Diversification of Intensively Used Grassland: Resilience and Good Fodder Quality across Different Soil Types

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Abstract: In Central Europe, grasslands for dairy production are typically characterised by monocultures with high input rates of artificial fertilisers. However, it was suggested that biodiversity could reduce the need for anthropogenic inputs in functionally diversified grassland mixes while maintaining or enhancing yields and fodder quality. To investigate this hypothesis, we developed five consecutively diversified grassland mixes consisting of ryegrass, legumes, a non-leguminous forb, and additional grass species for intensive fodder production, and tested them under regular agricultural conditions in a three-year experiment on sandy soil, marshland, and bog soil at one-hectare per mix and site. All mixtures produced similar high-quality forage in terms of utilisable crude protein content and net energy lactation rate, even under challenging climatic conditions. However, a high abundance of *Dactylis glomerata* can decrease these values, although factors such as seasonality and rainfall affect them to a greater degree. The seasonal composition changes between the functional groups, such as strong spring growth of grasses and strong summer growth of legumes, show complementarity rather than competition between the groups, resulting in consistent biomass production during the growth period. The results were consistent over the three soil types and provide the basis for further adaptation of mixes and breeding.

Keywords: grassland biodiversity; ecological intensification; fodder quality; legumes; multispecies mixtures

1. Introduction

Agriculture stands under enormous pressure worldwide to provide both food to cover the demands of an increasing population worldwide and, at the same time, sustain functional ecosystems and biodiversity. In Central Europe, decades to centuries of dramatic intensification in agricultural practices have resulted in highly productive systems but also to species decline and a homogenisation of ecosystems [1–4]. As these negative side effects are accumulating, they are further reinforced by climate change and extreme weather events. Intensive agriculture is scrutinizing how to be more environmentally sustainable but at the same time be economically profitable. A central discussion in this conflict is between the land sparing vs. land sharing strategies. Land sharing promotes integration of biodiversity preservation into the agricultural landscape while the land sparing approach advises a spatial separation of the different land uses [5]. While conventional intensification methods can increase yields, they are also resource-intensive and can negatively impact soil nutrient cycles, biodiversity, and greenhouse gas reduction goals [6]. The latest economic developments regarding increasing fuel, energy, and fertiliser prices as well as the growing awareness of the importance of biodiversity protection call for novel approaches in agriculture. One way is ecological intensification in which ecosystem services are harnessed to decrease the pressure on biodiversity while also reducing anthropogenic resource inputs [7,8]. This may help to create greater self-sufficiency for farmers and increase the resilience of agri-ecosystems while closing yield gaps [9,10].

Grasslands serve a vital function in this regard, as they constitute the most sustainable method for producing beef and dairy products. Further, they are a vital habitat for farmland biodiversity and present an option to exploit land agriculturally that would otherwise require extensive melioration procedures, often with detrimental effects on biodiversity, soil, and carbon stocks [11]. Ecological intensification of grasslands can be achieved by floral diversification with legumes, forbs, and grass species. This allows for the utilisation of biological nitrogen fixation, which can improve soil carbon stocks and soil life, and boost insect diversity that can further deliver services like pollination and pest control across field borders [12–14].

Several studies demonstrated that increasing diversity in species mixtures in grassland leads to increases in productivity. The increase results from transgressive overyielding of mixtures compared to monoculture stands, reduced weed invasion, reduced pressure by pathogens and pests, and more efficient use of resources like water and nutrients [15–19]. These benefits are created by biodiversity effects: First, the selection effect which hypothesizes that under given environmental conditions, a mix of species contains one that performs best [20]. This may not always be the same for any field and any time since changing conditions can lead to another species being the best performer. Secondly, the complementarity effect explains how different species can use resources more effectively, for example, by exploiting nutrients in different soil depths. This can also manifest in facilitation, e.g., by legumes providing N for neighbouring plants [20]. These effects are most successfully achieved by combining species of several functional groups differing in their characteristics like growth form, time of highest productivity, and rooting depth, e.g., highly productive grasses, deep-rooting and drought-resistant herbs, and nitrogen-fixing legumes. Further, increased intraspecific diversity can deliver several of these aspects as well [14]. In intensive agriculture, these effects are often not exploited and instead, monocultures of the most productive species are used. Seed mixtures for grass production on permanent as well as ley grasslands in northwest Germany usually consist of a few varieties of *Lolium perenne* to account for different phenologies in terms of bloom and time of strongest biomass production. Mixes for organic agriculture, but increasingly also conventional agriculture, further contain one variety of *Trifolium repens* to compensate for the lack of inorganic fertiliser inputs in this management system [21]. Up to now, non-leguminous forbs are rarely used in seed mixes for intensive grasslands. The potential of biodiversity effects for enhanced productivity as well as for diversification of fields is, therefore, largely unexplored and unexploited in intensive agriculture. The higher cost for diverse seed mixes may cause restraint in this regard [22]. Our study takes the experimental knowledge to large plots under agricultural management with four to five cuts per season.

Our aim was to provide options for productive grassland management that not only provide fodder for demanding livestock while requiring fewer external inputs but also buffer against extreme weather conditions. Additionally, such a grassland mixture is also supposed to be more pollinator-friendly, which will be investigated in a companion study.

We developed five grassland seed mixes of increasing diversity consisting of grasses, legumes, and a non-leguminous forb species, and surveyed their performance on ley grasslands, as defined by Allen, Batello [23], regarding fodder quality and vegetation development. Based on vegetation surveys our research questions are (i) can the seed mixes outperform a regular grass–clover ley regarding quality and (ii) is the species composition suitable for intensive grassland farming?

2. Materials and Methods

The study was conducted under regular agricultural conditions in Lower Saxony, north of the city of Oldenburg, Germany. Five field sites were divided into five sub-fields of 1 ha each that were sown with the five seed mixes, respectively (25 sub-fields overall). The sites were chosen to represent three different landscape types of northwest Germany with focus on the soil properties. Two sites each are located on marshlands (pH 6.4 and 6.1) and sandy soils (pH 5 and 5.1), and one on bog soil (pH 4.1). All sites are arable land

that is regularly used for grass leys. Before the start of the project, they were used to grow maize, wheat, and oilseed rape. They were tilled for seedbed preparation. All sites are characterized by a maritime climate with moderate temperatures in summer and mild, rainy winters (Supplementary Figure S2). The weather conditions over the course of the study were often challenging. The first study year was drier than usual, especially in spring. The second year had an unusually cold spring and a rainy summer that caused delays in mowing. The third year was characterised by a long summer drought and high temperatures.

The five seed mix treatments were developed in cooperation with Meiners Saaten GmbH, a major seed supplier in Northwest Germany. The first mix (BM, "basic mix") consists of four *Lolium perenne* varieties and one variety of *Trifolium repens*, representing the most commonly sold combination in the region (Table 1). The second mix (CD, "clover diversity mix") contains five more varieties of *Trifolium repens* to test the effect of increased genetic diversity in clover for better persistence and an increased blooming period. In the third mix (CP, "clover plantain mix"), a cutting-resilient forb species was added to the *mix, Plantago lanceolata,* to test for the effect of an additional functional group. The fourth mix (LD, "legume diversity mix") contains five additional legume species, *Lotus corniculatus, Medicago lupulina, Medicago sativa, Trifolium hybridum, Trifolium pratense* and *Trifolium resupinatum* to test for the effect of legume species diversity. In the fifth mix (GD, "grass diversity mix"), three grass species were added, *Dactylis glomerata, Festuca arundinacea* and *Phleum pratense* to test for the effect of higher grass species diversity. The fields were sown in September and October 2019 with 30 kg/ha and monitored for the following three years.

Table 1. Composition of seed mixes including varieties with percentage of total seed weight.

Species	Mix 1: BM	Mix 2: CD	Mix 3: CP	Mix 4: LD	Mix 5: GD
Lolium perenne 'Indicus'	25%	25%	25%	18%	5%
Lolium perenne 'Soraya'	20%	20%	20%	17%	10%
Lolium perenne 'Melpaula'	25%	25%	22%	18%	5%
Lolium perenne 'Melfrost'	21%	21%	21%	17%	10%
Trifolium repens 'Bombus	9%	2%	2%	2%	2%
Trifolium repens 'Liflex'		2%	2%	2%	2%
Trifolium repens 'Silvester'		2%	2%	2%	2%
Trifolium repens 'Jura'		2%	2%	2%	2%
Trifolium repens 'Pipolina'		1%	1%	1%	1%
Plantago lanceolata			3%	4%	4%
Lotus corniculatus				1%	1%
Medicago sativa				5%	5%
Trifolium resupinatum				4%	4%
Trifolium hybridum				1%	1%
Medicago lupulina				1%	1%
Trifolium pratense				5%	5%
Dactylis glomerata					10%
Festuca arundinacea					20%
Phleum pratense					10%

All sites were cut four times a year with the first cut in May and the last in September. The two marshland sites received an additional cut in early May of the first year for weed control.

Every season, surveys started in early to mid-April and were carried out biweekly until the first cut. Afterward, surveys were conducted every 10 to 14 days until the end of September. All 25 sub-fields were surveyed for vegetation structure on two 4 × 4 m plots each using the Braun–Blanquet scale extended by Reichelt and Wilmanns [24] to monitor changes in the sward composition.

Shortly before each cutting, vegetation samples from four representative 30 × 30 cm spots per plot were harvested at regular cutting height, chopped, mixed, and sent to LUFA Nordwest for fodder quality analysis (utilisable crude protein content and net energy lactation rate) according to the standards defined by the Lower Saxony Chamber of Agriculture [25]. Quantity measurements of all produced material were not possible due to the scale of the experiment; therefore, only two proxy measures could be taken. One was vegetation height, which was measured at each vegetation and yield survey with a folding ruler. Height was multiplied with vegetation coverage to approximate biomass. Another proxy were leaf area index (LAI) measurements using the SS1 Sunscan Canopy Analysis System [26]. In 2022, 50 measurements per plot were taken shortly before harvests.

All statistical analyses were carried out with R Version 4.3.0 [27]. For vegetation analysis, measurements from the first 20 days after the previous cut were excluded to account for regrowth periods. Earlier measurements were only included when there were no data points available otherwise. When normal distribution was required for analysis, data transformations were chosen by best result out of log-transformation, square-root-transformation, and boxcox-transformation, the latter using the packages 'car' v3.1-2 [28] and 'geoR' v1.9-2 [29]. After one-way analysis of variance (ANOVA), Scheffe post-hoc tests were performed for pairwise mean comparison using 'DescTools' v.0.99.48 [30]. If transformations did not result in normal distribution, non-parametric tests were used, namely Kruskall–Wallis test and pairwise Wilcoxon post hoc test. All plots were made using 'ggplot2' v3.3.6 [31].

Linear mixed-effect models (LMMs) were used to analyse the influence of seed mixture, site, cut of the season, soil pH, soil N, maximum field capacity, study year, monthly rainfall, and proportions of grasses (total proportion or divided in *Lolium perenne* and other mixture grasses), herbs, legumes, and weeds on fodder quality variables (net energy lactation rate 'NEL', utilisable crude protein content 'UCP'). The September cuts were excluded as they were often not timed for best quality but as preparation for autumn management. All numeric fixed effects were scaled prior to analysis. Year and n^{th} cut of the season were included as factors. Quality variables were set as response variables, site, plot ID, and cut were used to build different (nested) random effect structures with all other factors as fixed effects and optionally as random slope parameters with 'buildmer' v.2.11 [32]. The resulting models were rebuilt using 'lme4' v.1.1-35.1 [33] to check for possible simplifications and to test residuals for normality and homoscedasticity. Model selection was conducted based on model fit as given by marginal and conditional R^2 (package 'performance', Lüdecke, Ben-Shachar [34]). The significance of fixed effects was assessed using type II Wald X^2 tests (package 'car').

3. Results

3.1. Establishment

All seed mixes established well with a fast reduction in open soil within the first year (Supplementary Figure S1). In the second study year, the GD mix had a higher average open soil proportion than the other mixes but only significantly so if compared to BM (p = 0.046 *). The grasses in GD showed a fast and high growth, which led to overall higher vegetation (CD-GD: p = 0.006 **, CP-GD: p = 0.02 *, all other comparisons: n.s.; Figure 1). This difference in biomass was not visible in the LAI measurements (Supplementary Figure S2). Significantly higher values for GD only occurred in certain study sites. Within-year com-

parisons did not result in significant differences. All mixes had their highest biomass production in 2021 and significantly lower values in the drought year 2022 (all $p < 0.001$ ***). Biomass production was highest on the sandy sites (sandy:bog: $p < 0.001$ ***; sandy:marsh: $p = 0.007$ **) but this should be interpreted with caution as the bog and marshland sites were afflicted with vole infestation and damage caused by overwintering geese flocks, respectively. Since these effects cannot be quantified, the soil type cannot reliably be compared for biomass production.
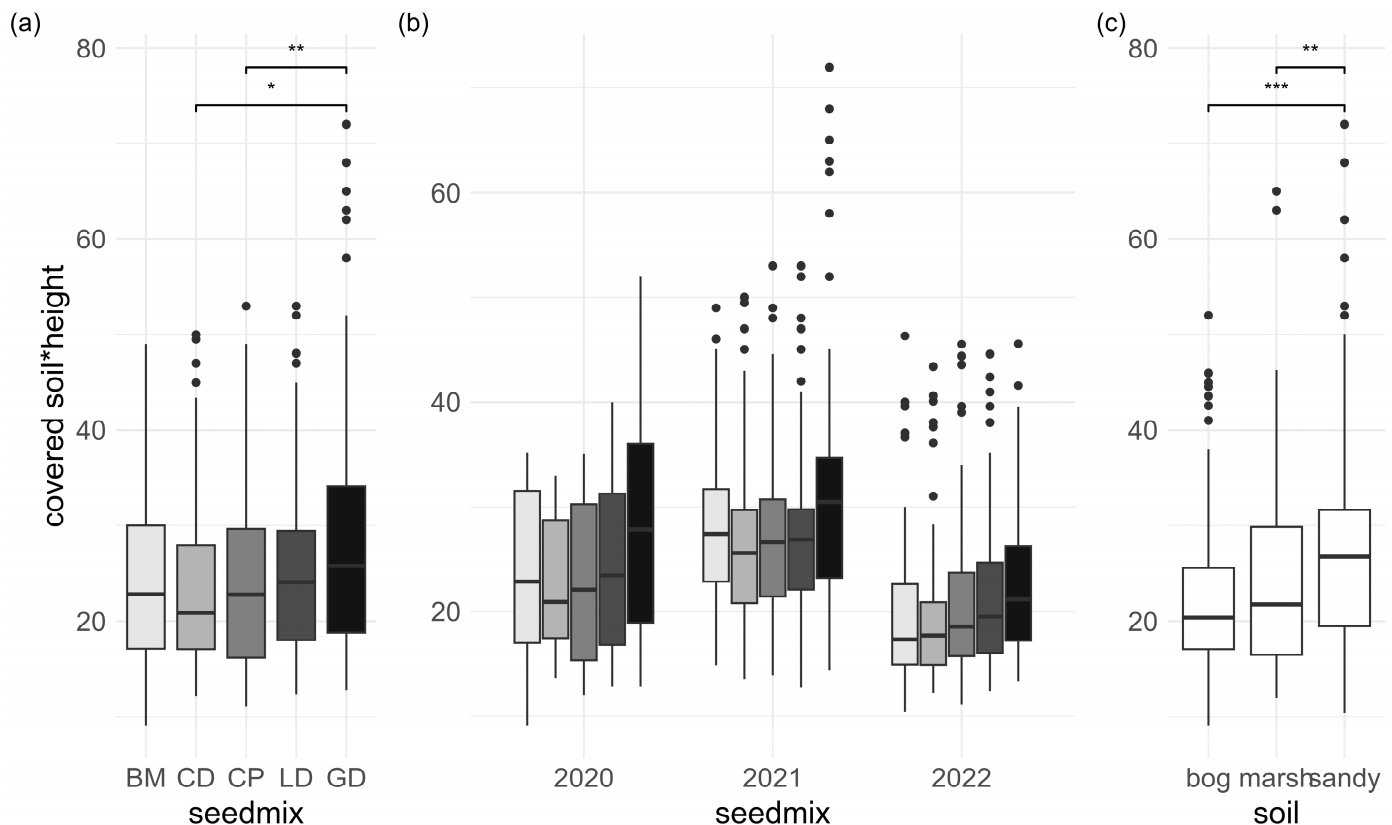

Figure 1. Vegetation height multiplied by proportion of soil covered with vegetation as proxy for biomass for seed mixes of all years (**a**), individual years (**b**), and soil types (**c**). The spring months of 2020 were excluded from all measurements to account for the establishment phase. The high number of outliers is due to differences between sites and seasonality. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.2. Plant Establishment

The legume species differed strongly in their establishment success. The proportion of *Lotus corniculatus*, *Medicago sativa*, and *M. lupulina* was negligible on all sites. *Trifolium hybridum* established slightly better. *Trifolium resupinatum* was only present in the first study year as it is a winter-annual and not winter hardy.

The proportion of legumes in the sward increased over the length of the season, which is met by a reduction in grasses and weeds (Figure 2). The mean proportion increased from 15.3% (±10.1) in May to 28.6% (±17.8) in September. This trend is consistent over the three-year period. Further, *Trifolium pratense* had its yearly maximum in August and did not show any signs of decrease over the years but differed strongly between sites (Supplementary Figure S3). The legume proportion was highest on the sandy soil (mean: 26.3% ± 13.3%) and significantly lower on the other soil types ($p < 0.001$ ***, respectively; mean marsh: 23.2% ± 18.3%, mean bog: 20.5% ± 13.8%). The seed mix BM on the bog site had a significantly higher legume proportion than all other mixes but LD on this site (BM:CP: $p = 0.005$ **; BM:CD: and BM:GD: $p < 0.001$ ***). *Plantago lanceolata* hardly established on the bog site but was frequent on all other study sites from June to August (means; sandy: 5.7% ± 4.1%, marsh: 9.6% ± 7.6%, bog: 2.3% ± 2.2%). The proportion of

this species differed significantly between soil types (sandy:marsh: *p* = 0.012 *; sandy:bog: *p* < 0.001 ***; marsh:bog: *p* < 0.001 ***). The proportion of seed mix grasses was significantly higher on sandy soils than on the other two soils (*p* < 0.001, respectively) and marsh still significantly more than the bog site (*p* = 0.003 **). The delta consists mainly of weed species (mean seed mix grasses bog: 39.9% ± 17%; marsh: 45% ± 17.8%; sandy: 66.6% ± 13.6%). The main grass species, *Lolium perenne*, performed well with stable coverages across all sites (Figure 2). In GD, *Phleum pratense* was present at very low coverages while *Festuca arundinacea* failed entirely. In contrast, *Dactylis glomerata* established itself on every site where it made up 24.6 to 60% of the average grass coverage. The species achieved its' highest values on the sandy sites.
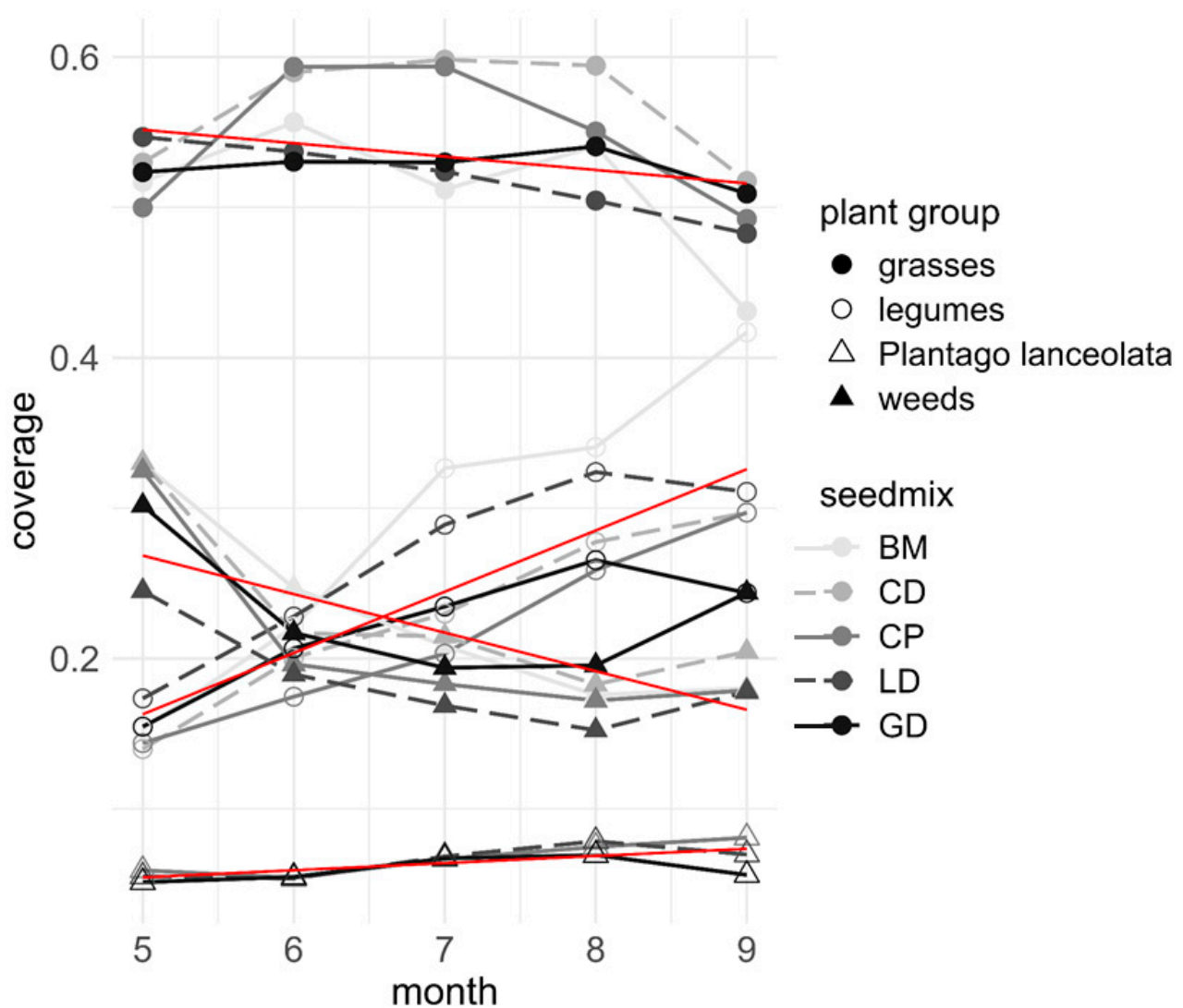

Figure 2. Proportion of vegetation groups over the season including all years, sites of all three soil types, and survey plots. Red lines indicate the trend of plant groups across seed mixes. The high legume proportions in the mix BM are partly due to an unusually high coverage on one study site that cannot be explained by the parameters tested for in this study. Standard deviation is not displayed for readability but is given in Supplementary Table S1.

3.3. Weeds

The most frequent weeds were common grassland weeds, such as *Ranunculus repens*, *Poa trivialis*, and *Rumex obtusifolius*. Weed invasion, measured as the proportion of vegetation coverage, was lowest in the LD mix and highest in GD but did not differ significantly between seed mixes (Figure 3). The differences between sites were strongly idiosyncratic with two sites, one marshland and one bog soil, being significantly more affected by weeds than the others ($p < 0.001$ ***). While bog sites are generally prone to weeds, one of the marsh sites was frequently visited by flocks of wild geese, which is most likely the reason for the vigorous weed invasion. This is reflected in the differences between the soil types, which are significantly different from one another in each study year as well as over the three years combined (all p-values < 0.001 ***). The sites on sandy soil were almost free from weeds once established.
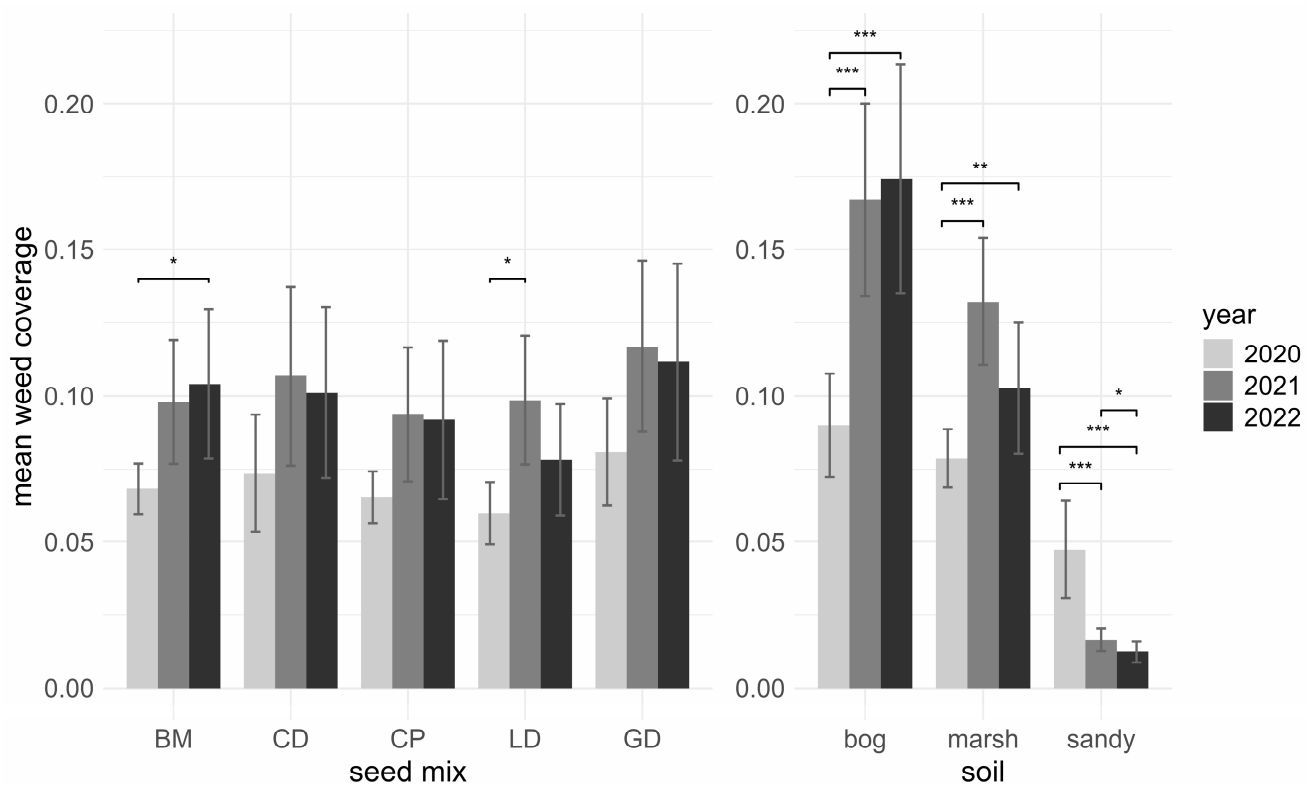

Figure 3. Mean weed coverage over the three study years in seed mixes (**left**) and on soil types (**right**). The wide standard deviation is due to differences between sites. Weeds were defined as non-mix species with no regard for their fodder values or productivity. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.4. Fodder Quality

The fodder quality (measured as UCP content and NEL) was not significantly affected by the seed mix. The desired minimum threshold for the average NEL of 6 MJ kg^{-1} dry matter was reached in all seed mixes and years, though the values fluctuate with season and weather conditions, and decrease over time (Figure 4). In all seed mixes combined, the value dropped significantly from the first and second to the third year but was still in an acceptable range (2020:2021 $p = 0.036$ *, 2020:2022 $p = 0.049$ *). This effect may be attributable to some degree to the long summer drought in 2022. When the individual seed mixes were analysed, only GD showed a significant decrease from 2020 to 2021 ($p = 0.046$ *). The NEL was significantly lower on the marshland sites in the first year (marsh:bog: $p < 0.001$ ***; marsh:sandy: $p = 0.009$ **) but not in subsequent years.

On average, the minimum threshold for UCP was achieved in all five seed mixes (>135 g kg^{-1} dry matter, Figure 4). There were no significant differences between mixes or years, the only exception being seed mix GD, which showed a significant decrease in UCP from 2020 to 2022 ($p = 0.0224$ *). UCP was significantly higher on bog sites in the first year (bog:marsh: $p < 0.001$ ***; bog:sandy: $p < 0.001$ ***) but not in subsequent years.
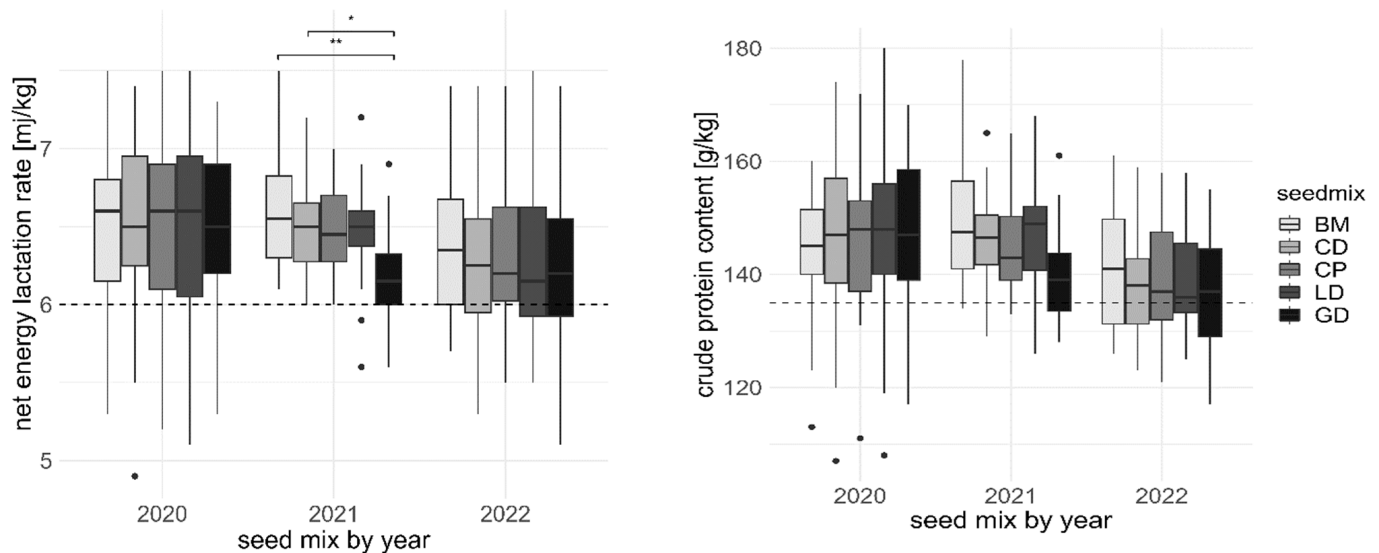

Figure 4. NEL (**left**) and UCP (**right**) of all seed mixes and sites by years. Dashed lines indicate the minimum values for good fodder quality as suggested by VDLUFA [25]. Significant differences between mixes within years are indicated by bars. The plot included all harvests from May to September. * $p < 0.05$, ** $p < 0.01$.

3.5. LMMs

Model optimisation for both GLMMs resulted in random slopes for rain and random intercepts for study sites. The NEL model achieved a slightly better model fit (conditional R^2: 0.73, marginal R^2: 0.63) than the UCP model (conditional R^2: 0.7, marginal R^2: 0.49).

For NEL, the most important predictors were the timing of the cut ($\chi^2 = 354.57$; df = 3; $p < 0.001$ ***), monthly rainfall ($\chi^2 = 4.61$; df = 1, $p = 0.002$**), and their interaction ($\chi^2 = 75.26$; df = 3; $p = 0.001$ ***). The first cut generally achieved the highest values. Rain overall had a negative effect but this seems to be a seasonal effect as the interaction effects with the later cuts all had positive estimates (Figure 5, Supplementary Table S3). The vegetation composition also played a role, mainly with positive effects by the proportion of legumes ($\chi^2 = 49.18$; df = 1; $p < 0.001$ ***) and *L. perenne* ($\chi^2 = 14.8$; df = 1; $p < 0.001$ ***).

For UCP, more variables constitute the best model but fewer variables show a significant influence. The legume proportion ($\chi^2 = 11.26$; df = 1; $p < 0.001$ ***) as well as the interaction of legumes to other vegetation groups were the most important factors, namely to the proportions of *L. perenne* ($\chi^2 = 20.22$; df = 1; $p < 0.001$ ***), other mix grass species ($\chi^2 = 9.94$; df = 1; $p = 0.002$ **) and weeds ($\chi^2 = 9.07$; df = 1; $p = 0.002$ **). The protein-rich legumes had a positive influence while the interaction terms all had negative estimates (Figure 5, Supplementary Table S3).
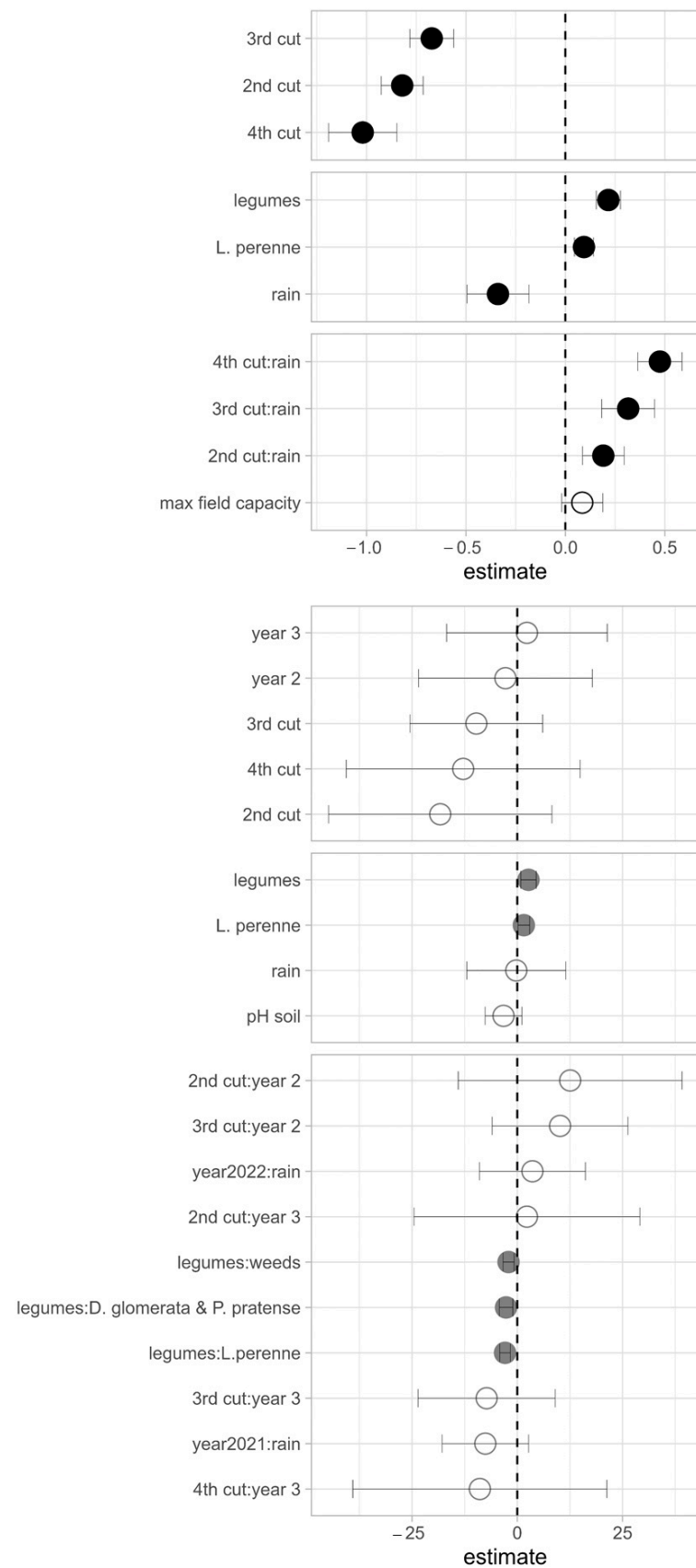
Figure 5. Effect sizes of parameters in LMMs for NEL (**top**) and UCP (**bottom**) sorted by categorical terms, numeric terms and interactions. Significant terms are displayed with filled circles.

4. Discussion

4.1. Mix and Species Performance

Diverse grassland seed mixes were suggested to improve biodiversity, climate change resilience and profitability [12,35–37]. Here, we provide evidence for some of the advantages of more diverse grassland seed mixes for farmers. The seed mixes of higher diversity produced higher and more stable biomass yields across varying weather conditions. Furthermore, the forbs and legumes in all mixes greatly complemented the biomass production of the grasses seasonally, with the grasses being strongest in early to mid-season and the other groups thereafter. This indicates complementarity rather than competition [18].

However, not all species included were proven valuable due to low establishment. The most successful ones were the commonly utilised agricultural cultivars of *Trifolium pratense* and *T. repens,* but also *Plantago lanceolata* established well on all but the bog soil. This was most likely because of the rather low pH value [38]. Recently, this species has been increasingly used in grassland studies in temperate regions worldwide for its range of useful properties like the deep rooting system that avoids competition with shallow-rooting companion grasses, high water stress tolerance, and the healthy nutrient content [38–40]. The deep roots likely serve as complementarity to the mix but also allow for selection effects under drought conditions. Further, there is evidence that the species can reduce N leaching when included in grass–legume mixtures [41]. In this study, the species demonstrated its benefits even under the intensive cutting regime and under drought conditions. A good establishment was already achieved when the species only accounted for 1% of the seed mix. *Trifolium resupinatum* appeared in the first study year only, due to its' lack of winter hardiness. The fast growth of this species likely bridged the period until *T. repens* and *T. pratense* fully established and successfully fulfilled a placeholder function. Just like in flower strips, annuals can be valuable for the establishment period [42]. However, summer annuals germinating after frost in the spring have an advantage in such uses in Central Europe over non-frost hardy winter annuals such as *T. resupinatum*, which germinates in the fall. In this study, *Trifolium hybridum* established itself on a small scale, likely since it was included only in low proportion in the seed mixes. This species was shown to be very persistent and may even become more important over longer time periods, potentially replacing the other *Trifolium* species as their persistence generally decreases over time [43,44]. *Medicago sativa* established itself poorly, likely due to slow development. However, this result is contradictory to Boschma, Lodge [45] who proposed complementarity between *M. sativa* and autumn-sown temperate grasses. Since the species is a very nutritious fodder plant, future experiments should evaluate it further. *Medicago lupulina* and *Lotus corniculatus* showed the poorest establishment. These species have not been bred as extensively for intensive grassland use as the *Trifolium* species and are still of low agricultural performance. Further breeding of *Lotus corniculatus* could prove valuable in the future, as the secondary metabolites are of high value for cows [46].

The stable legume proportions over the years are a positive outcome since they allow predictability for the farmer. The persistence of the species over longer time periods remains to be observed as species like *Trifolium pratense* tend to persist for two to three years only [47] but there was no sign of persistence issues, yet, in our experiment after three years. *Trifolium repens* established in all sites to differing degrees. We did not find an advantage for coverage by including more than one variety of this species over the course of the study but an influence on persistence and resilience over time as would be expected [48] remains to be observed.

The ideal proportion of legumes in meadows and pastures is still a matter of debate. The dry matter intake increases with legume content, and milk yield can increase until legume coverage reaches 50–60% [10,18,49,50] but there are possible downsides to such high values. The advantages, like high nutritive values and increased intake, can be counteracted by disadvantages like poor ensiling performance [51], potential N leaching [50,52], and a higher bloat risk [10]. Digestive problems like bloat are currently being tackled by breeding and by diversifying the legume mix with species containing higher tannin concentrations

but the risk is still perceived as relevant by practitioners [53]. Moreover, the N fixed by legumes per field does not increase further above a legume coverage of 30% [54]. The achieved 20 to 30% legume coverage is a good value to maximize advantages and avoid disadvantages. All farmers managed their fields independently and without further instructions, yet all of them reduced the amount of mineral N fertiliser by 10 to 15% in the later study years since they saw a positive influence of the legumes and were, therefore, able to reduce costs. However, no repeated soil or leaf N measurements were taken, therefore, no absolute numbers can be given on this subject.

Some differences in vegetation composition were detected, with the sandy soil often varying from the other two. Given the differences in weed pressure discussed above, we cannot quantify the magnitude of the soil influence. Lower legume and plantain proportions in bogs could be caused by soil acidity as the optimum for clover and plantain is a neutral pH value [38,52]. Nevertheless, the mixtures can be established on a range of common soil conditions successfully.

The higher biomass produced in the most diverse mixture GD was met with a lower fodder quality and more difficult management requirements. The best growth, but also most likely the lower performance, is due to the strong presence of *Dactylis glomerata*. The species grew quickly and produced a great amount of biomass. However, it also came with a narrower optimum for harvest since it quickly starts to produce sclerenchymatous tissue. The species matures quickly compared to other grasses and declines steadily in quality afterward [55]. In 2021, when ongoing rainfall prevented harvesting at ideal times, causing the rapidly maturing grass to affect the fodder quality. The dominance of the species also reduced the complementarity of the mix. The lower proportions of legumes in the GD swards are likely attributable to the strong growth of *D. glomerata* as there was only little light available for the smaller species like *Trifolium repens* that quickly filled the open gaps in the other swards [56,57]. The open soil left can become a risk for weed invasion. Better results may be achieved by combining *D. glomerata* with legume species selected for a higher competitive ability [58]. An advantage of the species is, however, that under drought conditions in 2022, it persisted much better than the main grass, *L. perenne*. The species should be used at smaller proportions and be considered for sites with high drought risk. *Phleum pratense* showed poor establishment whereas *Festuca arundinacea* did not establish at all, probably because of the competitiveness of the other grasses. Future research should investigate mixes with varieties that are more competitive or try mixes without ryegrass to evaluate the other grass species. These have shown their advantages, namely great fodder quality for *P. pratense* and drought resistance as well as high yields for *F. arundinacea*, in other studies without *L. perenne* [17,59]. Further, there is potential in breeding for community adaptation to increase the performance of the different species. This can be achieved by selecting a niche differentiation to strengthen the biodiversity effects [60].

4.2. Weeds

Weed invasion was partly site-specific and partly soil-specific. The high amount of weeds on two sites was most likely caused by the presence of wildlife, and the soil conditions of bogs making them vulnerable to weed invasion [61]. Furthermore, vole infestation during the establishment period damaged the seedlings, making the bog site even more vulnerable to weeds. It is not possible to determine the strength of this range of influences on weed invasion. While many of the weed species were harmless to yield and quality and the coverage of harmful forbs like dock (*Rumex obtusifolium, R. crispus*) was low, a grassy weed (*Poa trivialis*) known to reduce yields [62] spread on all but the sandy sites. The study shows no clear evidence for a better resistance against weed invasion in more diverse grasslands as was found elsewhere, e.g., [15,17,63] but does not contradict it either. Measurements of biomass samples divided into weeds and non-weeds should be taken to provide greater insights into this matter.

4.3. Fodder Quality

All mixes produced fodder of high quality. The NEL and UCP content decreased moderately in all mixes over time. This is partly attributable to extreme weather conditions and their impact on cutting time and water availability. The fodder quality of all seed mixes meets the requirements of dairy cows to the full extent, even under strongly fluctuating weather conditions. The LMMs show a great dependency of the fodder quality on the timing of the cuts and rainfall (Figure 5). The later cuts of the season usually come with a longer growth period to produce satisfactory yields, therefore, grass maturity decreases the fodder quality [64]. Rainfall is in general beneficial but can cause adverse effects if it leads to delayed harvest. On one hand, long periods of continuous rainfall deter from cutting at the ideal time which leads to quickly increasing quality declines with the maturity of the fodder grasses [65]. On the other hand, a lack of precipitation can halt biomass production and cause withering with drastic consequences for yield and quality. The latter effect, however, can be counteracted by increased biodiversity [66,67]. Vegetation composition was of lower importance for NEL as all seed mixes performed well. For UCP, it played a greater role, specifically in the proportion of protein-rich legumes in contrast to other vegetation groups. The soil parameters included in the model building were of low importance. Even though marsh soils, sandy soils, and bog soils differ in many regards, this was not reflected in the fodder values, as was also reported by Becker, Isselstein [59]. The simplification and homogenisation of the agricultural landscape driven by intensification are reflected to a great degree in the soil properties.

4.4. Drought

Positive biodiversity effects on drought resilience of grasslands were observed under a variety of pedo-climatic conditions [68]. In our project, monitoring of drought effects was initially not planned. Therefore, the results cannot give comprehensive insights into the effect of the drought in the summer of 2022. For a better understanding of drought effects, specific observations of the biomass production between functional groups on the same plot should be surveyed. However, even without bespoke drought effect monitoring, it was apparent that *L. perenne* suffered strongest under the conditions while *T. pratense*, *P. lanceolata*, and *D. glomerata* persisted much better (Supplementary Materials). Their development under drought was a great example of the selection effect under changing environmental conditions. Higher grassland diversity proves to be highly beneficial to withstand extreme weather conditions and stabilise yields [15]. Species-richness is especially valuable to increase drought resilience, i.e., the ability of the plant community to recover from drought, in high management intensities [67]. Further, reducing drought effects by plant diversity protects the soil from damage that can persist in the form of adverse legacy effects [69]. Both intra- and inter-specific variability can be utilised for drought resilience in grasslands. Unfortunately, it was not possible for us to differentiate between varieties in our plots and to understand the effect of intraspecific variability on drought resilience. Furthermore, well-adapted species or varieties can facilitate the survival and performance of the surrounding plants [35]. We frequently observed grasses remaining longer green adjacent to clover in comparison with tufts standing alone, suggesting complementarity in the form of facilitation.

4.5. Management

Temporary leys allow easy integration of moderately diversified grasslands into farm management, even under intensive regimes. Reduced fertiliser costs provide an additional incentive for incorporating diversity that also reduces pressures on the environment [14]. Oversowing or renewal of permanent grasslands is more labour-intensive but becomes indispensable at the latest when extreme weather events are damaging species-poor sites that require sward restoration afterward. Early action can prevent negative legacy effects on soil and sward [69]. Further, the moderate number of species included consists of cultivars that are not as costly as regional ecotypes and provide reliability regarding their

productivity and nutritive value. These factors should be taken into account to make recommendations for farmers as price and reliability are some of the most important criteria for management decisions [22]. The diverse swards did not cause indirect costs over the three-year period but the farmers reported that more caution is required for a successful drying and ensiling process.

5. Conclusions

In conclusion, diversified grassland mixes offer great fodder quality regardless of challenging weather conditions. The plant functional groups show complementarity rather than competition. *Trifolium repens* and *T. pratense* persisted well over the three-year period with no sign of decline. As several species in the more diverse mixes did not establish themselves, these can be excluded from the mixes to keep seed costs low. The *Medicago* species and *Lotus corniculatus* cannot be recommended at this point but further breeding efforts may enhance their suitability for grassland diversification. Testing them in different mixtures may also prove their worth. Further, the amount of *Dactylis glomerata* should be adjusted to a lower level to give more room to the other species. Overall, a mix of grasses, legumes and *Plantago lanceolata* can be recommended for farming on all soil conditions considered here. No adjustments in management were necessary to achieve great results from diversified grasslands, making this an easily accessible approach for resilience and stability of high-quality fodder production under changing environmental conditions. Farmers can, therefore, benefit from diversity in intensive land-use systems with stable yields, even with unpredictable weather conditions under the progressing climate change.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy14061152/s1, Figure S1: Percentage of open soil by years and seed mixtures. The data points from the first 18 days after a cutting event are excluded from the analysis. Figure S2: Total monthly precipitation (a) and mean temperature (b) averaged for all five study sites. Diamonds indicate the 30-year average. The data were averaged over several nearby weather stations of the DWD (2023). Figure S3: Trifolium pratense vegetation proportion in LD and GD by years and months. The data points from the first 18 days after a cutting event are excluded from the analysis. Figure S4: LAI by seedmix (left) and soil type (right). While there are no significant differences between seed mixes overall, there are differences between them within the sandy soil type, namely a lower value for GD (not displayed). Figure S5: Drought on sandy soil site 1, mix LD. *Lolium perenne* withered while *Trifolium pratense* and *P. lanceolata* still resist. Figure S6: Drought on sandy soil site 1, border between LD and GD. *Dactylis glomerata* can persist around clover and plantain. Table S1: Mean and standard error of functional group vegetation coverage by seed mix and month as addition to figure 2 of the main article. Table S2: Input data for linear mixed effect models. All numeric values were scaled before analysis. Soil data were only measured in 2021 as no substantial changes were expected. Table S3: Effects of framing variables and vegetation composition on NEL and CP. All vegetation composition variables refer to the proportion of the group in a vegetation survey. Cut number represents the nth cut of the year as not all years allowed for the same amount and timing of harvests.

Data Availability Statement: All data that is not given in the Supplementary Materials can be shared upon reasonable request.

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