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Dry matter yield and herbage quality of field margin vegetation as a function of vegetation development and management regime

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Abstract

Dry matter (DM) yield and herbage quality of unfertilized mown field margin strips were studied during early succession in a field experiment over a period of three years. The experiment aimed to maximize botanical diversity and was conducted at two different locations with contrasting soil type and comprised four vegetation types (spontaneously regenerated versus sown vegetation) and three herbage removal strategies (herbage left versus herbage removed). The experimental factors investigated were location, vegetation and herbage removal. Margin strips were mown twice a year with a late first cut around 15 June and a regrowth cut around 15 September to meet nature conservation objectives. Average DM yield over the first three years was not significantly affected by herbage removal but increased significantly over time, irrespective of vegetation or herbage removal. Initially, sown margin strips significantly outyielded unsown margin strips, but differences in DM yield converged over time. The mid-June cut yielded significantly more than the regrowth cut but its herbage quality was significantly lower. Herbage from the unsown margin strip had a significantly better forage quality than herbage from sown margin strips. Forage quality decreased over time, irrespective of location or vegetation. Changes over time in DM yield and quality were attributed to changes in species composition. The herbage quality of field margins was lower than the herbage quality of intensively managed grassland, limiting its use in rations for highly productive livestock.

Additional keywords: biomass, digestibility, herbage removal, biodiversity, succession, legumes, crude protein, crude fibre

Introduction

Despite an ongoing reduction in field boundary habitats (Chapman & Sheail, 1994), in northern and western Europe a series of public initiatives has resulted in the creation of new field margin features on former arable land. Support mechanisms are available to encourage farmers to create new habitats, to restore old ones or to expand existing ones. Generally, the expansion of existing field boundaries is done by setting aside the outer metres of arable fields, allowing them to regenerate naturally, or sowing them to grass or a grass/forbs mixture thus creating field margin strips. Such strips usually are managed under a mowing regime (e.g. Smith & MacDonald, 1989; Marshall & Nowakowski, 1992; Dunkley & Boatman, 1994; Hart *et al.*, 1994). In many cases field margin strips are managed according to management prescriptions agreed on between the farmer and a governmental organization. Contrary to intensively managed grassland, field margin strips usually are not fertilized since fertilizer use is incompatible with the objective of creating or maintaining a species-rich vegetation (Peeters & Janssens, 1998). Low nutrient availability, particularly low extractable soil phosphorus, appears to be a key factor in maintaining a botanically rich vegetation (Marrs, 1993; Janssens *et al.*, 1997). In order to accelerate mineral depletion of the soil, many management agreements prescribe to cut the vegetation once or twice a year and remove the cuttings. The first cutting date is scheduled around mid-June or even later so as to allow seed set of the valuable species. Around mid-June many grass species reach maturity. The removal of cuttings from margin strips is a controversial issue to farmers who are particularly concerned about the on-farm valorization of the cuttings (Hopster & Van De Voort, 2004). Processing the cuttings into compost, particularly off-farm composting, is expensive. Moreover, most composting installations have a low capacity (De Wilde & Hermy, 2000). The forage quality of mature grass is low because of a low leaf/stem ratio, high cell wall content and increased lignification of cell walls, all resulting in a low digestibility of the herbage (Korevaar, 1986; Kirkham & Tallowin, 1995; Bruinenberg *et al.*, 2002). Protein content is low and mineral content may drop below animal needs (Armstrong *et al.*, 1986; Tallowin & Jefferson, 1999). The succession patterns in the vegetation are expected to result in an ever changing botanical composition, resulting in herbage of variable nutritional value (Korevaar *et al.*, 2004; Korevaar & Geerts, 2004).

However, field margin forage quality might be affected by the type of vegetation. In practice, apart from spontaneously regenerated margins, many margins are established by sowing either species-rich, commercially available mixtures or mixtures of local origin, which generally are preferred by nature conservationists.

We examined the effects of sown and unsown margin strips, mown twice a year, on dry matter yield and herbage quality during early vegetation succession of former arable land. The margin strips developed under different herbage removal strategies commonly applied in agri-environmental practice. In particular the following questions were addressed: (1) does the herbage removal strategy and/or the type of vegetation affect dry matter yield over time? (2) what is the impact of vegetation type and its composition on herbage quality? and (3) is there a difference in herbage quality between first and regrowth cut?

Materials and methods

Experimental details

In June 2001, a field margins experiment of the split-plot design was established on nutrient-rich arable land, with four vegetation types (main factor), three herbage removal strategies (split factor) and three replications (blocks). Different vegetation types and herbage removal strategies were chosen to study the latter's influence on botanical diversity. The experiment was established on two contrasting soil types in the province of West Flanders, Belgium: a well-drained sandy loam at Poperinge (SITE1: 50°52'N, 2°45'E) and a sandy soil at Beernem (SITE2: 51°09'N, 3°20'E). For the soil chemical properties see Table 1. The experimental strips (360 m x 10 m each) were established in a sward of 8-months-old Italian ryegrass (*Lolium multiflorum* Lamk.) and were ploughed in May 2001. Each strip was divided into 36 plots (10 m x 10 m) arranged side by side at the southern side of an east-west oriented watercourse at SITE1 and an east-west oriented tree row at SITE2.

Apart from an unsown spontaneously established plant community (CONTR), three different sown communities were studied: MIXT1, MIXT2 and MIXT3 (Table 2). MIXT1 was established with a seed mixture from 63 native plant species, comprising seeds of local origin. MIXT2 and MIXT3 were established with a commercially available seed mixture from 77 plant species, comprising species completely unrelated to the region. The plant species in these seed mixtures had been selected from a wide range of vegetation types: annual and perennial forbs from dry to moist grassland and perennial forbs thriving on nutrient-rich soils. Nitrogen-fixing dicotyledons were included to improve the quality of the herbage.

Once established, the species diversity of MIXT3 was increased by adding once a year seed-rich herbage from neighbouring roadsides. These roadsides were cut around the end of September. The fresh unchopped herbage was immediately removed and spread uniformly over the MIXT3 plots at a rate of approximately 5000 kg fresh herbage per hectare. The principal seed bearing species were *Daucus carota* L., *Centaurea jacea* L., *Tanacetum vulgare* L., *Plantago lanceolata* L., *Torilis japonica* DC. and *Pulicaria dysenterica* Bernh.

Table 1. Chemical properties of the soil at the two locations. Sampling depth 0–0.30 m.

Location	Soil texture	pH KCl	Org. C	Total N	Extractable	
					P	K
			(%)	(kg ha^{-1})	(mg per 100 g)	
Poperinge	Sandy loam	6.8	1.5	43	27	31
Beernem	Sand	5.7	3.3	113	75	31

Table 2. Seed mixtures sown: composition, origin and seed rate of native and commercial seed mixtures.

Functional group/ species	Native mixture (MIXT1)			Commercial mixture (MIXT2)		
	n [1]	Seed rate (g ha⁻¹)	Origin	n	Seed rate (g ha⁻¹)	Origin
Non-nitrogen-fixing dicots	45	6560	Pleijboza (NL [2])	59	5000	Barenbrug (NL)
Native wildflowers	45	6560				
Commercial wildflowers				59	5000	
Legumes	6	9200		6	9200	
Medicago sativa		1800	FF [3] (G)		1800	FF
Trifolium incarnatum		1500	FF		1500	FF
T. pratense		2000	CLO-DvP [4] (B)		2000	Barenbrug
T. repens		1400	CLO-DvP		1400	Barenbrug
T. resupinatum		1500	FF		1500	FF
Vicia sativa		1000	Pleijboza		1000	FF
Grasses	12	26500		12	26500	
Agrostis tenuis		2000	collected [5]		2000	Barenbrug
Anthoxanthum odoratum		600	Pleijboza		600	FF
Arrhenatherum elatius		3000	Pleijboza		3000	FF
Cynosurus cristatus		1200	Pleijboza		1200	FF
Festuca arundinacea		3600	collected		3600	Barenbrug
F. pratensis		3000	CLO-DvP		3000	Barenbrug
F. rubra		5000	CLO-DvP		5000	Barenbrug
Holcus lanatus		1000	Pleijboza		1000	FF
Lolium perenne		3000	CLO-DvP		3000	Barenbrug
Phleum pratense		1400	CLO-DvP		1400	Barenburg
Poa trivialis		700	collected		700	Barenburg
Dactylis glomerata		2000	collected		2000	Barenburg

[1] n = number of species sown.
[2] NL = Netherlands; G = Germany; B = Belgium.
[3] FF = Feldsaaten Freudenberger.
[4] CLO-DvP = Department of Plant Genetics and Breeding, Agricultural Research Centre, Merelbeke, Belgium.
[5] Collected in the neighbourhood of the trials.

During the first year the plots were cut once, on 15 September, and the cuttings were removed. In each of the following three years (2002–2004) they were cut twice, with the cut material either left or removed, which resulted in three different herbage removal strategies: (1) no removal of cuttings (REMOV0), (2) removal of cuttings from the first cut (REMOV1), and (3) removal of the cuttings from the first and the second cut (REMOV2). To allow a major part of the species to set seed and to enhance the establishment of young seedlings, the first cutting date was postponed until 15 June (first cut). The vegetation was cut a second time around 15 September (regrowth cut). Care was taken to avoid seed scattering when removing the cut material. In the experiment no fertilizers, pesticides or herbicides were used.

Variables measured

Botanical composition

The botanical composition of the vegetation was recorded yearly on 15 July, 30 days after the mid-June cut. The importance (expressed in %) of each species was derived from its presence in 16 quadrats (13 cm x 13 cm) randomly placed within the central 4 m x 4 m area of each plot, using the combined frequency-rank method of De Vries & De Boer (1959). The percentage of importance (I%) of a species is a measure for its contribution to the total biomass and is based on the ranking of the biomass contributed by the various plant species within each quadrat. The original method was modified for use in species-rich grassland containing many dicotyledons: quadrat size was increased from the original 10 cm x 10 cm to 13 cm x 13 cm so as to ensure each occurring species to be recorded with the same probability. The botanical composition in terms of importance of six functional groups was recorded over time by calculating the proportion of these groups to the total importance (= 100%). The following functional groups were distinguished: annual legumes (ANLEG), perennial legumes (PERLEG), annual non-N-fixing dicotyledons (ANDIC), perennial non-N-fixing dicotyledons (PERDIC), annual monocotyledons (ANMON) and perennial monocotyledons (PERMON). The I% of each functional group was calculated by totalizing the I% of all contributing species of that group.

Herbage yields

Herbage yields were determined twice a year, around 15 June (hereafter called first cut) and 15 September (hereafter called regrowth cut), by cutting the central 4 m x 4 m quadrat of each plot at a height of 5 cm, using an Agria motor cutter (Agria-Werke GmbH, Möckmühl, Germany). Fresh herbage yield was recorded in the field. Herbage samples were taken per plot and dried for 12 hours at 75 °C to calculate dry matter (DM) yield. DM yields of both first and regrowth cut were added to determine annual DM yields. The mean annual DM yield over the period 2002–2004 was calculated by averaging the annual DM yields of the three consecutive years. The mean annual DM yields of both first and regrowth cut over the experimental period were calculated in the same way.

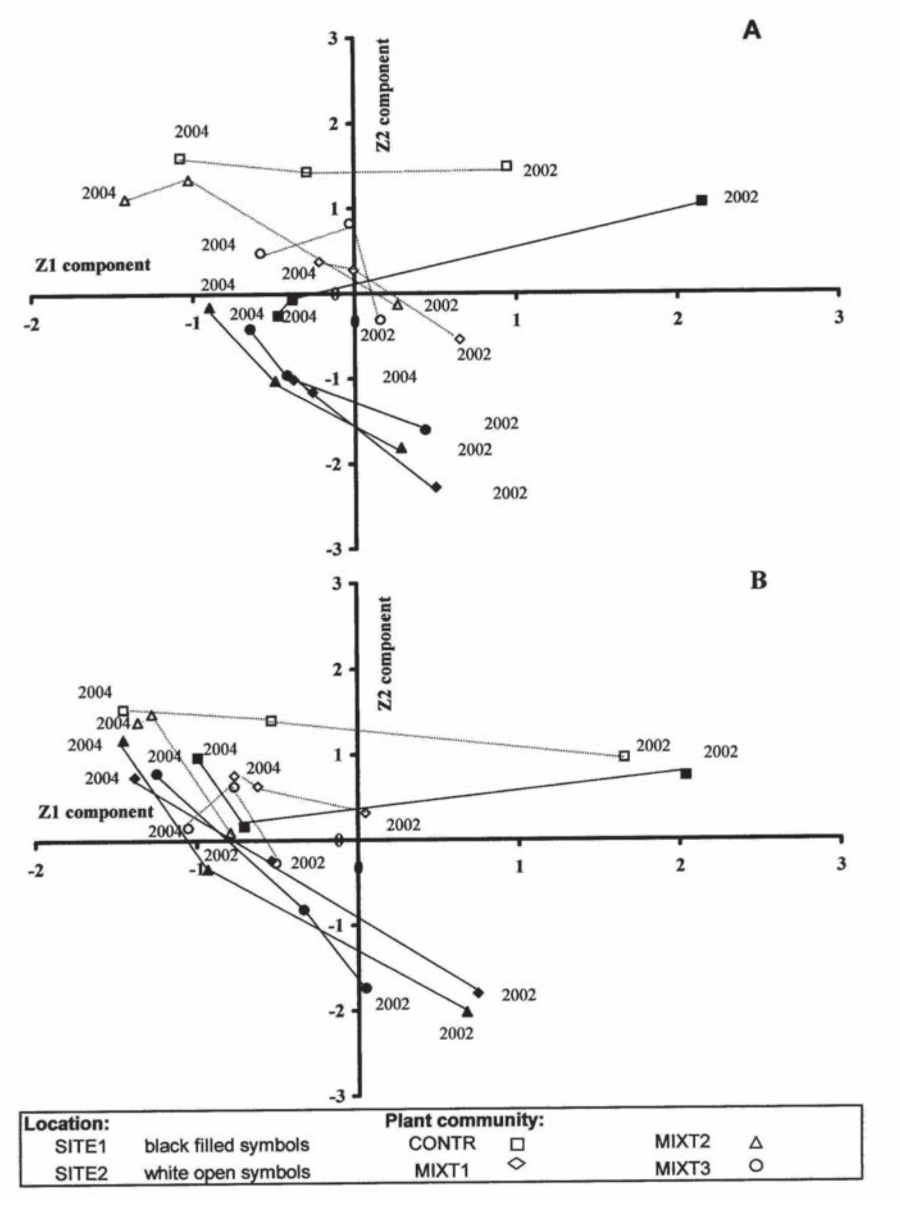

Figure 1. Time-trajectories of spontaneously regenerated and sown plant communities plotted against the first two principal components (Z1 and Z2) for variables of the functional groups ANDIC, PERDIC, ANMON, PERMON, ANLEG and PERLEG at two sites under REMOV2 (A) and REMOV0 (B). For the abbreviations see text.

Herbage quality

Herbage quality was determined annually for each plot with cutting regime REMOV2. Dried herbage samples, ground in a Retsch mill (Retsch GmbH, Haan, Germany) fitted with a 1-mm-mesh sieve, were analysed for crude protein (CP, %), crude ash (ASH, %), crude fibre (CF, %) and organic matter digestibility (OMD, %). Crude ash content was determined gravimetrically after incineration for 4 hours at 550 °C. Crude fibre content was determined gravimetrically after incineration of the non-soluble residues that remained after heating these successively in 0.26 mol l^{-1} H_2SO_4 and 0.23 mol l^{-1} NaOH. Crude protein content was calculated as 6.25 x Kjeldahl-N content. OMD (%) was determined *in vitro* according to the pepsine-cellulase method (De Boever *et al.*, 1988). The energy value of the herbage was calculated from OMD and ASH, CP and CF contents, using formulas of CVB (Anon., 1999). The energy value was expressed as Dutch Feed Units (VEM; De Boer & Bickel, 1988). One VEM unit corresponds with 6.9 kJ Net Energy for Lactation (NEL) per kg DM (Van Es, 1978).

Except for 2002, herbage quality parameters were determined per individual cut. In 2002, herbage quality was determined in a composite DM sample, bulked according to the proportional share of each cut in the annual DM yield. In 2003 and 2004, herbage quality of the annual yield was calculated as the weighted average of herbage quality of both first and regrowth cut. Mean herbage quality of the annual yield over the period 2002–2004 was then calculated by averaging herbage quality of the three consecutive years. Similarly, mean herbage quality of first and regrowth cut over the period 2003–2004 was calculated by averaging herbage quality of the years 2003 and 2004.

Vegetation development

The pattern of succession over the experimental period in terms of functional groups was determined using a principal component analysis of a variance-covariance matrix of the I% data for the functional groups following the multivariate statistical methods of Manly (1994). Changes in DM yield and I% of individual plant species or functional groups over the period 2002–2004 were analysed using linear regression analysis. DM yields and I%s were analysed with analysis of variance using the statistical programme S-plus 2000 for Windows. Mowing time was added as split-split factor for analysis of the DM yields at cut level. The herbage quality parameters for treatment REMOV2 were statistically analysed with SPSS10 for Windows.

Results

Botanical composition

Principal component analysis of the data on I% show that the components Z1–Z6 explained 56.4, 36.9, 6.1, 0.6, 0.1 and 0.0% of the total variance, respectively. Since the first two components accounted for 93.3% of the total variance, the remaining ones were further ignored. The contribution of the various functional groups to these two components could be written as follows:

$$Z1 = 0.815(ANDIC) + 0.506(PERDIC) + 0.720(ANMON) – 0.952(PERMON) + 0.275(ANLEG) – 0.070(PERLEG), \text{ and}$$

$$Z2 = 0516(ANDIC) + 0.172(PERDIC) + 0.362(ANMON) + 0.303(PERMON) – 0.228(ANLEG) – 0.990(PERLEG)$$

In Z1, I% of PERMON (negative coefficient) contrasts with I% of ANDIC, PERDIC and ANMON (positive coefficients). Similarly in Z2, I% of PERLEG contrasts with I% of ANDIC, ANMON and PERMON. Time-trajectories of plant communities at SITE1 and SITE2 were plotted against the first two principal components Z1 and Z2 under REMOV2 (Figure 1A) and REMOV0 (Figure 1B). For clarity reasons the time-

Table 3. Importance (%) of the most important species at two locations in sown/unsown plant communities under different herbage removal strategies, in 2004. For abbreviations used see text.

LOC [1]	COM [1]	HR [1]	Grasses [2]										Legumes [2]		
			Agr	Arel	Dag	Elre	Far	Hol	Lm	Lp	Php	Ptr	Msa	Tpr	Tr
SITE1			6.9	8.1	8.6	0.4	1.4	1.1	19.1	0.3	8.0	11.6	13.3	6.0	3.3
SITE2			9.7	11.7	25.2	9.8	2.0	2.5	4.9	0.4	1.3	3.1	9.3	1.7	0.7
	CONTR		16.0	0.6	1.0	11.4	0.2	5.3	31.3	0.6	0.3	5.2	0.0	5.6	4.1
	MIXT1		2.0	19.7	8.4	3.9	1.0	1.1	3.0	0.4	14.8	6.8	17.9	3.4	1.5
	MIXT2		4.3	10.2	33.0	2.8	4.7	0.6	9.2	0.4	1.3	9.3	8.3	2.9	1.8
	MIXT3		10.9	9.2	25.2	2.3	1.2	0.1	4.4	0.2	2.1	8.0	18.9	3.6	0.5
		REMOV0	8.5	15.6	15.4	8.9	0.5	1.8	11.9	0.6	3.6	11.2	8.4	1.1	0.8
		REMOV1	6.9	6.2	17.0	3.2	2.9	1.8	13.5	0.3	4.8	5.5	13.3	4.7	2.0
		REMOV2	9.5	7.9	18.3	3.3	1.9	1.8	10.5	0.4	5.5	5.4	12.1	5.9	3.2
SITE1	CONTR		4.1	0.0	0.0	0.0	0.0	3.7	45.7	0.0	0.3	7.8	0.0	11.3	7.9
	MIXT1		3.1	16.7	2.1	0.4	0.9	0.0	5.3	0.2	25.2	11.2	23.2	4.1	1.0
	MIXT2		2.5	11.3	16.6	0.9	3.4	0.3	16.8	0.8	2.6	15.7	10.5	4.3	3.7
	MIXT3		17.9	4.4	15.7	0.5	1.5	0.3	8.5	0.3	4.0	11.9	19.5	4.5	0.6
SITE2	CONTR		28.0	1.1	1.9	22.9	0.3	6.9	16.9	1.2	0.4	2.6	0.0	0.0	0.2
	MIXT1		0.9	22.7	14.7	7.4	1.1	2.1	0.6	0.6	4.4	2.5	12.7	2.7	2.1
	MIXT2		6.1	9.0	49.3	4.7	5.9	0.9	1.6	0.0	0.0	2.9	6.1	1.6	0.0
	MIXT3		3.9	14.0	34.8	4.2	0.9	0.0	0.3	0.0	0.3	4.2	18.2	2.7	0.4
SITE1		REMOV0	11.2	14.4	4.9	1.3	0.4	1.3	21.2	0.0	5.7	17.6	7.0	1.6	1.4
		REMOV1	4.8	4.3	11.1	0.0	1.6	0.6	19.5	0.4	9.3	8.6	16.5	6.4	3.6
		REMOV2	4.7	5.6	9.8	0.0	2.4	1.3	16.5	0.6	9.1	8.8	16.3	10.1	4.9
SITE2		REMOV0	5.8	16.8	25.9	16.4	0.6	2.3	2.6	0.9	1.6	4.8	9.7	0.5	0.2
		REMOV1	9.0	8.1	23.0	6.3	4.1	3.0	7.5	0.2	0.3	2.5	10.1	3.0	0.4
		REMOV2	14.3	10.3	26.7	6.7	1.4	2.2	4.5	0.2	1.9	1.9	7.9	1.7	1.5

Table 3. continued

	Grasses [2]										Legumes [2]		
	Agr	Arel	Dag	Elre	Far	Hol	Lm	Lp	Php	Ptr	Msa	Tpr	Tr
Results of Analysis of Variance [3]													
LOC	NS	NS	*	NS	NS	NS	*	NS	NS	**	NS	*	NS
LSD							12.0			3.3			
COM	*	**	***	***	*	*	**	NS	***	NS	***	NS	*
LSD		9.2			3.1	3.7	15.7				7.0		
HR	NS	***	NS	*	NS	NS	NS	NS	NS	**	**	***	*
LSD		4.4		4.6						2.9			1.5
LOC x COM	**	NS	*	***	NS	NS	NS	NS	***	NS	NS	**	**
LSD within LOC	11.9		12.3	4.0					4.2			3.4	2.8
LSD otherwise	26.7		12.7	16.7					12.4			4.0	6.0
LOC x HR	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**	NS
LSD within LOC	5.5										4.4	3.1	
LSD otherwise	25.9										16.6	3.6	
COM x HR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LOC x COM x HR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] LOC = location; COM = plant community; HR = herbage removal strategy.

[2] Agr = *Agrostis stolonifera* L.; Arel = *Arrhenatherum elatius* J. & C. Presl; Dag = *Dactylis glomerata* L.; Elre = *Elymus repens* Gould; Far = *Festuca arundinacea* Schreber; Hol = *Holcus lanatus* L.; Lm = *Lolium multiflorum* L.; Lp = *Lolium perenne* L.; Php = *Phleum pratense* L.; Ptr = *Poa trivialis* L.; Msa = *Medicago sativa* L.; Tpr = *Trifolium pratense* L.; Tr = *Trifolium repens* L.

[3] Statistical significance. NS = statistically not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; LSD = least significant difference.

trajectories of plant communities under REMOV1 are not shown since they were intermediate between the time-trajectories under REMOV2 and REMOV0.

The values of Z1 decreased over time, indicating that the vegetation succession in the period 2002–2004 was characterized by a steady increase in I% of perennials (both grasses and dicotyledons) at the expense of the annuals. The plant communities became grassier, as shown by increasing values of Z2 while values of Z1 decreased. The I% of legumes decreased, irrespective of herbage removal, location or plant community, except for the unsown spontaneously developing plant community (CONTR) when both cuttings were removed (REMOV2). At SITE1, the I% of legumes increased whereas at SITE2 it remained stable.

Vegetation succession differed considerably between the locations, irrespective of herbage removal or plant community. Succession patterns at SITE1 (Figure 1A and 1B) showing lower values of Z2, legumes were more abundant at this site than at SITE2. When cuttings were not removed (REMOV0), the I% of monocotyledons increased more rapidly than when both cuttings were removed (REMOV2), as shown by the more negative values of Z1 without removal. Similarly, the I% of legumes decreased more rapidly when no cuttings were removed, as shown by the less negative values of Z2 for REMOV0 compared with the values for REMOV2. Furthermore, the difference between unsown and sown communities became smaller over time, irrespective of herbage removal or location. So the composition of the vegetation of sown and unsown communities in terms of functional groups gradually became similar.

Table 3 lists the I% and significance of the most important species in the year 2004. The plant species that were significantly affected by herbage removal, irrespective of location or plant community, were: *Arrhenatherum elatius* J. & C. Presl, *Elymus repens* Gould, *Poa trivialis* L. and *Trifolium repens* L. When cuttings were left, *A. elatius*, *E. repens* and *P. trivialis* were significantly more important than when both cuttings were removed. On the other hand, *T. repens* was significantly more important when both cuttings were removed. For the legumes *Trifolium pratense* L. and *Medicago sativa* L. the effect of herbage removal was significantly influenced by location, irrespective of plant community. Although no statistically significant differences were observed for

Table 4. Annual importance (%) of the most important species at two locations in sown/unsown plant communities under herbage removal strategy REMOV2, in the years 2002–2004. For abbreviations of treatments see text.

LOC [1]	COM [1]	Year	Grasses [2]											Legumes [2]		
			Agr	Arel	Dag	Elre	Far	Hol	Lm	Lp	Php	Poan	Ptr	Msa	Tpr	Tr
SITE1	CONTR	2002	0.0	1.0	0.0	0.0	0.0	1.8	1.6	0.0	0.0	15.8	3.6	0.0	0.0	3.1
		2003	0.7	0.0	0.5	0.0	0.0	5.3	28.5	0.0	0.0	0.0	13.9	0.0	3.8	19.6
		2004	3.0	0.0	0.0	0.0	0.0	4.5	44.1	0.0	0.0	0.0	4.0	0.0	18.4	9.0
	linear regression [3]		*						***			*			**	
		R^2	0.38						0.92			0.37			0.69	
	MIXT1	2002	0.0	1.3	0.6	0.0	0.6	2.5	0.0	9.3	12.7	0.0	0.9	9.3	31.1	17.8
		2003	0.0	5.9	6.2	0.0	2.4	0.0	0.7	5.7	23.0	0.0	4.0	17.5	17.6	6.8
		2004	0.0	10.7	5.3	0.0	0.9	0.0	4.3	0.7	24.9	0.0	5.9	28.0	9.4	2.3
	linear regression			*	*			**	**	*				*	*	*
		R^2		0.32	0.25			0.71	0.71	0.39				0.48	0.72	0.50
	MIXT2	2002	2.4	4.3	9.8	0.0	0.0	0.5	0.5	1.8	3.9	0.0	11.5	2.8	32.3	15.1
		2003	1.7	5.5	8.8	0.0	3.9	1.9	2.9	0.0	11.1	0.0	18.1	5.6	17.4	17.6
		2004	1.6	8.9	17.9	0.0	6.9	0.0	14.5	0.8	4.4	0.0	11.1	11.7	8.3	7.3
	linear regression				*		**		*					*	*	*
		R^2			0.24		0.75		0.42					0.60	0.76	0.27
	MIXT3	2002	1.4	2.3	5.3	0.7	0.7	0.0	2.9	4.5	0.0	0.0	14.7	5.3	25.0	18.1
		2003	4.7	0.0	8.5	0.0	4.3	0.6	2.2	4.9	2.9	0.0	23.9	12.0	13.6	13.6
		2004	14.2	2.7	16.2	0.0	1.8	0.8	3.2	1.0	6.9	0.0	14.1	25.6	4.2	1.2
	linear regression		*		*									*	**	*
		R^2	0.51		0.56									0.49	0.69	0.55

Table 4 continued.

LOC [1]	COM [1]	Year	Grasses [2]											Legumes [2]		
			Agr	Arel	Dag	Elre	Far	Hol	Lm	Lp	Php	Poan	Ptr	Msa	Tpr	Tr
SITE2	CONTR	2002	13.2	0.0	0.9	14.9	0.0	7.7	1.1	0.0	0.0	6.3	5.8	0.0	0.9	0.0
		2003	26.2	0.0	3.1	15.6	0.0	7.8	6.4	0.0	0.0	0.8	7.0	0.0	1.6	2.1
		2004	35.7	0.0	1.3	20.9	0.0	5.0	16.2	0.0	0.0	0.0	1.0	0.0	0.0	0.0
	linear regression		*						*			*	*			
		R^2	0.20						0.19			0.31	0.24			
	MIXT1	2002	1.5	9.3	2.0	1.9	0.0	8.9	0.0	2.8	4.8	3.2	1.5	7.1	14.4	10.3
		2003	1.2	21.0	17.8	8.6	1.8	1.4	0.0	0.0	3.9	0.0	2.9	5.4	11.2	4.2
		2004	0.9	16.2	16.5	4.5	0.0	2.6	1.9	0.9	6.8	1.8	2.6	12.5	2.1	4.7
	linear regression			*	*			**						*	*	*
		R^2		0.23	0.51			0.36						0.28	0.32	0.19
	MIXT2	2002	3.9	8.9	12.6	0.0	2.2	1.4	0.0	3.3	3.2	0.0	10.8	2.6	19.0	5.0
		2003	9.9	16.8	34.3	1.0	5.5	1.6	0.0	0.0	1.6	0.1	7.7	3.2	3.0	0.0
		2004	11.1	6.7	59.1	0.0	2.8	1.3	0.0	0.0	0.0	0.2	2.4	6.0	2.7	0.0
	linear regression				**					*			*	*	*	*
		R^2			0.67					0.43			0.42	0.22	0.59	0.51
	MIXT3	2002	4.6	7.1	21.9	0.0	0.0	5.9	0.0	2.0	1.4	0.3	3.7	4.7	15.9	7.3
		2003	7.5	17.7	16.0	3.5	2.9	0.0	0.0	0.0	1.6	0.4	8.8	7.8	6.2	0.2
		2004	9.6	18.1	29.9	1.4	2.6	0.0	0.0	0.0	0.9	0.5	1.7	13.0	2.2	1.3
	linear regression				*		*	**		*				*	***	*
		R^2			0.19		0.38	0.70		0.38				0.23	0.84	0.52

[1] LOC = location; COM = plant community.

[2] Agr = *Agrostis stolonifera* L.; Arel = *Arrhenatherum elatius* J. & C. Presl; Dag = *Dactylis glomerata* L.; Elre = *Elymus repens* Gould; Far = *Festuca arundinacea* Schreber; Hol = *Holcus lanatus* L.; Lm = *Lolium multiflorum* L.; Lp = *Lolium perenne* L.; Php = *Phleum pratense* L.; Poan = *Poa annua* L.; Ptr = *Poa trivialis* L.; Msa = *Medicago sativa* L.; Tpr = *Trifolium pratense* L.; Tr = *Trifolium repens* L.

[3] Statistical significance of linear regression of % importance on year. * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$. R^2 values (Determination Coefficient).

these species at SITE2, the I%s of *T. pratense* and *M. sativa* at SITE1 were significantly lower when the cuttings were left than when both cuttings were removed. As a result, the I% of legumes at SITE1 was significantly lower when cuttings were left than when both cuttings were removed (10.0% versus 31.3%, LSD = 5.1%). Furthermore, when both cuttings were removed, the I% of all legumes was significantly higher at SITE1 than at SITE2: 31.3% versus 11.4%, LSD = 13.3%. *Lolium multiflorum* Lamk. and *P. trivialis* were significantly more important at SITE1 than at SITE2.

The I% of *Arrhenatherum elatius* was significantly higher in plant community MIXT1 than in the other plant communities (Table 3). The I%s of *Holcus lanatus* L. and *L. multiflorum* were significantly higher in the unsown plant community than in

Table 5. Annual dry matter yield of sown/unsown plant communities under different herbage removal strategies at two locations in the years 2002–2004. For abbreviations of treatments see text.

LOC [1]	COM [1]	HR [1]	Annual dry matter yield (kg ha^{-1})				Linear regression coefficient [2, 3]	
			2002	2003	2004	mean		
SITE1	CONTR		4165	8157	10331	7551	3083***	(0.70)
	MIXT1		14312	16062	16422	15599	1055*	(0.20)
	MIXT2		13457	14753	15359	14523	951*	(0.13)
	MIXT3		12874	13845	14259	13659	692*	(0.12)
SITE2	CONTR		6145	6717	8638	7167	1246***	(0.32)
	MIXT1		9373	8720	9936	9343	282	
	MIXT2		10830	8998	10975	10267	73	
	MIXT3		11114	7880	10048	9680	–533	
SITE1		REMOV0	10914	12676	13269	12286		
		REMOV1	11316	13315	14643	13091		
		REMOV2	11376	13621	14366	13121		
SITE2		REMOV0	9625	8074	10219	9306		
		REMOV1	9122	7874	9648	8881		
		REMOV2	9349	8288	9831	9156		
Results Analysis of Variance [3]								
LOC			NS	*	**	*		
COM			***	***	***	***		
HR			NS	NS	NS	NS		
LOC x COM			***	***	*	***		
LSD within location			1424	1286	1336	904		
LSD otherwise			3531	4120	1481	2398		
LOC x HR			NS	NS	***	**		
LSD within location					1252	848		
LSD otherwise					1812	2609		
LOC x COM x HR			NS	NS	NS	NS		

[1] LOC = location; COM = plant community; HR = herbage removal strategy.
[2] Linear regression coefficient of annual dry matter yield on year.
[3] Statistical significance: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; NS = statistically not significant; LSD = least significant difference. R^2 values (Determination Coefficient) in brackets.

the sown ones. At SITE2, the I%s of *Agrostis stolonifera* L. and *E. repens* in the unsown communities were significantly higher than in the sown ones while plant community MIXT2 showed a significantly higher I% of *Dactylis glomerata* L. compared with the other plant communities. At SITE1, the I% of *Phleum pratense* L. was significantly higher in plant community MIXT1 than in the other communities, whereas the unsown plant community had a significantly higher I% of *T. pratense* and *T. repens* than the sown ones. At SITE1, the I% of *D. glomerata* was significantly higher in the communities MIXT2 and MIXT3 than in CONTR or MIXT1 and the I% of *Agrostis stolonifera* was significantly higher in community MIXT3 than in the other plant communities.

In the REMOV2 plots, where the forage quality was determined, a number of statistically significant changes in annual I% over time were observed irrespective of location: (1) in the sown communities *D. glomerata* and *M. sativa* had increased and *T. pratense* and *T. repens* had decreased, (2) in plant community MIXT1 *Arrhenatherum elatius* had increased, and (3) in the unsown community *Agrostis stolonifera* and *L. multiflorum* had increased (Table 4). Compared with the sown communities, the unsown community showed significantly lower mean I%s of *Arrhenatherum elatius, D. glomerata, M. sativa* and *T. pratense* and significantly higher mean I%s of *Poa annua* and *L. multiflorum*, irrespective of location. At SITE2, *E. repens* and *Agrostis stolonifera* were more important in the unsown community than in the sown ones. At SITE1, the mean I%s of *L. perenne, L. multiflorum, Poa trivialis, Phleum pratense, M. sativa, T. pratense* and *T. repens* were significantly higher and the mean I%s of *E. repens, D. glomerata, Arrhenatherum elatius* and *Agrostis stolonifera* significantly lower than at SITE2.

Dry matter production

The annual DM yields during the experimental period are summarized in Table 5. There was a statistically significant location x community interaction for both annual yield and mean annual DM yield. The DM yields were not significantly affected by herbage removal. The sown plant communities outyielded the unsown one, irrespective of location. Within plant communities, annual DM yield and mean annual DM yield were significantly higher at SITE1 than at SITE2 except for the unsown community. Mean annual DM yield within the sown plant communities at SITE1 was significantly higher for community MIXT1 than for communities MIXT2 and MIXT3. At SITE2 no statistically significant differences in mean annual DM yield were found.

As for mean DM yield per cut there was a statistically significant plant community x location interaction ($P < 0.001$), a plant community x mowing time interaction ($P < 0.001$) and a location x herbage removal interaction ($P < 0.01$). The mean annual DM yields of the first cut (4739, 8106, 7861 and 7181 kg ha^{-1} for the plant communities CONTR, MIXT1, MIXT2 and MIXT3, respectively) were significantly higher than the mean annual DM yields of the regrowth cut (2620, 4365, 4535 and 4489 kg ha^{-1} for CONTR, MIXT1, MIXT2 and MIXT3, respectively), irrespective of plant community (LSD = 549 kg ha^{-1}). At SITE1, the mean annual DM yield per cut was significantly lower when the cuttings were left (REMOV0) than when the cuttings from the first cut or from both cuts were removed (REMOV1 or REMOV2): 6143 kg ha^{-1} for REMOV0

Table 6. Chemical composition and energy content of the dry matter yield of sown/unsown plant communities at two locations. For abbreviations of the experimental treatments see text.

LOC [1]	COM [1]	Chemical composition [2]				Energy content
		CF	CP	ASH	OMD	
		– (kg per 100 kg DM [3])		–	(%)	(VEM units [4])
SITE1	CONTR	30.9	9.0	8.7	59.2	660
	MIXT1	37.5	9.6	7.6	55.2	611
	MIXT2	35.9	9.9	8.4	56.5	622
	MIXT3	35.8	9.9	8.3	57.0	629
SITE2	CONTR	31.8	10.5	8.4	61.4	689
	MIXT1	34.8	10.4	8.8	57.6	633
	MIXT2	37.3	9.6	8.2	57.6	638
	MIXT3	35.8	10.1	8.7	58.4	644
Means						
SITE1		35.0	9.6	8.3	57.0	631
SITE2		34.9	10.1	8.5	58.8	651
	CONTR	31.4	9.8	8.5	60.3	674
	MIXT1	36.1	10.0	8.2	56.4	622
	MIXT2	36.6	9.7	8.3	57.1	630
	MIXT3	35.8	10.0	8.5	57.7	637
Results Analysis of Variance [5]						
LOC		NS	NS	NS	**	**
LSD					1.1	14
COM		***	NS	NS	***	***
LSD		1.4			1.5	20
LOC x COM		*	NS	*	NS	NS
LSD		2.0		0.7		

[1] LOC = location; COM = plant community.
[2] CF = crude fibre; CP = crude protein; OMD = digestible organic matter.
[3] DM = dry matter.
[4] One VEM unit corresponds with 6.9 kJ Net Energy for Lactation per kg dry matter.
[5] Statistical significance: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; NS = statistically not significant.

Table 7. Linear regression coefficients [1] (% per year). Regression of crude fibre (CF), crude protein (CP), ash, digestible organic matter (OMD) and energy content of annual dry matter yield, all expressed as %, on year (period 2002–2004), for two locations and four plant communities. For abbreviations of the experimental treatments see text.

LOC [2]	COM [2]	CF		CP		ASH		OMD		Energy content	
SITE1	CONTR	0.4		0.5		−0.9 *	(0.59)	−1.6*	(0.31)	−10	
	MIXT1	1.4 *	(0.42)	−0.8 *	(0.51)	−0.6 *	(0.46)	−3.8*	(0.74)	−42 **	(0.71)
	MIXT2	0.9 *	(0.30)	−1.3 **	(0.66)	−0.8 ***	(0.84)	−3.2 ***	(0.88)	−33 ***	(0.79)
	MIXT3	0.8		−1.3 **	(0.64)	−0.4		−2.3 *	(0.50)	−25 *	(0.43)
SITE2	CONTR	0.0		−1.2 *	(0.36)	−0.9 *	(0.46)	−0.3		3	
	MIXT1	0.4		−0.6*	(0.57)	−1.3 ***	(0.91)	−3.1 **	(0.66)	−29 *	(0.52)
	MIXT2	−0.6		−0.7 *	(0.32)	−1.0 ***	(0.84)	−1.6*	(0.31)	−12	
	MIXT3	0.3		−0.6		−0.9 *	(0.54)	−2.4**	(0.71)	−23 *	(0.52)

[1] Statistical significance: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$. R^2 values (Determination Coefficient) in brackets.
[2] LOC = location; COM = plant community.

versus 6546 and 6561 kg ha^{-1} for REMOV1 and REMOV2, respectively; LSD = 391 kg ha^{-1}. Such effects were not found at SITE2. The mean DM matter yield per cut was significantly lower for the unsown community than for the sown ones both at SITE1 (3775 kg ha^{-1} for CONTR versus 7799, 7262 and 6830 kg ha^{-1} for MIXT1, MIXT2 and MIXT3 respectively) and SITE2 (3584 kg ha^{-1} for CONTR versus 4671, 5134 and 4840 kg ha^{-1} for MIXT1, MIXT2 and MIXT3, respectively; LSD = 464 kg ha^{-1}). At SITE1, the

Table 8. Crude fibre (CF), crude protein (CP), ash, digestible organic matter (OMD) and energy content of cuts taken from sown/unsown plant communities at two locations. For abbreviations of experimental treatments see text.

LOC [1]	COM [1]	Cut [2]	CF	CP	ASH	OMD	Energy [3]
			(kg per 100 kg dry matter)			(%)	(VEM units)
SITE1	CONTR	CUT1	30.7	6.6	7.5	60.2	680
		CUT2	32.3	13.4	9.2	55.4	613
	MIXT1	CUT1	39.4	7.4	6.6	51.8	574
		CUT2	36.6	12.0	8.2	55.2	613
	MIXT2	CUT1	37.2	6.9	7.2	53.3	589
		CUT2	34.9	12.6	9.1	58.2	642
	MIXT3	CUT1	36.2	7.4	7.4	54.2	600
		CUT2	36.3	11.4	8.7	57.4	634
SITE2	CONTR	CUT1	33.0	9.3	7.6	59.8	673
		CUT2	28.3	13.1	9.1	64.8	733
	MIXT1	CUT1	36.6	9.1	7.4	53.3	588
		CUT2	30.8	13.1	10.1	62.5	691
	MIXT2	CUT1	37.5	8.5	7.3	54.3	602
		CUT2	34.3	12.3	9.2	64.0	719
	MIXT3	CUT1	36.8	9.0	7.7	54.8	605
		CUT2	33.5	12.0	9.7	63.2	704
Means							
SITE1		CUT1	35.9	7.1	7.2	54.9	611
		CUT2	35.0	12.4	8.8	56.6	625
SITE2		CUT1	36.0	9.0	7.5	63.3	617
		CUT2	31.8	12.6	9.5	63.6	712
	CONTR	CUT1	31.9	8.0	7.5	60.0	677
		CUT2	30.3	13.3	9.2	60.1	673
	MIXT1	CUT1	38.0	8.2	7.0	52.6	581
		CUT2	33.7	12.5	9.1	58.9	652
	MIXT2	CUT1	37.4	7.7	7.2	53.8	596
		CUT2	34.6	12.4	9.2	61.1	681
	MIXT3	CUT1	36.5	8.2	7.6	54.5	602
		CUT2	34.9	11.7	9.2	60.3	669

Table 8 continued.

	CF	CP	ASH	OMD	Energy [3]
	(kg per 100 kg dry matter)			(%)	(VEM units)
Results Analysis of Variance [4]					
LOC	***	***	*	***	***
LSD	0.9	0.6	0.5	1.3	8
COM	***	NS	NS	***	***
LSD	1.3			1.8	24
Cut	***	***	***	***	***
LSD	0.9	0.6	0.5	1.3	8
LOC x COM	*	NS	NS	NS	NS
LSD	1.8				
LOC x Cut	***	*	NS	***	***
LSD	1.3	0.9		1.8	24
COM x Cut	NS	NS	NS	***	**
LSD				2.6	34
LOC x COM x Cut	NS	NS	NS	NS	NS

[1] LOC = location; COM = plant community.

[2] CUT1 = first cut; CUT2 = regrowth cut.

[3] See Table 6 for explanation.

[4] Statistical significance: NS = statistically not significant; * = $P < 0.05$; ** = $P < 001$; *** = $P < 0.001$; LSD = least significant difference.

mean DM yield per cut was significantly higher for community MIXT1 than for the communities MIXT2 and MIXT3. No statistically significant differences among sown communities were found at SITE2.

Even without any fertilization, annual DM yield at SITE1 increased significantly during the experimental period as is shown by the slope of the linear regression equations (Table 5). Except for community MIXT3, a similar trend was observed for SITE2. The difference in DM yield between the unsown community and the sown ones decreased over time because yield increased more rapidly in the unsown community than in the sown ones.

Herbage quality of annual yield

The average herbage quality of the annual DM yield is shown in Table 6. The slopes of the linear regression equations of annual CF, CP and ASH contents and OMD and VEM on years are shown in Table 7. As for the average values of CF content, there was a statistically significant location x plant community interaction (Table 6). Herbage from the unsown community had a significantly lower mean CF content than herbage from sown communities, irrespective of location. The herbage at SITE1 did not significantly differ in CF content among sown communities, whereas at SITE2, the herbage from plant community MIXT1 had a significantly lower mean CF content than the herbage from the other communities. Location or plant community had no statistically significant effect on mean CP content but significantly affected mean OMD and mean VEM. Values of OMD and VEM were higher at SITE2 than at SITE1, and higher for the unsown community than for the sown ones, which did not differ significantly among them.

Annual CP and ASH contents and OMD significantly decreased over time, the rate of decrease for CP content and OMD being higher at SITE1 than at SITE2. CF content increased over time for all plant communities at SITE1, whereas at SITE2 changes depended on plant community. Annual VEM content of the herbage from sown communities significantly decreased over time, irrespective of location, except for the community MIXT2 at SITE2.

Herbage quality per cut

Mean CF content of the herbage per cut was characterized by statistically significant location x plant community and location x mowing time interactions (Table 8). Mean herbage CF content was significantly lower for the unsown plant community than for the sown ones, both at SITE1 and SITE 2. Within sown communities at SITE1, mean CF content was significantly higher for herbage from community MIXT1 than for herbage from the communities MIXT2 and MIXT3, but at SITE2 the mean CF content was significantly lower for herbage from community MIXT1 than for herbage from community MIXT2. At SITE2, herbage CF content was significantly lower for the regrowth cut than for the first cut. At SITE1, no difference was found between the two cuts.

As for mean herbage CP content per cut there was a statistically significant location x

Table 9. Maximum and minimum ash, crude protein (CP), crude fibre (CF), digestible organic matter (OMD) and energy content of the herbage per location and per cut, averaged over plant communities, compared with parameters for intensively managed grassland.

Parameter	Minumum–maximum in present study				Intensively managed grassland [1]
	SITE1		SITE2		
	First cut	Regrowth	First cut	Regrowth	
ASH [2]	6.6–7.5	8.2–9.2	7.3–7.7	9.1–10.1	9.7
CP	6.6–7.4	11.4–13.4	8.5–9.3	12.0–13.1	22.5
CF	30.7–39.4	32.2–36.6	31.8–36.7	29.5–37.8	20.0
OMD	51.8–60.2	55.4–58.2	53.3–59.8	62.5–64.8	80.0
Energy [3]	574–680	613–642	588–673	691–733	997

[1] Source: Anon. (1999).
[2] ASH, CP and CF expressed as kg per 100 kg dry matter, and OMD expressed as % of organic matter.
[3] Expressed as VEM units. For explanation see Table 6.

mowing time interaction. At both sites the regrowth had a significantly higher mean herbage CP content than the first cut, but mean herbage CP content of the first cut was significantly higher at SITE2 than at SITE1.

Mean herbage ASH content per cut was significantly affected by mowing time only, with values being highest for the regrowth cut.

For OMD there were statistically significant location x mowing time and plant community x mowing time interactions. Unlike at SITE1, the herbage from the regrowth cut at SITE2 had a significantly higher OMD than the herbage from the first cut. Within plant communities, OMD of the first cut was higher for the unsown community than for the sown ones. No statistically significant differences in OMD of the regrowth cut were found among plant communities.

Compared with intensively managed grassland, the forage quality of both cuts harvested in the field margin strips was inferior (Table 9).

Discussion

For environmental organizations the role of field margins in agri-environmental schemes as tools for nature conservation definitely takes priority over the destiny of the removed biomass. Questions as to the possible use of the removed cuttings nevertheless remain. The nature conservation value of the different plant communities and cutting treatments mentioned in this study is addressed in another paper (De Cauwer *et al.*, 2005). Here we consider the potential use of the removed biomass as forage.

Dry matter yield and nutrient depletion

Even without any fertilization, the mean annual DM yield of the sown and unsown field margin strips was relatively high during the experimental period (between 7360 and 12470 kg ha^{-1}), reflecting a high nutrient status of the soil at the experimental sites formerly used as arable land. Annual DM yields increased significantly over time, irrespective of plant community, herbage removal or location. Changes in species composition may explain this increase. During succession, white clover, known for its stimulation of grass growth, became more abundant in the unsown communities. In the sown communities, grass species that perform better under poor conditions, such as *Arrhenatherum elatius* and *Dactylis glomerata*, became more abundant. Apparently, the nutrient reserves were high enough to allow high DM yields despite mineral depletion resulting from the removal of the cuttings. Other researchers too have reported high nutrient levels in soils that previously had been used for arable cropping, and high yields during the subsequent period. Marrs (1993) reported very high nutrient levels for arable land in western Europe as a result of the application of large amounts of inorganic fertilizer over the last 50 years. Soils tend to contain high levels of P and K, while N may be relatively low due to leaching (Sinclair *et al.*, 1992). From a nature conservation point of view, such soils must be depleted of P, e.g. by removal of the harvested biomass. However, substantially reducing the soil's mineral content may take several decennia, depending on the actual soil fertility level.

Although much N was exported with the cuttings, annual DM yield was not significantly affected by herbage removal. N depletion was probably compensated by N-fixing legumes, which were more important when cuttings were removed than when cuttings remained in the field. The correlation between higher yields from sown plant communities and the greater importance of legumes at SITE1 supports this hypothesis. Annual DM yield was significantly lower for the unsown community than for the sown ones, irrespective of location. But this discrepancy decreased over time. Initially, low-productive annuals were very important in the unsown community but were quickly replaced by more-productive perennial grasses and to a lesser extent by perennial legumes.

Forage quality

Mean digestibility of the forage was low (< 60%), irrespective of plant community or location. Similar low values for digestibility were found by Kirkham & Wilkens (1994) and Kirkham & Tallowin (1995) for semi-natural grasslands when cutting time was delayed. Around mid-June, most of the grasses and legumes like *M. sativa* are at an advanced stage of phenological maturity, characterized by a high proportion of lignin and structural carbohydrates in the dry matter, thus reducing their digestibility (Chesson *et al.*, 1995).

The digestibility of the herbage from the sown communities, which contained a high proportion of improved grass and legume varieties, was significantly lower than the digestibility of the herbage from the unsown community.

Differences in digestibility between the unsown and the sown communities were attributed to changes in species composition during the experimental period. Compared with sown communities, the unsown plant community was characterized by a significantly higher importance of late-flowering grasses (e.g. *Agrostis stolonifera*) and dicotyledons. Peeters & Janssens (1998) found that the digestibility of dicotyledonous species such as *Ranunculus repens* L. and *Rumex acetosa* L. decreased more slowly than the digestibility of grasses. On the other hand, the sown communities included significantly more early-flowering grasses such as *D. glomerata* and *Arrhenatherum elatius*, and legumes, particularly *M. sativa* and *T. pratense*. The low digestibility of stemmy lucerne, and to a lesser extent of flowering red clover, is well documented (Hacker & Minson, 1981; Wilman & Altimimi, 1984; Armstrong *et al.*, 1986; McDonald *et al.*, 1988; Holmes, 1989).

During the experimental period, annual digestibility of the forage decreased at a significantly faster rate in the sown plant communities than in the unsown one. The first cut, taken around mid-June, allowed early-flowering grasses, abundantly present in sown communities, to survive and to scatter part of their seeds before cutting. As a result, the importance of these species generally increased over time. In the unsown plots, the share of these grasses was very low.

The significantly higher digestibility of the forage harvested at SITE2 compared with SITE1 may be ascribed to the very heavy first cuts at SITE1.

In the sown communities, annual herbage CP content significantly decreased over time, irrespective of location, probably because of the corresponding decrease in percentages of importance of the legumes *T. pratense* and *T. repens*. In the unsown community at SITE1, annual herbage CP content increased over time, which corresponds with an increase in *T. pratense* and *T. repens*.

The mid-June cut and the mid-September regrowth cut differed in mean DM yield and herbage quality. As expected, the first cut significantly outyielded the second cut. Herbage quality was higher in the regrowth cut than in the first cut, but digestibility of the former remained below 65% because of leaf senescence and occurrence of flowering species such as *M. sativa* and *L. multiflorum*. For the same reasons as discussed above, the herbage from the unsown community had a higher mean digestibility, lower CF and higher mean CP contents for each cut.

Recommendations

As illustrated in Table 9, the quality of the herbage harvested in the field margin strips in all respects is inferior to the quality of herbage from intensively managed grassland. If one wants to use the harvested material as forage, it is recommended to modify the initial species composition when establishing the field margins. As long as management agreements for field margins prescribe not to mow before mid-June, it may be beneficial to compose initial sowing mixtures with late-flowering and late-maturing forage species or with species producing forage that slowly decreases in digestibility with ageing. The incorporation of *M. sativa* in our mixtures in order to try and improve the forage value was no success. However, it may be beneficial, both for agriculture and for species diversity, to take the first cut earlier in the season, e.g. around mid-May. At that time, digestibility of the forage will be better and the mineral export and hence soil depletion will be maximal, as shown by Nevens & Reheul (2002). An earlier cut will enable various wildflower species to grow and reproduce during summertime. When after several years of nutrient depletion biomass yields have dropped substantially, the first cut may be delayed to enable early-flowering species to set seed. For similar reasons, sown productive perennial-legume-rich field margins are preferred to unsown ones. The extra N input from the legumes will accelerate soil nutrient depletion through the development of a larger biomass, extracting relatively more P and K. The legumes are expected to decrease over time, which was demonstrated in this research for *T. pratense* and *T. repens*. During the experimental period this did not apply to *M. sativa*.

The quality of the harvested produce is too low to be used as regular forage for highly productive livestock. But herbage or hay from field margins might be used as a source of crude fibre in feeding rations for non-lactating cows or heifers. A better solution is to use it as feed for horses, which require tasteful energy- and protein-low hay. The herbage might also be used as a component of compost. As a matter of fact, a considerable quantity of the forage harvested in our experiment was used either as horse feed or for compost making.

However, studies by Wilman & Riley (1993) indicated that *in vitro* digestibility does not provide a conclusive indication of the potential feeding value of forages containing wildflower species. The presence of dicotyledonous species in field margins may have an unexpected positive influence on the intake of hay and on the digestibility of the forage. Furthermore, the tissues of dicotyledonous species break down more easily in the rumen than those of grasses (Wilman *et al.*, 1997), again enhancing a higher intake than forecasted by standard quality analyses.

Conclusions

The results of our field experiment showed that the annual DM yield of field margins was not affected by mowing management. DM yields of sown and unsown communities converged over time. Compared with herbage from intensively managed grassland, the feeding value of herbage from field margins was extremely low, due to low CP and high CF contents and low digestibility. The spontaneously established plant community produced forage of a higher quality than the plant communities sown to improved commercially available grassland varieties. Because of a changing botanical composition, both digestibility and CP content decreased over time, irrespective of plant community or location. Mid-June cuts were more productive than mid-September cuts but their digestibility and CP content were lower. Based on the forage quality data, the use of herbage from field margins as hay for horses or as a component of compost may be good alternatives to its limited use in rations for ruminants.

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