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Effects of agri-environment schemes on plant diversity in Bavarian grasslands

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Abstract: Grasslands play an important role in terms of biodiversity, landscape and agriculture. For 25 years, the Bavarian agri-environment scheme (AES) "Agricultural landscape program" (KULAP) has been funding management practices which are intended to conserve cultural landscapes and enhance biodiversity. The aim of this study was to evaluate the Bavarian AES schemes in terms of plant diversity. As AES is divided into many different, clearly divergent schemes, each of these schemes was evaluated separately. The evaluation focussed not only on species richness but also on other diversity parameters such as the presence of rare and common species, the percentage of species group members and the evenness as well as agronomic values such as forage value, percentage of agronomically desirable species or percentage of weeds. In order to achieve this goal, we selected about 950 pairs of grassland plots with and without AES. Differences in species richness between AES and control plots were most significant in the site related AES schemes and organic farming, whereas plots with other farm related AES schemes hardly differed from their controls. Obviously, schemes which really demand management changes on the part of the farmer have a definite effect on plant species diversity in grasslands compared to those which closely resemble conventional management.

Abbreviations: AES – Agri-Environment Scheme, BGS – Bavarian Grassland Monitoring, CNP – Contract Nature Protection Scheme, FGM – Frequency according to German grid maps, KULAP – Agricultural Landscape Program ("Kulturlandschafts-programm"), NLU – Natural Landscape Unit.

Nomenclature: Wisskirchen and Haeupler (1998).

Introduction

In many respects, biodiversity is an important environmental property. According to Tilman et al. (2006), ecosystem stability is directly related to high biodiversity. Considering the increased CO_2 concentration in the atmosphere (Körner 2002) and global change, genetic diversity becomes increasingly important as a pre-condition for the evolution of new species and, accordingly, for the adaptation to changing conditions (van der Maarel 1997). Many studies document that grassland biomass increases with the species richness of the sward (Adler and Bradford 2002, Pfisterer and Schmid 2002). Moreover, plant diversity and the species composition have a powerful impact on the functioning of the ecosystem (Scherer-Lorenzen et al. 2003).

As the vast majority of the area of the European Union (EU) consists of agricultural land, it is not sufficient to restrict biodiversity efforts to the few natural habitats that are left. In Germany, for example, 47.5% of the total area is made up of agricultural land (Bavarian Ministry for Agriculture and Forestry 2006). The high diversity of plant species and communities of grasslands still found in some semi-natural, unimproved sites in Europe dates back to the Middle Ages and the early Modern Era. Various traditional management systems and differing site conditions led to a variety of plant species compositions. Later on, however, with the industrialisation of agricultural production, grassland management was also intensified. High-yielding sites were further improved by means of a high nitrogen input or drainage systems. The consequence was the alignment of grasslands and a decrease in habitat diversity on one hand and a decrease in species per area on the other(Isselstein et al. 2005). This led to the creation of highly productive sites, which were sown with vigorous plant species that tolerate four and more cuts. Abandonment of less productive grasslands also leads to a reduction in species richness (Marriott et al. 2004). Many studies document that intermediate disturbance leads to the highest species richness (e.g., Connell 1978). Thus, both intensification and abandonment caused species to decline (Poschlod and Schumacher 1998, Diemer et al. 2001).

In the 1990s, European agricultural policy makers became aware of the environmental impact of agriculture (Herzog et al. 2005). Following two earlier attempts, the breakthrough in the application of agri-environment schemes (AES) was finally achieved in 1992 (EEC 2078/92). In the late 1990s, about 20% of EU farmland stood under some form of AES (Herzog 2005), rising to 25% of all farmland in the 15 older EU countries in 2005 (Kleijn et al. 2006). In most countries, the scheme has been adopted primarily in areas of extensive agriculture, where species richness is still relatively high anyway (Kleijn and Sutherland 2003, Hodgson et al. 2005). Referring to ART (2005), this does not apply to the grassland programs of the Bavarian KULAP ("Agricultural Landscape Program"), where farms in highly productive regions take part in the schemes as well. The KULAP as one of the Bavarian AES was one of the first in Europe and was covered by the regulation EEC 797/85. In 1992, the KULAP was updated to comply with EEC 2078/92. About 55% of Bavaria's farmland is linked to some KULAP scheme. The financial framework for KULAP as a whole amounted to about 200 million € in 2006 (Bavarian Ministry for Agriculture and Forestry 2006). The actual aims of KULAP are: 1) protection of soil and water bodies from contamination by reducing fertiliser input and chemical pest control; 2) landscape conservation; 3) decreasing soil erosion; 4) maintenance of biodiversity and habitat protection.

Because of the great importance of biodiversity, the aim of the studies presented here was to evaluate KULAP in terms of its plant diversity effects. Subject of the presented studies is the Bavarian agricultural grassland, which accounts for about 35% of total farmland. The Bavarian Grassland Survey (BGS), a monitoring program conducted all over Bavarian agricultural grassland, was implemented in 2002. The BGS was conceived to describe the actual state of agricultural grassland vegetation of different management intensity on one hand and to pursue the development of individual plots on the other. One specific aim of analysing BGS data is to evaluate AES in respect of their nature conservation success.

Most of the previous European evaluations of AES were content with estimations of the application of AES, but pure application rates do not reveal anything about the effects (Kleijn and Sutherland 2003). In 2000, Kleijn et al. (2001) assessed the Dutch AES in respect of species diversity. They surveyed pairs of grassland plots with and without AES. At that time they found no significant difference in plant species richness between the AES plots and the control. A later review of the evaluation results from five EU countries showed neither a positive nor a negative effect of AES on the investigated species groups (Kleijn and Sutherland 2003). Referring to Kleijn and Sutherland (2003), the problem was a lack of robust evaluation studies. So a research program comprising studies in five European countries was launched (Kleijn et al. 2006). Now Kleijn et al. (2006) discovered that AES had a positive effect on species richness throughout those five countries. A Swiss assessment of hay meadows also showed that AES meadows had a significantly higher species richness and evenness than conventional ones (Knop et al. 2006). This is one of the few studies also taking evenness into account. In most cases, diversity simply means the number of species, but, according to Haeupler (1982), the dominance structure presented by the evenness value is the second important measure of species diversity.

The aim of our analysis was not only to find out whether AES affects plant diversity in general, but to compare various types of AES in terms of their influence. For the sake of comparison, we selected pairs of plots from the whole pool of BGS permanent plots – one control plot and the nearest neighbour employing a specific type of AES. With this data set we wanted to evaluate the Bavarian AES from various points of view: Firstly, since the different KULAP schemes are clearly divergent, they were evaluated separately and then compared. Secondly, as there are so many different aspects of plant diversity, we did not content ourselves with merely assessing species richness, but also compared and contrasted the dominance structure of species (evenness), aspects of nature conservation (presence of rare and frequent species), environmental indicator values, percentages of taxonomic-functional groups and the agronomic values of species (forage value, percentage of agronomically desirable species or percentage of weeds). Thirdly, farming intensity measures were taken into account in order to identify relationships between KULAP types, farming intensity and species diversity.

Materials and methods

Agri-environment schemes in Bavaria

The Bavarian AES is composed of the Agricultural Landscape Program (KULAP), which offers four farm and numerous site related schemes to be applied to grassland management, and the Contract Nature Protection Scheme (CNP) applied on sites of special ecological value for nature conservation. Farm related measures, such as the abandonment of mineral fertilizer, have to be applied to all grasslands of the farm, whereas site related measures are only applied on selected, individual fields.

The different KULAP schemes allow for a fixed combination of measures, while the CNP allows individual contracts to be drawn up with the farmer for individual fields. The measures range from limiting livestock units per hectare (LU/ha), restricting the use of fertiliser (mineral, organic, none), restrictions on chemical pest management to special management requirements such as a late first cut of the sward.

In this study, we first tested plots with some form of KULAP against control plots without KULAP, to detect the general effects of the KULAP. Then we investigated the most widespread individual schemes (Table 1). Some less widespread schemes with similar measures were pooled in the group noCPM/F (no chemical pest management and fertilizer).

As the uptake of site related schemes remained far behind the uptake of some single farm related schemes, we tested these as one group (site KULAP) as well.

Study design

The study was conducted in the federal state of Bavaria in the South of Germany. Studied agricultural grassland types vary from semi-natural Alpine pastures to improved permanent or sown swards. To analyse the effect of the dif-

Table 1. Investigated AES schemes and measures; –: no prescriptions. LU = livestock units.

AES type	name/explanation	LU/ha limitation	fertilizer	chemical pest management	first cut	n (pairs)
any KULAP	site or farm related KULAP	yes	depending on type	depending on type		215
site KULAP	any site related KULAP	yes	depending on type	depending on type		90
farm related						
K33	extensive permanent grassland	0.5 - 2.5	any	restricted	-	189
K34	extensive permanent grassland	0.5 - 2.5	no mineral	restricted		125
org	organic farming	0.5 - 2	no mineral	none	-	85
site related						
no CPM/F	no fertilizer, no chemical pest control	max 2	none	none	-	57
cut 1	delayed first cut	max 2	no mineral	-	June 15	51
cut 2	delayed first cut	max 2	no mineral	restricted	July 1	40
trad.orch.	traditional orchard	no	any	-	-	26
CNP	nature conservation program		individual contracts			58

ferent AES measures, pairs of plots from the Bavarian Grassland Survey (BGS; 4400 plots in total)–one with and one without AES–were selected (936 pairs in total). Starting with the relevés without any AES (control), the nearest plot under a different AES scheme was identified using the GIS (ArcGIS 9.2, ESRI) "nearest neighbour" tool. Only pairs situated in the same natural landscape unit (Meynen and Schmithüsen 1953) were accepted. Only about 10% of pairs were situated more than 10 km away from each other. The 25 m^2 plots were located in typical, homogeneous vegetation in the field. The centre of the circular plot was marked permanently by means of a magnet and the GPS coordinates of the plot were noted. The surveys were conducted during the vegetation season between April and October where all vascular plants were recorded. An analysis of variance (ANOVA) showed that about 13% of all pairs were recorded in significantly different months according to species number. Seven different people were involved in the relevés. To calibrate their estimations, all field workers were trained at least once every year. Despite this, about 28% of the pairs of plots were recorded by people significantly different in the recorded species number. According to the method devised by Klapp and Stählin (1936), the total yield of the field per hectare and the percentage biomass of every species were estimated by visual inspection. In addition, information on livestock units per hectare (LU/ha), management type, participation in AES and the area of arable land and grassland of the farm were obtained from the agricultural administration.

Data analysis and statistics

Species evenness was calculated as

$$E = H'/\ln S,$$

where $H' = -\Sigma\, p_i \ln p_i$ (Shannon index), $p_i = n_i / N$, n_i is the abundance of the *i*th species, N is the total abundance and S is the total number of species per plot (Pielou 1969, 1975). The average Ellenberg moisture and nitrogen value (Ellenberg et al. 1991) and the forage value (Klapp et al. 1953) of the vegetation were calculated for every relevé. The mean annual precipitation of the site was determined by means of the GPS coordinates of each relevé (Bavarian Climate Research Association 1996).

To study the effect of the AES on vegetation composition, different variables were calculated by grouping the plant species according to different attributes. According to their affiliation to the appropriate plant family, different species were classified as grasses (Poaceae, Cyperaceae, Juncaceae), legumes (Fabaceae) and herbs (all other families), the taxonomic functional groups. The percentage of biomass of *Rumex obtusifolius*, *R. crispus*, *Taraxacum officinale*, *Poa trivialis* and *Elymus repens* was totalled to create the weed group. *Lolium* spp., *Trifolium repens*, *Poa pratensis* and *Dactylis glomerata* were classified collectively in the group of agronomically desirable species.

Based on their frequency in Germany (FGM) and within the Bavarian Grassland Survey (BGS), two other variables were derived. Ellenberg et al. (1991) assigned species to nine frequency classes ranging from extremely rare to nearly omnipresent, according to the number of grid squares occupied by the species in Germany (Haeupler and Schönfelder 1988). For this study in each case two frequency classes were combined to the groups FGM middle (class 4 and 5), FGM frequent (class 6 and 7) and FGM very frequent (class 8 and 9). Rare species (classes one to three) were left out due to their negligible occurrence.

Additionally species were grouped according to their frequency within the BGS. The groups BGS very frequent (in more than 65% of the relevés), BGS frequent (30-65%), BGS middle (5-29%) and BGS rare (less than 5%) were generated.

To test for significant differences in the different variables between AES and control plots, we used a Wilcoxon matched pairs signed rank test when the differences between control and AES plot were not normally distributed. In case of normal distribution, we used the two-sample paired *t*-test.

All analyses were computed using SAS 9.1 software (SAS Institute Inc., Cary, NC, USA.).

Results

Tables 2 and 3 show some basic differences between AES and control plots. AES plots were situated at a higher altitude with a slightly higher precipitation. Farms with AES were those with larger grassland and arable areas. The mean moisture figure was significantly higher on some of the site related AES plots, whereas mean nitrogen figure was rather lower on the AES plots.

Estimated average yield was significantly lower on plots with site related KULAP, organic farming, very late cut and CNP, LU/ha on plots where no pesticide or fertilizer were applied (noCPM/F). But these two management intensity indicators showed no significant difference compared with the control, neither for any KULAP nor for the farm related KULAP schemes K33 and K34. A positive trend from the control to the AES plots was recognizable in species number, evenness, very frequent species in terms of FGM and rare to middle frequent species according to BGS. A decreasing tendency was observed from the control to AES for the percentage of grasses, mean forage value, percentage of agronomically desirable species, percentage of weeds and the percentage of very frequent species (BGS frequency).

In general, the most significant differences to the control were recorded for CNP, noCPM/F, cut 2 and site KULAP, whereas the differences shown by K33 and K34 were hardly significant.

Mean species numbers on the control plots varied between 17.8 and 21.5, on the KULAP plots between 18.3 and 23.3 and the maximum mean species richness was achieved on the CNP plots with 25.8 (Fig. 1).

Discussion

Sampling design and site conditions

By selecting pairs of plots out of the total BGS monitoring program, we intended to avoid excessive differences in the site conditions between KULAP plots and the control plots. As shown in Tables 2 and 3, however, there are some substantial differences between the paired plots. KULAP plots are situated at a higher elevation. This phenomenon was observed by Kampmann et al. (2008) as well. As their study combined high altitude with much less intensive management, they concluded that higher species richness on AES meadows was not a direct effect of the AES. AES did not improve biodiversity by means of reduced farming intensity but preserved the high biodiversity that was already apparent on long-term extensively managed grasslands (Kampmann et al. 2008). This is consistent with other studies that found AES in rather less productive regions (Kleijn and Sutherland 2003, Hodgson et al. 2005). Conditions in Bavaria are somewhat different. No significant difference was detected in the productivity of regions with and without KULAP, at least for the grassland KULAP as a whole (ART 2005). Perhaps those schemes which involve severe changes in agricultural management for the farmers (organic farming and the site related KULAP) are located in less productive regions, whereas measures such as K33 or K34, which are easily observed, are also adopted in fairly productive regions, too. Actually, Köbler (2001) figured out that K33 was not specific for any region in Bavaria, whereas organic farming was over-represented in South Bavaria. In addition, these differences between KULAP schemes are also recognizable on a smaller spatial scale – the plots. As opposed to some of the site related AES schemes, K33 and K34 plots showed no significant differences in mean moisture and nitrogen figures compared to their control plots (Table 2).

Farms adopting KULAP measures had significantly larger areas of grassland and arable land (Tables 2 and 3, ART 2005). Probably the large, professionally organised farms are more likely to accept the huge administrative effort to apply for AES.

Plant species diversity and management intensity

In our data set we have included two parameters representing a farm's management intensity: estimated yield and LU/ha (Tables 2 and 3). The results showed that grasslands of some KULAP types are less intensively managed than conventional ones. An additional factor of extensive man-

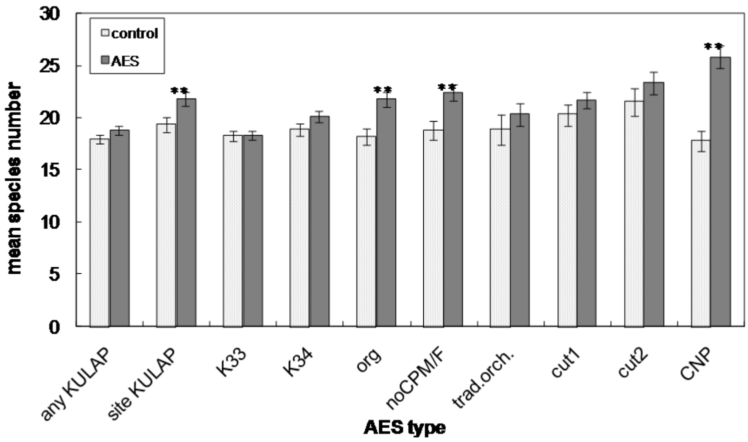

Figure 1. Mean species numbers of AES plots and the corresponding control plots.

Table 2. Mean differences between control plots and AES schemes: any KULAP, total site related KULAP, particular farm related KULAPs. SE: standard error; sig.: significances; ns: not significant; *** p<0.0001; ** p<0.005; * p<0.05; GL: grassland; AL: arable land; FGM: frequency in grid maps; BGS: Bavarian Grassland Survey; LU: livestock unit; %: mean percentage of estimated total yield. [1] annual precipitation in classes: 1: <550 mm; 2: 550-650 mm; 3: 650-750 mm; 4: 750-850 mm; 5: 850-950 mm; 6: 950-1100 mm; 7: 1100-1300 mm; 8: 1300-1500 mm; 9: 1500-2000 mm; 10: >2000 mm.

	any KULAP			site KULAP			K33			K34			org		
	mean	SE	sig.	mean	SE	sig.	mean	SE	sig.	mean	SE	sig.	mean	SE	sig.
abiotic site conditions:															
altitude (m a. s. l.)	0.91	2.32	ns	4.51	7.03	ns	4.33	3.20	ns	9.70	5.58	ns	13.41	6.19	*
precipitation[1] /mm	-0.05	0.03	ns	0.01	0.06	ns	-0.03	0.04	ns	0.02	0.06	ns	0.01	0.07	ns
GL-area /ha	11.66	4.91	***	8.98	3.03	***	5.28	1.34	***	17.72	5.42	***	28.21	12.17	***
AL-area /ha	7.33	2.67	**	9.17	3.38	*	9.86	2.81	**	7.75	3.91	*	1.47	3.49	ns
moisture figure	0.05	0.06	ns	0.36	0.10	**	0.00	0.06	ns	-0.05	0.08	ns	0.08	0.09	ns
nitrogen figure	-0.09	0.06	ns	-0.22	0.11	ns	0.00	0.07	ns	-0.10	0.08	ns	-0.20	0.11	ns
intensity measures:															
yield (estimated)	-1.71	1.14	ns	-5.94	2.17	*	-0.67	1.30	ns	-2.12	1.53	ns	-6.18	2.15	*
LU/ha	-0.09	0.06	ns	-0.13	0.10	ns	-0.02	0.06	ns	-0.08	0.08	ns	-0.16	0.09	ns
diversity measures:															
species number	0.88	0.47	ns	2.50	0.83	**	0.13	0.51	ns	1.32	0.71	ns	3.60	0.92	**
evenness	0.03	0.01	***	0.03	0.01	ns	0.03	0.01	**	0.03	0.01	*	0.06	0.02	***
weeds %	-1.03	1.24	ns	-2.29	2.01	ns	-0.11	1.19	ns	-2.30	1.78	ns	-2.01	1.94	ns
agro. desir. Spec. %	-0.43	1.69	ns	-7.06	2.34	*	2.75	1.75	ns	2.29	2.44	ns	-3.31	2.68	ns
forage value	-0.01	0.08	ns	-0.42	0.14	*	0.04	0.09	ns	0.12	0.12	ns	-0.16	0.14	ns
grass %	-0.01	1.28	ns	-0.24	2.45	ns	0.20	1.46	ns	-0.58	1.87	ns	-7.18	2.45	**
herb %	-0.20	1.08	ns	1.89	1.83	ns	-0.84	1.26	ns	-0.55	1.63	ns	3.88	2.06	ns
legume %	0.79	0.65	ns	-0.54	1.25	ns	1.25	0.62	ns	2.11	1.07	*	4.33	1.23	**
FGM middle %	0.00	0.02	ns	0.06	0.05	ns	0.01	0.03	ns	-0.04	0.03	ns	0.08	0.05	ns
FGM frequent %	-0.08	0.07	ns	0.20	0.14	ns	-0.20	0.09	*	-0.20	0.11	ns	0.08	0.15	ns
FGM very frequent %	1.01	0.40	*	2.13	0.67	**	0.40	0.43	ns	1.45	0.60	*	3.24	0.74	***
BGS rare %	0.62	1.07	ns	3.61	1.91	ns	-1.14	1.22	ns	-0.14	1.29	ns	2.87	1.95	ns
BGS middle %	2.15	0.78	*	3.27	1.18	*	1.59	0.82	ns	-0.29	0.96	ns	1.99	1.37	ns
BGS frequent %	-0.64	1.01	ns	-0.82	1.40	ns	-0.41	1.05	ns	1.45	1.15	ns	1.02	1.50	ns
BGS very frequent %	-2.17	0.89	**	-6.21	1.19	***	-0.09	0.87	ns	-1.11	0.99	ns	-5.79	1.31	***

Table 3. Mean differences between control plots and AES schemes: particular site related KULAPs, CNP. SE: standard error; sig.: significances; ns: not significant; *** $p < 0.0001$; ** $p < 0.005$; * $p < 0.05$; GL: grassland; AL: arable land; FGM: frequency in grid maps; BGS: Bavarian Grassland Survey; LU: livestock unit;%: mean percentage of estimated total yield. [1] annual precipitation in classes: 1: <550 mm; 2: 550-650 mm; 3: 650-750 mm; 4: 750-850 mm; 5: 850-950 mm; 6: 950-1100 mm; 7: 1100-1300 mm; 8: 1300-1500 mm; 9: 1500-2000 mm; 10: >2000 mm.

	noCPM/F			trad.orch.			cut1			cut2			CNP		
	mean	SE	sig.	mean	SE	sig.	mean	SE	sig.	mean	SE	sig.	mean	SE	sig.
abiotic site conditions:															
altitude (m a. s. l.)	-16.53	8.12	*	20.12	13.85	ns	42.67	14.72	*	49.70	20.47	*	12.26	12.05	ns
precipitation[1] /mm	-0.16	0.11	ns	0.04	0.14	ns	0.25	0.11	*	0.30	0.13	*	-0.07	0.10	ns
GL-area /ha	11.32	3.73	**	7.85	2.09	**	8.49	2.40	**	15.55	7.48	**	14.53	3.72	***
AL-area /ha	19.61	6.16	**	8.77	6.64	ns	13.37	6.98	ns	19.83	5.84	**	4.78	7.06	ns
moisture figure	0.49	0.13	**	0.04	0.20	ns	0.31	0.12	*	0.23	0.18	ns	0.41	0.16	*
nitrogen figure	-0.05	0.15	ns	-0.12	0.15	ns	0.00	0.14	ns	-0.53	0.21	*	-0.71	0.20	**
intensity measures:															
yield (estimated)	-3.68	2.84	ns	-6.54	3.93	ns	-2.84	2.37	ns	-10.38	3.77	*	-16.90	3.08	***
LU/ha	-0.35	0.12	*	0.19	0.18	ns	0.16	0.11	ns	-0.15	0.14	ns	-0.22	0.13	ns
diversity measures:															
species number	3.58	1.20	**	1.42	1.84	ns	1.43	1.13	ns	1.85	1.41	ns	8.07	1.12	***
evenness	0.07	0.02	**	0.01	0.03	ns	0.00	0.02	ns	0.01	0.03	ns	0.05	0.02	*
weeds %	-4.33	2.57	ns	1.23	4.82	ns	1.41	2.62	ns	-5.15	2.64	ns	-6.29	2.63	*
agro. desir. Spec. %	-9.53	3.37	*	2.92	5.11	ns	-9.61	2.66	**	-9.40	3.13	*	-15.71	3.41	***
forage value	-0.54	0.20	*	-0.04	0.31	ns	-0.14	0.17	ns	-0.50	0.22	*	-1.14	0.25	***
grass %	-6.49	3.02	*	3.19	4.91	ns	-1.22	2.79	ns	2.53	4.10	ns	-7.31	2.98	*
herb %	7.99	2.42	**	-1.54	4.56	ns	2.00	2.54	ns	-0.90	2.96	ns	8.07	2.59	**
legume %	0.00	1.47	ns	-1.07	1.99	ns	-0.42	1.50	ns	-1.43	2.01	ns	1.12	0.82	ns
FGM middle %	-0.04	0.04	ns	0.08	0.08	ns	0.10	0.06	ns	0.10	0.09	ns	0.40	0.15	*
FGM frequent %	0.35	0.20	ns	-0.15	0.25	ns	0.18	0.21	ns	0.10	0.24	ns	0.93	0.26	**
FGM very frequent %	3.00	0.99	**	1.15	1.47	ns	1.22	0.90	ns	1.85	1.13	ns	6.10	0.89	***
BGS rare %	1.63	2.97	ns	3.27	2.61	ns	-1.04	2.32	ns	7.55	3.47	*	18.98	2.96	***
BGS middle %	2.02	1.42	ns	1.46	2.20	ns	5.22	1.56	**	3.48	2.13	ns	2.28	1.22	ns
BGS frequent %	0.16	2.08	ns	0.96	2.48	ns	-0.63	1.87	ns	-6.70	2.52	*	-10.81	1.85	***
BGS very frequent %	-3.88	1.57	*	-5.69	2.20	*	-3.67	1.42	*	-4.53	1.87	*	-10.62	1.67	***

agement is low nitrogen input. Some former studies revealed that low nitrogen input results in a higher species richness (Zechmeister et al. 2003, Tallowin et al. 2005). In Bavaria, KULAP grassland showed a significantly higher species number than the controls, which may be an effect of less intensive management. A similar relationship was found in several European countries (Kleijn et al. 2006, Knop et al. 2006). The persistently lower mean nitrogen figures in KULAP grassland contribute to the presumption that nitrogen input is a key factor. Both weeds and agronomically desirable species are vigorous species and accordingly depend on a certain level of nitrogen input. This also applies to species with a high forage value (Bahmani et al. 2002). Higher percentages of both weeds and desirable species in the control plots are therefore consistent. Referring to Haeupler (1982), a further important measure of plant species diversity apart from the species number is the structure of dominance expressed in the evenness value. According to Knop et al. (2006), the evenness on AES grassland was higher than on conventional grassland. Thus, both diversity measures (species number and dominance structure) improved on AES plots.

What about the presence of rare species? An analysis of Red Data Book species is hardly rational, due to their statistically proven rareness. Species frequency according to German grid maps (FGM) indicates the incidence in terms of all habitat types in Germany, based on the percentage of 10×10 km^2 grid squares occupied by the species (Ellenberg et al. 1991). Rare species in terms of FGM are those present in really uncommon habitats. Hardly any of the grassland species can be regarded as rare when applied to the whole of Germany. But some of the grassland species are more rare than others. In order to address this problem, we calculated the BGS frequency, which means the frequency of species within the Bavarian Grassland Survey. Comparing the two frequency approaches led to the same result found by Kleijn et al. (2006), but also helps to explain it: the species supported by AES measures were neither the Red Data Book species nor the rare species in terms of FGM, but the common species. But among these common species there are some rare grassland species. Table 3 shows that BGS rare species increased with AES (at least on cut2 and CNP plots), while the BGS very frequent species decreased in most cases. Thus, the Bavarian AES not only has the ability to conserve species richness but to support the not so common grassland species.

Plant species diversity and region

Species richness on the plots cut1 and cut2 was not significantly higher than that on the control plots (Table 3). Figure 2 shows that this is not due to a lower number of species on the KULAP plots but to a high species richness on the control plots, instead. Natural landscape units (NLU) in Bavaria differ in terms of grasslands' species richness (Heinz et al. 2008). Cut1 and cut2 plots and their controls are most densely distributed in some of the NLUs with the greatest diversity of species. This may indicate that the perceived effectiveness of AES also depends on the region.

Comparison of different AES

The grassland KULAP schemes most frequently adopted by farmers are the farm related ones K33, K34 and organic farming (ART 2005). Of this group only organic farming showed a significant difference in one of the intensity parameters (yield) compared with the control. Differences in species diversity parameters were not significant at K33 and K34 in most cases, whereas organic farming showed several significant differences (Table 2). Thus, within the group of farm related KULAP schemes, organic farming was the most efficient one in terms of plant species diversity. The percentage of legume species was significantly higher on organic farming and on K34 plots. As N-fertilisers are rather restricted under these forms of management, farmers may try to improve their grassland soils by sowing legumes to fix atmospheric nitrogen. Alternatively, it could be that legumes spread by themselves because they cope best with nitrogen poor conditions.

The site related KULAP schemes in general were more or less equally efficient in improving plant diversity as organic farming (Table 2). Within the group of site related KULAP schemes, there were probably insufficient data on the traditional orchards for differences to be significant. Of the remaining three schemes, the noCPM/F type was the most efficient one (Table 3). The big difference in the percentage of herbs is the most striking feature. noCPM/F does not include any fertiliser or any chemical pest control at all. Under such conditions, nutrient supply is inadequate for the productive grasses, so the less competitive herbs have a chance to establish themselves.

As mentioned above, the cut1 and cut2 plots do not differ significantly from their control plots in terms of species richness. So, can we assume that there is no difference whatsoever? Despite the similarity in species number there is a significant difference in species composition between the cut2 plots and their control plots. Weeds and agronomically desirable species present in the control plots were replaced by rare species referring to BGS in the cut2 plots (Table 3).

In general, the percentage of agronomically desirable species is significantly lower on site related KULAP plots but not on farm related KULAP plots, even on the organic farming plots. This suggests a more intensive management of grasslands with farm related KULAP (Bahmani et al. 2002). Unfortunately, those KULAP types which turned out to be less efficient are the ones which are mainly taken up by farmers. They are the ones subject to the least restrictions (Table 1).

The most significant differences compared to the control plots were observed on the CNP plots. CNP are measures aligned to the specific situation on a field. This is a completely different approach from the general management specifications of the KULAP.

Conclusion and perspectives

With our data analysis, which applied to a part of the Bavarian Grassland Survey data only, we tried to meet the demands for a sound evaluation of the Bavarian KULAP on agricultural grassland. We selected pairs of plots with and without AES with enough replicates to achieve significant results (Kleijn and Sutherland 2003). The results presented here show that AES grassland in Bavaria is more diverse than conventional grassland.

In order to attribute the effects to the influence of agri-environment schemes clearly, long-term observations are necessary (Herzog 2005). At the moment, we are not able to decide if agri-environment schemes only conserve species rich grasslands or whether they are able to improve species richness. As species often have no chance to reach and occupy new habitats, restoration measures are then necessary (Bischoff 2002, Mariott et al. 2004). Such measures are not incorporated in the Bavarian KULAP.

With our Bavarian Grassland Survey, we hope to be able to estimate the direct effects of AES in the future and to answer the question as to what extent AES is in a position to improve species richness and composition.

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