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Original article

Agri-environment incentive payments and plant species richness under different management intensities in mountain meadows of Switzerland

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ABSTRACT

We investigated whether agri-environmental incentive payments help to maintain biodiversity. We studied the effect of agricultural management intensity on vascular plant species richness and plant assemblages of mountain meadows in Switzerland. Other factors such as slope, altitude or accessibility (distance from farmyard) were also taken into account. Vegetation sampling was conducted at 69 sites representing five different management types, differing with respect to nutrient input and soil moisture: (i) dry extensive meadows; (ii) extensive meadows; (iii) dry low-intensive meadows; (iv) low-intensive meadows; (v) intensive meadows. There was a significant negative relationship between plant species richness and management intensity: The mean number of plant species per management type declined markedly when management intensity increased, although dry sites harboured slightly more species regardless of management intensity (dry extensive > dry low intensive > extensive > low intensive >> intensive meadows). Species richness was clearly affected by management intensity, but not so by slope, altitude or accessibility. There was a gradual shift in plant assemblages among management types with only intensive meadows differing from the other four types of differently managed meadows. We therefore found, in contrast to many studies done in the European lowlands, positive effects of incentive payments on plant species richness.

1. Introduction

Traditionally managed meadows are among the most species rich plant communities of Central Europe and the Alps (Zoller and Bischof, 1980; Willems, 1982; Ellenberg et al., 1991). Currently, mountain agriculture has to choose between intensification of meadows or their abandonment, since the traditional management is not profitable any more. This polarisation of agriculture has negative effects on biodiversity and the cultural landscape (Ostermann, 1998). Species richness usually decreases with increases in land use intensity including increased input of fertilizers and management homogenisation, which lead to a loss of habitat complexity (Mander et al., 1999; Zechmeister and Moser, 2001). Changes in land use practices

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have greatly diminished the abundance of semi-natural meadows, which were formerly widespread. This was paralleled by a dramatic decline of characteristic species as observed in most parts of Western and Central Europe (Willems, 1982; Fischer and Stöcklin, 1997; Ostermann, 1998). For instance, a wide range of plants, especially many herbs, sedges and bryophytes, cannot make use of higher nitrogen inputs and are out-competed by more competitive species such as grasses (Smith et al., 1971; Huston, 1979; Chapin, 1980; Mountford et al., 1993). An important aim in plant species conservation is thus to preserve semi-natural, traditionally managed meadows (Bakker et al., 1998).

Many European countries offer agri-environmental incentive payments to potentially increase or at least preserve biodiversity in agricultural landscapes. With respect to meadows, these measures can mainly be classified into three categories: (i) alteration on the same piece of land from an intensive to an extensive management (e.g. sowing of species-rich meadows in former intensive, species-poor meadows); (ii) organic farming (e.g. farming without artificial fertilizer); (iii) conservation of traditionally managed farmland (e.g. preservation of already species-rich meadows). Corresponding agri-environmental measures for the conservation of biodiversity were also integrated into the Swiss agriculture policy in 1993 in order to counteract the negative impact of agriculture on the environment. Farmers get incentive payments for extensively or low-intensively managed meadows.

The effectiveness of political incentive payments has been evaluated throughout Europe with the disillusioning result that management agreements are often not effective in enhancing species richness in formerly intensively managed landscapes (Kleijn et al., 2001, 2004; FAL, 2002), while organic farming shows at least, a positive effect on certain groups of organisms such as birds and plants (Hole et al., 2005). Few studies investigated whether management agreements lead to the effective conservation of biodiversity of sites that are still traditionally managed. This is also true for mountain meadows within the montane or subalpine altitudinal belts of the Alps. To fill this gap, we studied how different management intensities and therefore different amounts of incentive payments affect plant species richness of mountain meadows.

The specific aims of the present study were (a) to provide information on the influence of five different management types, as defined by the Swiss law (ALSV, 2003), on vascular plant species richness and plant assemblages of meadows of centre-alpine valleys in eastern Switzerland, (b) to link plant species richness in meadows with abiotic factors such as slope, altitude and accessibility, i.e. distance to the corresponding farmyard, and (c) to evaluate the effectiveness of agri-environmental incentive payments in mountain areas.

2. Material and methods

2.1. Study region

The study was carried out in the valleys of Albula and Surses in the eastern part of Switzerland (Canton of Grisons; 46°,39′,47″ N/9°,34′,35″ E) at an altitude of about 900–1600 m a.s.l. Both valleys are dry centre-alpine valleys, with a slightly continental climate (Braun-Blanquet, 1961). The study region covered 15.2 km^2. Annual precipitation is about 800 mm (Spiess, 1997). The Albula-valley has an east-west and the Surses-valley a north-south orientation. The agricultural land is strongly dominated by grasslands (meadows and pastures) of different management intensity. In both valleys, meadows are usually positioned on south- or southeast exposed slopes or in the valley bottoms and span over two altitudinal belts, namely the montane and supalpine zones.

2.2. Vegetation survey and environmental data

During summer 2003, a field survey was conducted at 69 sites of three different management intensities (= getting different amounts of incentive payments) according to the official assessment of the corresponding farmers and an expert from the Cantonal authority: (i) Extensive meadows, no fertilizer or manure input; (ii) low-intensive meadows, manure input about 30 kg N ha^{-1} yr^{-1}; (iii) intensively used meadows with fertilizer input of ca. 90 kg N ha^{-1} yr^{-1}. Within the extensive and the low intensive meadows, two additional types were distinguished, namely moist and dry, again according to the official definition. Note that there were no dry intensive meadows in the study region. This resulted in a total of five different management types (Table 1). These management types only refer to the 'officinal' assessment (declaration of farmers and visual inspection of Cantonal expert in the field) and do not take into account any qualitative of quantitative measurements of soil properties.

Data on areas and locations of the corresponding sites were delivered by the Cantonal authorities (ALSV, 2003). The vegetation at each site was sampled within a circle of 3 m radius (28 m^2), selected to be representative for each site. Within the circles, all species of vascular plants were identified, and

Table 1 – Management types according to official assessments of mountain meadows in the study region in eastern Switzerland. The manure and/or fertilizer input, cutting regime and incentive payments are indicated

Management type	Manure and/or fertilizer input (kg N ha^{-1} yr^{-1})	Cutting regime	Incentive payments (Euro ha^{-1} yr^{-1})
Dry extensive meadow	0	One cut after July 15, grazing possible after September 1	300
Extensive meadow	0	One cut after July 15, grazing possible after September 1	300
Dry low intensive meadow	30	One cut after July 15, grazing possible after September 1	200
Low intensive meadow	30	One cut after July 15, grazing possible after September 1	200
Intensive meadow	90	Three or four cuts, no restrictions	0

their abundance was estimated as percentage cover on a continuous scale (BUWAL, 2001). The species list was then extended by spending 30 min on listing all additional species but without assessing their abundance at the whole site (area defined by the official assessment). The species list of the whole site constituted the dependent data of the present study. Nomenclature followed Heitz (1990).

In a GIS query (ArcView 3.2), management type as assessed above was coupled with slope, altitude and distance to farmyard (assessed as distance or accessibility). This resulted in the following explanatory variables. (i) Management type: five categories as described above. (ii) Slope: in three categories of 0–18%, 18–35% and more than 35%. Because slope often changes within a site, we assessed the slope at the whole site level using categories instead of exact inclination. (iii) Altitude: continuous data from 900 to 1600 m above sea level. (iv) Distance from farmyard to site, i.e. accessibility of a site. The latter continuous variable was calculated with a GIS based road network model within the SULAPS project (Lauber et al., 2004). Aspect was not taken into account (see above). For the ecological characterization of the study sites, the ecological indicator values of Landolt (1977) were used. Landolt indicator values are similar to the well known Ellenberg indicator values (Ellenberg, 1996), but are adjusted for the ecology of plant species in Switzerland. The three indicator values of soil moisture, soil nutrients and light were considered. Generally, there is a strong correlation between soil moisture, availability of nutrients and plant growth (Larcher, 1994; Ellenberg, 1996). On steeper slopes less water and nutrients are available, and plant growth should thus decrease resulting in sparser vegetation with more light reaching the ground.

2.3. Statistical analysis

One-way ANOVA was used to examine the impact of management type on plant species number and the three mean indicator values per site. Mean indicator values were calculated on the basis of presence/absence data. We tested the normality of the data with Kolmogorov–Smirnov tests. No data had to be transformed. To separate the effects of the different management types, we used Bonferroni *a posteriori* tests (Sokal and Rohlf, 1995). We also used a two-way ANCOVA to examine whether species richness differed among management types (fixed effect), slope (random effect), altitude (covariate) and accessibility (covariate). To check whether the official assessment of management was accurate, we correlated the ranking order of the management types with respect to nutrient input and soil moisture with the mean indicator values of soil nutrients and soil moisture per site using a Spearman correlation coefficient. All analyses were performed using SPSS 11.0.

Correspondence Analysis (CA) was used to examine whether the composition of plant species differed between different management types. As input data, we used presence/absence data. We did not down-weight rare species, because species with conservation importance could be expected to be rare even in the extensively managed meadows (Ellenberg, 1996). This multivariate analysis was performed with CANOCO 4.0 (ter Braak and Smilauer, 1994). To show the relation between plant assemblages and plant species richness, we used the score of the first CA axis and the number of species at each site (Wilson et al., 2003). The correlation was again evaluated with a Spearman coefficient using SPSS 11.0.

3. Results

3.1. Species richness

In total, 252 species of vascular plants were recorded at the 69 sites on 23 farms. There were considerable differences in the mean number of species per site among the management types (Table 2). Intensive meadows averaged 37 species, whereas the dry extensive meadows contained an average of 57.6 species (Table 2). Low-intensive meadows had a mean number of 49.7 species. The mean number of species per management type declined with increasing management intensity, and dry sites harboured slightly more species regardless of their management intensity (dry extensive > dry low intensive > extensive > low-intensive >> intensive meadows). One-way ANOVA indicated significant differences of species richness among types ($F_{4,64} = 12.123$, $P < 0.001$), but pairwise comparisons showed that only intensive meadows significantly differed from the other four management types (Table 2).

A two-way ANCOVA on the effect of slope, altitude, management type and accessibility on plant species richness again showed that management type had a strong significant influence ($P = 0.002$), whereas slope, altitude and accessibility did not (Table 3). Management type and slope were not related to each other as the interaction term was not significant.

3.2. Ecological indicator values

The ranking order of management types with respect to nutrient input and soil moisture were significantly correlated with the mean indicator values for soil nutrients and soil moisture ($r_s = 0.525$, $P < 0.001$ and $r_s = 0.393$, $P = 0.001$, respectively), indicating that the official assessment was generally correct.

There were significant differences between management types for mean indicator values of moisture and nutrients (one-way ANOVA; $F_{4,64} = 5.06$; $P = 0.001$ and $F_{4,64} = 11.8$; $P < 0.001$, respectively), but not for mean indicator values of light ($F_{4,64} = 1.79$; $P = 0.142$). Intensive meadows generally

Table 2 – Plant species richness and management intensity (see Table 1) in mountain meadows in the eastern Swiss Alps. Mean values ± standard error of number of species are given

Management type	N	Mean
Dry extensive meadow	13	57.6 ± 2.1^{A}
Dry low-intensive meadow	10	55.3 ± 2.3^{A}
Extensive meadow	17	52.9 ± 2.3^{A}
Low-intensive meadow	15	49.7 ± 2.8^{A}
Intensive meadow	14	37.0 ± 1.5^{B}
Total	69	50.2 ± 1.3

Mean values having the same superscript capital letter are not significantly different.

Table 3 – Effect of four variables on plant species richness in mountain meadows in the eastern part of the Swiss Alps. Two-way ANCOVA on number of plant species, with management type as fixed effect and slope as random effect and altitude and accessibility as covariates

Source	SS	*df*	MS	*F*	*P*
Accessibility (covariate)	5.004	1	5.004	0.056	0.814
Altitude (covariate)	121.407	1	121.407	1.353	0.250
Management	1796.962	4	449.241	5.007	0.002
Slope	186.228	2	93.114	1.038	0.361
Management * slope	400.786	8	50.098	0.558	0.807
Error	4665.107	52	89.714		

had higher soil moisture than low-intensive and extensive management types (Fig. 1a). Intensive meadows had also more soil nutrients (Fig. 1b) and, partly, showed a more dense coverage than meadows of the other management types (Fig. 1c). Differences between the low intensive and the

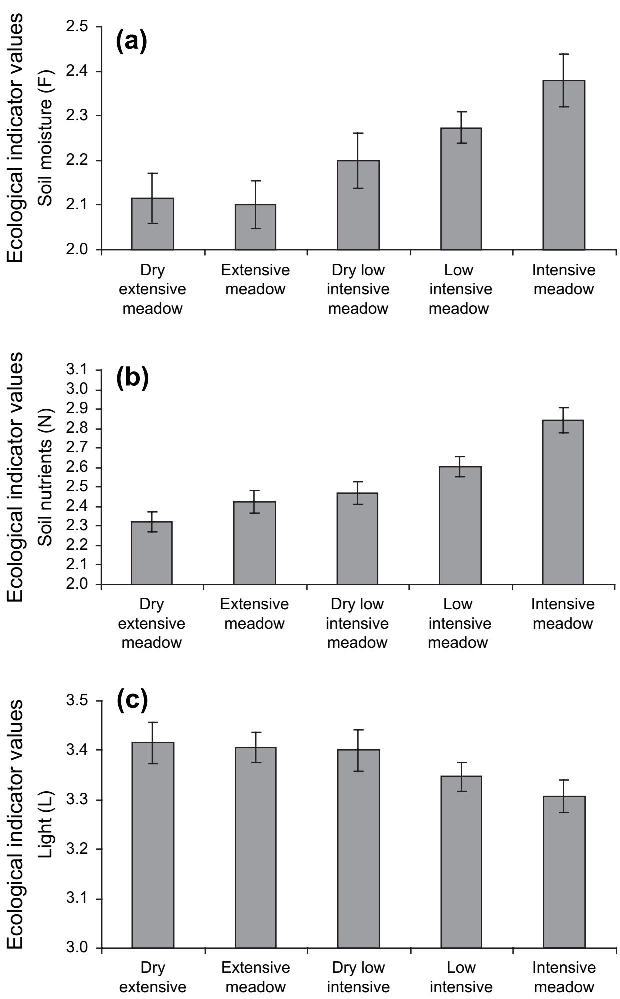

Fig. 1 – Mean values (±standard error) of ecological indicator values (Landolt, 1977) of soil moisture (a), soil nutrients (b) and light (c) of five management types (see Table 1) of meadows in mountain valleys of the eastern part of the Swiss Alps.

extensive meadows were most pronounced for mean soil nutrients (Fig. 1b). Differences between the mean indicator values of soil moisture and soil nutrient of the intensively and the other four, less intensively used meadows were mostly significant, whereas almost no significant differences could be found among the latter four management types (Table 4). In summary, intensively managed meadows had higher soil moisture, more soil nutrients and had a higher vegetation cover than the less intensive management types.

3.3. *Correspondence Analysis (CA)*

The correspondence analysis given in Fig. 2 showed that the species composition of extensive and low intensive meadows, including the dry variants, was similar and did not exhibit clear boundaries. Although the CA results indicated gradual shifts among management types, the plant assemblages of intensive meadows clearly differed from extensive meadows (Fig. 2).

There was a clear statistically significant relationship ($r_s = -0.438$, $P < 0.001$) between plant assemblage (as estimated by the values of the CA axis 1) and species richness. However, assemblages of high diversity were found across all four low-intensive or extensive management types, while intensive meadows had the lowest species diversity (Fig. 3).

4. Discussion

This investigation focused on the question of how management intensity, altitude, slope and accessibility (distance from farmyard) affect vascular plant species richness in mountain meadows in order to evaluate the potential effectiveness of agri-environmental incentive payments in Switzerland.

4.1. *Management intensity*

We found significant differences of species richness between meadows with high nitrogen supply (90 kg N ha^{-1} yr^{-1}) and four management types with lower (30 kg N ha^{-1} yr^{-1}) or no fertilizer application. This supports numerous previous studies linking a general decline in species richness in grasslands with an increase in nitrogen supply, which in turn increases with management intensity (Jonsdottir et al., 1995; Joyce, 2001; Pitcairn et al., 1998). There was little variation among the less intensively or extensively managed meadows; i.e. no significant differences of species richness between meadows with manure input rate of 0 to 30 kg N ha^{-1} yr^{-1}, but a considerable decline in species richness with nitrogen application rate of 90 kg N ha^{-1} yr^{-1} (Table 1). Mountford et al. (1993) also showed that there was no significant change in species number at an application rate of 25 kg N ha^{-1} yr^{-1}. In their study, more than 50 kg N ha^{-1} yr^{-1} had to be supplied before a decline was detectable in species richness after three years of application. Likewise, Eek and Zobel (2001) stated that vascular plants had the highest species richness at an intermediate nitrogen supply with a tendency of species richness to decrease with increasing fertilisation.

Table 4 – Significance levels of pairwise Bonferroni post hoc tests on the mean indicator values of soil moisture and soil nutrient between five management types (see Table 1) of mountain meadows from Eastern Switzerland

Management type	Dry low-intensive meadow	Extensive meadow	Low-intensive meadow	Intensive meadow
Soil moisture				
Dry extensive meadow	1	1	0.377	0.009
Dry low-intensive meadow		1	1	0.318
Extensive meadow			0.154	0.002
Low-intensive meadow				1
Soil nutrient				
Dry extensive meadow	1	1	0.01	≤0.001
Dry low-intensive meadow		1	1	0.001
Extensive meadow			0.207	≤0.001
Low-intensive meadow				0.049

In Switzerland the extensive and less intensive management types are supported by incentive payments based on management agreements (DZV, 1998). Low input meadows with 0 or 30 kg N ha^{-1} yr^{-1} contribute to 86% of the total agri-environmental compensation area of Switzerland with extensively used meadows reaching 50% and low-intensive meadows 36% (BLW, 2004). In the lowland parts of Switzerland, the Swiss Plateau, the ecological quality measured as species richness of these extensively used meadows is often rather poor (FAL, 2002). Here, intensively managed meadows and low-intensively managed meadows, for which the farmers get incentive payments, do not or only slightly differ in plant species richness. However, less-intensively managed meadows in mountain regions tend to have higher ecological quality in terms of plant species richness, as shown by the present study. An explanation for this pattern is the more constant agricultural regime in mountain areas. This traditional management system was only abandoned or changed during the last few decades of the 20th century. Historically, an extensive meadow in alpine valleys had a much lower probability of undergoing agricultural improvement, hence leading to species loss, than extensive meadows in the lowlands of Switzerland, where almost all meadows were intensified due to former agricultural policy. As a consequence, very few lowland meadows still have high plant species richness (FAL, 2002), while a considerable proportion of meadows in the mountains are still managed in a more traditional way, thus exhibiting considerable plant species richness. Kleijn et al. (2001, 2004) pointed out that agri-environment compensation schemes do not have the desired effects on plant richness or even have unexpected adverse side effects (e.g. on birds), when implemented on lowland farms in Western Europe. However, the management history of sites, together with the motivation and expertise of the farmers, plays a crucial role for attaining the target of higher plant diversity (Baur, 1998; Kleijn et al., 2001). Our study indicates that agri-environment schemes and incentive payments seem to be effective in the case of mountain areas. Here, they help to maintain meadows of high species diversity. It is nevertheless questionable whether the different amounts of incentive payments

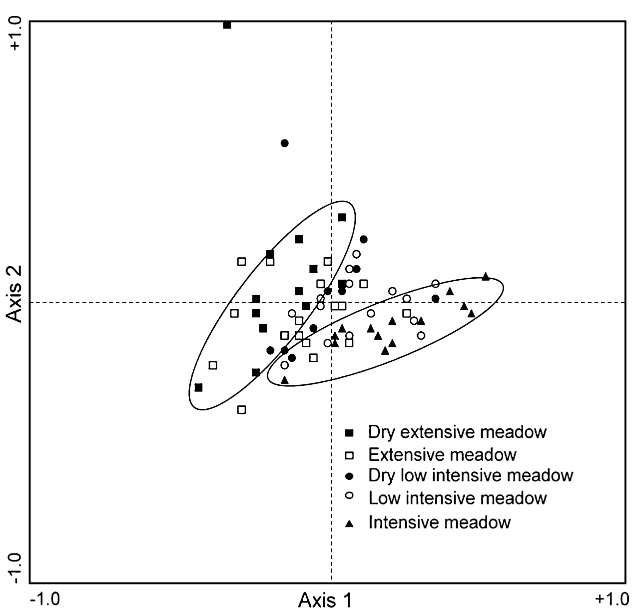

Fig. 2 – Correspondence analysis (CA) of 69 sites using species occurrence data of meadows from the eastern Swiss Alps. The five management types (see Table 1) are given by different symbols. Encircled are the two extreme management types, namely dry extensive meadows and intensive meadows.

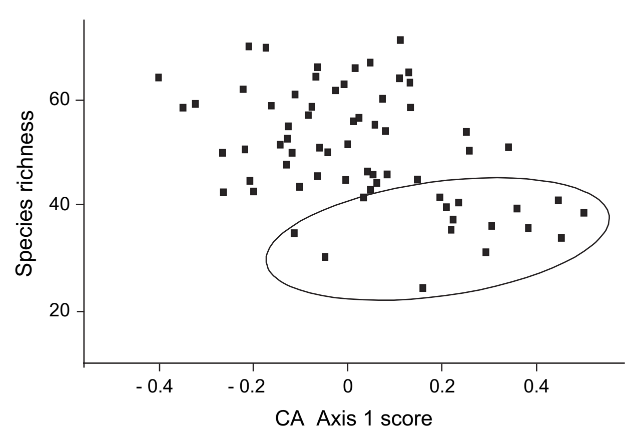

Fig. 3 – Relationship between plant species richness and CA axis 1 scores of the 69 sampling sites of mountain meadows from the eastern Swiss Alps. Scores of intensive meadows are encircled.

given for extensive and low-intensive management types (Table 1) are justifiable. For instance, we found highest plant species richness at dry sites regardless of whether they were extensively or low-intensively used.

Zechmeister et al. (2003) postulated a negative correlation between the species richness of a site and the money invested into a meadow by farmers as calculated from petrol- and fertilizer costs or costs of machines. Assuming that the distance from a meadow to the farmyard reflects these costs, at least in part, our study did not support such a correlation. In our study region, management intensity neither depended on the accessibility of a site nor on favourable topography (slope), but did depend on soil conditions (Table 3, Fig. 1). The expected pattern of intensively used meadows being located at favourable terrains (e.g. terraces, valley bottoms, etc.) and extensively used meadows being more limited to intermediate or steep slopes could not be shown. Based on this result, we conclude that more remote and steeper sites, as the farmyards usually lay at the valley bottom, did not generally show a higher plant species richness than more accessible sites. Intensive meadows were often located at quite remote places as well.

4.2. *Ecological indicator values*

Indicator values are widely used in vegetation assessment. Vegetation data can provide information on management (Bakker, 1989) or the availability of soil nutrients or soil moisture (Ellenberg et al., 1991; Wamelink et al., 2002). The vegetation-based results of the present study showed that low availability of water and nutrients enhanced plant species richness in meadows.

The well known negative relationship between species richness and nutrient conditions has been described by several authors (Tilman, 1982; Chapin et al., 1997). In our study, intensive meadows with high fertilizer input exhibited especially low species richness. They were dominated by fast- and tall-growing species such as *Arrhenatherum elatius, Dactylis glomerata* and *Trisetum flavescens* - typical species of intensively used mountain meadows (Ellenberg, 1996).

4.3. *Species composition*

The extreme management types of extensive and intensive meadows showed different plant assemblages (Figs. 2 and 3). In dry extensive meadows, only one species had high abundances of 25–50%, namely *Bromus erectus*. *Bromus erectus* is a characteristic species of dry and nutrient-poor meadows (Ellenberg, 1996). Species like *Centaurea scabiosa*, *Salvia pratensis*, *Carex caryophyllea*, *Dactylis glomerata*, *Rhinanthus alectorolophus* and *Arrhenatherum elatius* became increasingly frequent with increasing management intensity. Biogeographically characteristic species of the studied mountain region, such as *Astragalus monspessulanus, Lactuca perennis* or *Peucedanum verticillare* (Becherer, 1972), never occurred in intensively managed meadows.

The intensive meadows varied rather substantially in their species composition as compared with the other management types (Figs. 2, 3). Abundant species were *Arrhenatherum elatius*, *Dactylis glomerata*, *Heracleum sphondyllium*, *Trisetum flavescens*, *Trifolium pratense*, *Carum carvii*, *Taraxacum officinalis*, *Achillea millefolium*, *Anthriscus sylverstris* and *Helicotrichon pratense*. In contrast, the ordination pattern of the correspondence analysis only showed a weak separation of the four less intensively or extensively used meadows. The reason for this could be that similar species dominate all these meadows. This again, sheds doubt on the justification of different amounts of incentive payments for these management types (see above).

In conclusion, we showed that decreasing management intensity leads to higher species richness in mountain meadows of eastern Switzerland. Surprisingly, this pattern was not dependent on slope, altitude or accessibility from farmyard site. While intensive meadows differed substantially from extensive and low-intensive meadows, the latter management types formed a continuum both with respect to variation in species richness and species assemblages. Our results show that incentive payments can indeed maintain high species richness in mountain meadows, but also shed doubt on whether different amounts of incentive payments are justified for extensive and low-intensive management types.

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