (Figure 3). The maximum microrelief in the pastures was on average twice as large as in the meadows (Appendix S3). We found no differences in maximum vegetation height, total cover, and individual layer cover (Appendix S3).

FIGURE 2 One of the land-use boundaries between grazed (left) and mown (right) wet grasslands analysed in this study (photograph: J. Dengler)

TABLE 1 Ecological indicator values and CSR strategies from Landolt *et al.* (2010) used for comparison of the two management types

Category	Parameter	Range of values
Ecological indicator values	Moisture	1–5
	Reaction	1–5
	Nutrients	1–5
	Humus	1–5
	Aeration	1–5
	Mowing tolerance	1–5
CSR strategies	Competitiveness	0–3
	Ruderality	0–3
	Stress tolerance	0–3

Note: "Mowing tolerance" comprises tolerance to mowing and grazing (Landolt et al., 2010). The range of indicator values according to Landolt et al. (2010) differs from the widespread scale used by Ellenberg *et al.* (1992), which has 1–9 or 1–12.

Abbreviation: CSR, Competitor, stress-tolerator, ruderal.

3.2 | Biodiversity

In total we recorded 110 vascular plant species, 96 in the meadows and 87 in the pastures. We found no significant differences in the biodiversity indices (species richness $p = 0.957$, Shannon index $p = 0.610$ and Shannon evenness $p = 0.404$) across all the plots studied (Appendix S3). The mean species richness in 10 m^2 was 30.3 for grazing and 30.4 for mowing.

3.3 | Frequency of individual species

At the species level, we found significant differences for eight species (Table 2). Five species (*Cirsium oleraceum*, *Filipendula ulmaria*, *Geum rivale*, *Juncus effusus* and *Veronica chamaedrys*) occurred more frequently in grazed plots and three species (*Plantago lanceolata*, *Rhinanthus minor* and *Trifolium pratense* subsp. *pratense*) occurred more frequently in mown plots.

We did not observe any endangered species within the surveyed plots. However, we found three near threatened species (*Carex distans*, *Dactylorhiza incarnata* subsp. *incarnata* and *Ranunculus flammula*) in the grazed plots. In addition, the following character species and dominant species of the small sedge fens were present: *Carex davalliana*, *Carex panicea*, *Eriophorum latifolium* of the *Caricion davallianae*, and *Carex canescens*, *Carex echinata*, *Carex nigra* of the *Caricion fuscae*. Species of the shrub layer were not present in any of the surveyed plots (Appendix S2).

3.4 | Ecological indicator values and CSR strategies

The analysis revealed significant differences for three ecological indicator values. The grazed plots showed higher nutrient values and the mown plots higher aeration values (Figure 4). We did not find significant differences in other indicator values between the management types (Appendix S3).

Regarding plant strategies, competitive species were significantly more represented in the grazed plots, whereas the mown plots had a higher number of ruderal species (Figure 5). We did not find significant difference regarding the stress value.

3.5 | Ordination

Of the total variance (sum of eigenvalues: 1.2), 34% is explained by the first axis (eigenvalue 0.41) and 27% by the second axis (eigenvalue 0.32). In particular, the plots of site 1 distinguish themselves from the other plots along this gradient (Figure 6). The gradient length of the second axis is 2.53 *SD*, giving the underlying gradient a rather low significance for the variation in species composition. However, the plots are clearly divided along the second axis into the management types (Figure 6).

4 | DISCUSSION

4.1 | Validity of the sampling

We did not find any differences in abiotic environmental factors between mowing and grazing (Appendix S3), which allows us to exclude them as causal factors for differences in the vegetation. It is nevertheless important to note that in the past, additional manure application was permitted at some sites and autumn mowing is carried out on certain pastures (see Section 2.1). A major influence of sheep grazing on the vegetation studied at site 4 in 2021 can be excluded, because the samples were taken near the land-use boundary at rather wet sites. When drier patches are present, wet patches are avoided by sheep (Putfarken et al., 2008). In fact, the large maximum microrelief of up to almost 30 cm in some of these areas (Appendix S1) was likely caused by previous cattle grazing, supporting this view. Overall, the selected study sites are thus very suitable for a floristic comparison between mowing and grazing without confounding factors.

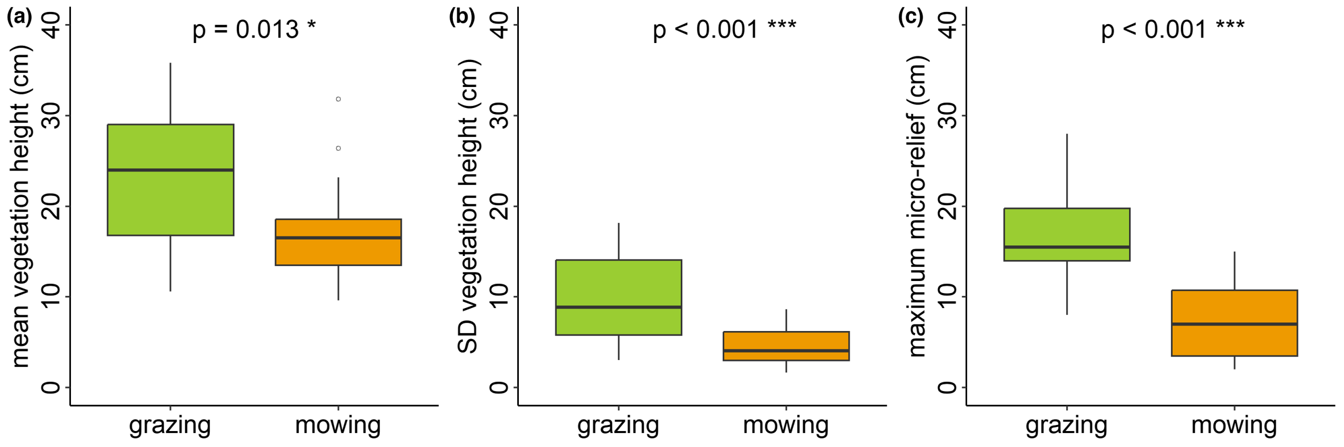

FIGURE 3 Structural parameters recorded in the field with significant differences between management types

TABLE 2 List of species that occurred significantly more often in one of the management types

Species	Frequency grazing	Frequency mowing	*p*-value
Grazing			
Filipendula ulmaria	13	4	0.004
Veronica chamaedrys	12	3	0.004
Juncus effusus	18	10	0.008
Geum rivale	7	0	0.016
Cirsium oleraceum	8	2	0.031
Mowing			
Rhinanthus minor	1	10	0.004
Plantago lanceolata	4	12	0.008
Trifolium pratense subsp. *pratense*	7	15	0.039

Note: Frequency indicates the number of plots in which the species was present. The number of plots per management type was 18.

4.2 | Impact on biodiversity

We did not find any differences between mowing and grazing in the three tested diversity metrics, which is consistent with the results of a similar study by Seer and Schrautzer (2014). However, the biodiversity effects of the two management types in the semi-natural grasslands of Europe are generally quite divergent and case-specific (Dengler et al., 2014). Some studies observed significantly higher species richness in mown mires (Stammel et al., 2003) or other mown semi-natural grasslands (Turtureanu et al., 2014). Other studies, however, found higher diversity in grazed mires (Voss, 2001) or in other grazed grasslands (Schaich & Barthelmes, 2012; Moinardeau et al., 2019; Karami et al., 2021). Potential causes for higher fine-grain biodiversity in mown grasslands are non-selective biomass removal that reduces interspecific competition (Dengler et al., 2014) or trampling damage in grazed sites (Stammel et al., 2003), whereas arguments for higher diversity in pastures include increased micro-relief due to grazing (Voss, 2001) or improved diaspore dispersal (Schaich & Barthelmes, 2012). It is likely that these assumed causes of biodiversity increase or decrease also apply in the Gantrisch region, but the opposing effects have offset each other. In some ways, our results are similar to those of Stammel et al. (2003) who found no difference in fen target species between mowing and grazing.

The mean number of vascular plant species in wet grassland throughout Switzerland is 31 species in 10 m^2 (GrassPlot Diversity Explorer version 2.10; https://edgg.org/databases/GrasslandDiversityExplorer; see Biurrun et al., 2021). Thus, the average of 30 species per 10 m^2 found in this study corresponds to the common numbers in wet grassland.

4.3 | Impact on species composition

4.3.1 | Frequency of individual species

Among the species significantly more abundant in pastures, *Filipendula ulmaria*, *Juncus effusus*, *Geum rivale* and *Cirsium oleraceum* are companion species of wet grasslands (*Molinietalia caeruleae*), especially nutrient-rich types (*Calthion*), and *Veronica chamaedrys* is a species found in diverse habitats (including mesic meadows and pastures; Delarze et al., 2015). Across Europe, the former are diagnostic species of wet, mesotrophic to eutrophic hay meadows (Chytrý et al., 2020). In the study of Seer and Schrautzer (2014), tall species such as *Filipendula ulmaria* were more abundant in meadow vegetation. Whereas mowing is hardly effective against the spread of *Filipendula ulmaria* (Kołos & Banaszuk, 2021), trampling by grazing livestock supposedly reduces the competitive ability of tall species (Seer & Schrautzer, 2014). However, we could not find this effect in our study. On the contrary, grazing seems to have favoured the spread of tall species.

Under mowing, *Plantago lanceolata* and *Trifolium pratense*, two mesophilic species, and *Rhinanthus minor* were significantly more abundant. *Rhinanthus minor* is a typical species of meadows (Oberdorfer, 2001) which are rather nutrient poor (Landolt et al., 2010), and its seed dispersal is enhanced by mowing (Coulson

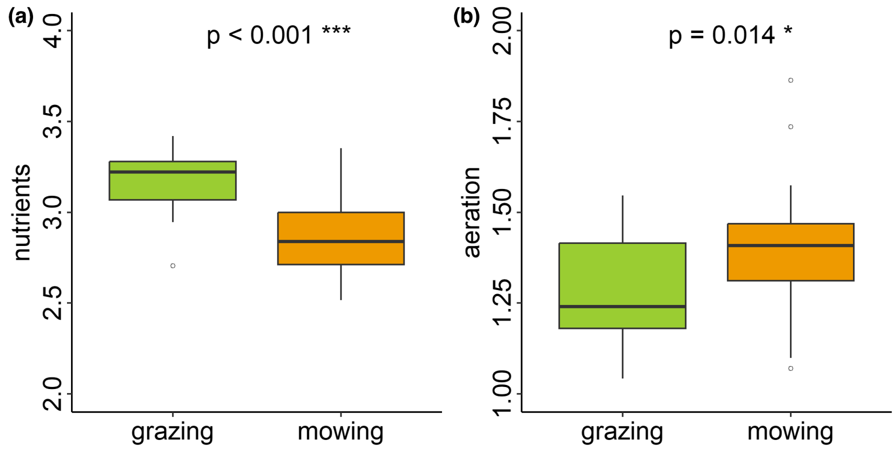

FIGURE 4 The community-weighted mean of the ecological indicator values with significant differences between management types

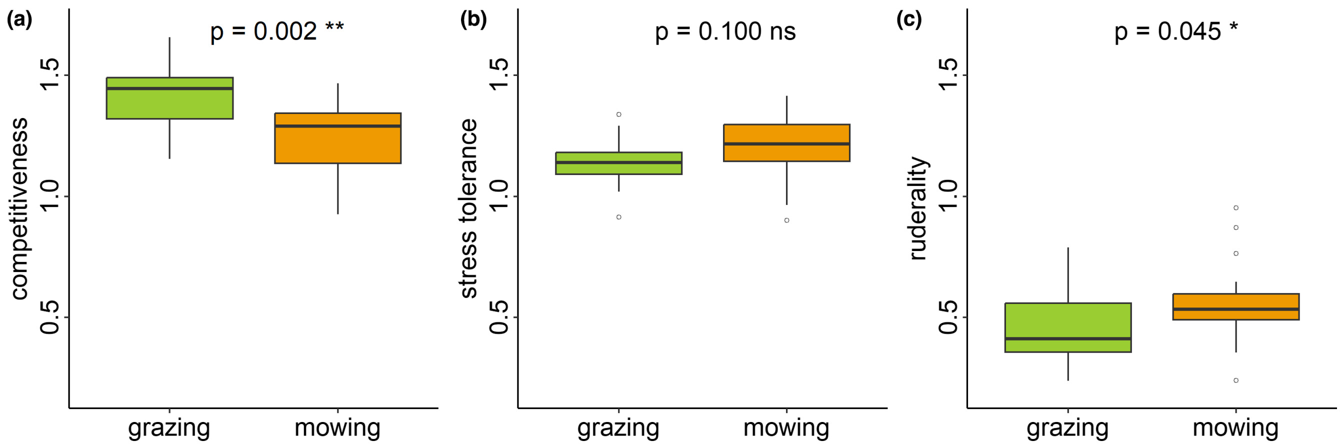

FIGURE 5 Differences in the community-weighted mean of the Competitor, stress-tolerator, ruderal strategies between management types

et al., 2001). *Plantago lanceolata* and *Trifolium pratense* are typical of the *Arrhenatherion* alliance according to Delarze et al. (2015). In fact, these species are diagnostic of mesic hay meadows at low and middle elevations throughout Europe (Chytrý et al., 2020).

At first glance, the fact that some species of wet grasslands are favoured by grazing and some typical of mesic conditions by mowing could indicate that grazing is more favourable for maintaining typical wet grassland vegetation. However, this impression was not supported by the mean indicator values for moisture, which did not differ significantly between the two management regimes. Thus, the typical wet grassland species might rather be favoured in the grazed parts by the more variable moisture conditions due to the larger microrelief with drier hummocks and water-filled hollows, whereas in mown parts the conditions are moderately wet throughout.

4.3.2 | Structural parameters

The large heterogeneity in vegetation height and the large maximum microrelief under grazing (Figure 3) are a typical characteristic of pastures (Rūsiņa, 2017). Owing to the pronounced microrelief, small-scale niche differentiation can occur, hence higher species numbers can be found in pastures than in meadows (Voss, 2001). However, as mentioned above, we did not find any differences in biodiversity indices between mowing and grazing. Thus, the pronounced microrelief does not appear to have promoted additional niche colonizers. This is consistent with findings in a study by Stammel and Kiehl (2004), which revealed that rhizomes of surrounding species tend to colonize hoof prints, preventing new fen species from establishing themselves. The variable soil surface in pastures is more likely to have favoured taller species such as *Filipendula ulmaria* and *Cirsium oleraceum*, as confirmed by the significantly larger mean vegetation height as well as community-weighted mean (CWM) of canopy height in pastures.

4.3.3 | Ecological indicator values

The higher mean indicator values in the grazed plots suggest that grazing might increase nutrient availability, which would be problematic for typical species of nutrient-poor fens. Although Küchler et al. (2009) also found higher nutrient values in grazed areas, other studies in wetlands did not find an increase in nutrient availability related to grazing (Güsewell et al., 2007; Seer & Schrautzer, 2014; Bart, 2021). However, Güsewell et al. (2007) found nutrient redistribution within the grazed area. The eutrophicated resting places

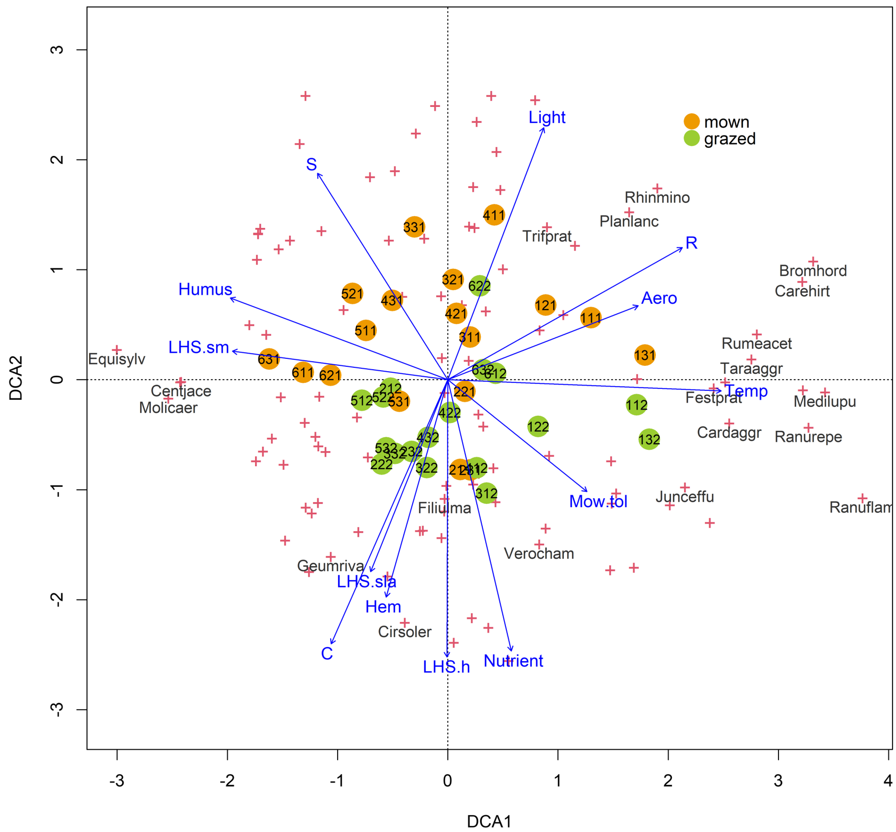

FIGURE 6 Ordination of 36 plots with a total of 110 vascular plant species (eigenvalues first/second axis: 0.41/0.32; total variance: 1.20; length first/second axis: 3.45/2.53). Arrows indicate parameters correlating with the ordination axes ($p \leq 0.001$). Light: light value; aero: aeration value; temp: temperature value; nutrient: nutrient value; humus: humus value; C: competition value; S: stress value; R: ruderal value; LHS.h: canopy height according to leaf-height-seed; LHS.sm: seed mass according to leaf-height-seed; hem: hemicryptophytes. In addition, the names of the species that occurred significantly more often in one of the management types are shown. Cirsole: *Cirsium oleraceum*; Filiuma: *Filipendula ulmaria*; Geuriva: *Geum rivale*; Junceffu: *Juncus effusus*, Planlanc: *Plantago lanceolata*; Rhinmino: *Rhinanthus minor*; Trifprat: *Trifolium pratense* subsp. *pratense*; Verocham: *Veronica chamaedrys*, as well as several other species; Bartalpi: *Bartsia alpina*; Bromhord: *Bromus hordeaceus*; Cardaggr: *Cardamine pratensis* aggr; Carehirt: *Carex hirta*; Centianace: *Centaurea jacea* subsp. *jacea*; Ceravulg: *Cerastium fontanum* subsp. *vulgare*; Equisylv: *Equisetum sylvaticum*; Festprat: *Festuca pratensis*; Holclana: *Holcus lanatus*; Medilupu: *Medicago lupulina*; Molicaer: *Molinia caerulea*; Ranuflam: *Ranunculus flammula*; Ranurepe: *Ranunculus repens*; Rumeacet: *Rumex acetosa*; Taraaggr: *Taraxacum officinale* aggr

of cattle are either located in patches of more nutrient-rich vegetation (Güsewell et al., 2007) or outside the wet patches (Voss, 2001). Such drier patches are often present in the pastures studied due to variable topography, which allows cattle to rest outside the fen vegetation. Moreover, nutrient inputs from the surrounding intensive agriculture or atmospheric nitrogen deposition (Bergamini et al., 2019), as well as the previous additional manure application, can be excluded as causes because the compared plots were each located directly next to each other and were equally influenced in this respect (see Section 4.1). Therefore, eutrophication of the studied fens by grazing seems unlikely; we rather assume that this is a spurious effect resulting from different indicator values, such as those for nutrients and moisture, not being fully independent. One also needs to take into account that indicator values of species are expert judgements, and any biases there will lead to biases in the mean indicator values of plots. For example, Landolt et al. (2010) assigned high nutrient values to species that are significantly more abundant in the pastures (Table 2), whereas Ellenberg et al. (1992) rated the same species as indicators of only moderately nutrient (nitrogen)-rich sites. For a better understanding, further investigations with direct measurement of nutrient content are recommended. The only other mean indicator that showed significant differences between management types was aeration, with higher values in meadows. This finding is plausible because the trampling impact of livestock leads to stronger local compaction of soil compared with mowing machinery, which nowadays has very broad tyres and therefore relative low pressure per area.

The mean number of competitive species was significantly higher in the pastures than in the meadows, and the mean number of ruderal species was lower. An increased number of competitive strategists indicates species with tall growth and strong light competition (Grime, 2001). This is typical for areas that are abandoned or less intensively managed (Menichino et al., 2016). In the study area, all areas were managed constantly over the years. Trampling by grazing cattle promotes ruderal species adapted to disturbance (Grime, 2001). Thus, the slightly lower number of ruderals under grazing does not correspond to these expectations, indicating that grazing does not constitute a greater disturbance than mowing.

4.4 | Ordination

The axes lengths of the ordination graph are rather short and thus indicate a homogeneous data set (Leyer & Wesche, 2007). The mean indicator value for temperature correlated with the first axis and the plots of site 1 are distinguished from the rest of the plots in the direction of the increasing temperature value (Figure 6) because an increased temperature value indicates species of lower altitudes (Landolt et al., 2010). Site 1 is at the lower limit of the altitudinal distribution, but not lower than sites 3 and 4 (Appendix S1). The clear division of the vegetation records into the two management types along the second axis of the ordination graph is based on the gradient of canopy height (Figure 6). This corresponds to a higher proportion of tall species, greater measured vegetation height and greater mean canopy height in the pastures.

4.5 | Present vs desired vegetation

Small sedge fens are listed as target habitats in the charter of the Gantrisch Nature Park (2020), and corresponding conservation plans exist (Hintermann & Weber & UNA, 2017). A significant part of our study areas was classified formerly as base-rich small sedge fens (*Caricion davallianae*). Based on our relevés, we consider all plots as belonging to the alliance *Calthion palustris*, with only a smaller subordinate fraction of *Caricion davallianae* species, such as *Carex davalliana* or *Eriophorum latifolium* (Appendix S2). Whether the original classification in the conservation database of the canton reflected the status at the time of the original inventory about a decade ago and since then a deterioration has occurred or rather this was “wishful thinking” cannot be answered definitely. Evidently, a major and continuing threat to mire ecosystems in Switzerland (Bergamini et al., 2019), as throughout Europe, is that they are getting drier and drier, which leads to the disappearance of fen specialists. Also, in our studied fen grasslands there are installed ditches and drainages, which should be closed or removed to achieve the conservation target.

Regarding the small sedge fens as target vegetation, the higher nutrient values and vegetation heights in pastures could indicate a potential problem. Low-nutrient conditions and good light availability are particularly important for the emergence of characteristic fen species (Bergamini et al., 2009; Seer & Schrautzer, 2014; Bart & Yantes, 2021). Therefore, the nutrient conditions in the soil and the spread of tall species such as *Filipendula ulmaria* and *Cirsium oleraceum* should be monitored in local pastures. Considering the spread of species that benefit from climate warming and the simultaneous disappearance of habitat specialists in fens of the Swiss Pre-Alps (Moradi et al., 2012), monitoring fens is particularly important.

5 | CONCLUSION AND OUTLOOK

In conclusion, grazing and mowing have a different influence on the structure and species composition of montane wet grassland. However, this difference has no discernible effect on the floristic diversity in these grasslands, such that neither of the management methods can generally be preferred over the other. In a review of various studies on the effects of grazing vs mowing in grassland management, Tälle et al. (2016) conclude that grazing should be preferred in most cases. This could not be confirmed in our study. At a landscape level, both management methods are important and therefore both mowing and grazing should be maintained (Stammel et al., 2003; Schaich & Barthelmes, 2012; Karami et al., 2021). Because both mowing and grazing have ecological advantages, it is possible to optimally address the individual objectives of farmers and landowners and choose the approach best suited to their goals while also maintaining ecologically valuable habitats. Because with a few notable exceptions (Stammel et al., 2003) management studies in the fen grasslands of Europe up to now have looked at either mowing or grazing but not conducting a comparison, our study adds significantly to the body of knowledge despite being regional.

Finally, vascular plants are only one component of biodiversity. For example, it is thought that varied management is essential for a diverse and vital moss layer in fens (Záleská et al., 2021). On the other hand, grazing can have both positive (Bergamini et al., 2001) and negative (Spitale, 2021) influences on the number of endangered moss species. The characteristic butterfly fauna in fens is also strongly influenced by the type of management (Cozzi et al., 2008; Weking et al., 2013; Schwarz & Fartmann, 2021). We thus recommend that further studies should analyse the influence of grazing vs mowing on the bryophyte and invertebrate diversity of the fens of the Gantrisch Nature Park.

AUTHOR CONTRIBUTIONS

The study was planned by Pascal Reutimann and Jürgen Dengler and conducted by Pascal Reutimann under the supervision of Jürgen Dengler and Regula Billeter. Pascal Reutimann wrote the manuscript while Jürgen Dengler and Regula Billeter revised and approved it.

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DATA AVAILABILITY STATEMENT

The plot data are available in the Supporting Information and are also stored in the GrassPlot database (Dengler et al., 2018).

ORCID

Pascal Reutimann https://orcid.org/0000-0001-5850-4859
Regula Billeter https://orcid.org/0000-0003-3422-6107
Jürgen Dengler https://orcid.org/0000-0003-3221-660X

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1. Plot (header) data of the vegetation plots.

Appendix S2. Species cover data of the 36 surveyed plots.

Appendix S3. Mean, standard deviation, minimum and maximum for the environmental parameters, ecological indicator values, plant strategies and functional traits of all plots.

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