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Vegetation changes in a semi-natural grassland during mowing and grazing periods

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Mowing and grazing are often used as alternative methods of grassland management, but the effects on plant species richness are often found to be contradictory. In order to compare the methods, changes in plant species composition were studied in a restored dry semi-natural grassland after mowing (1990–1995) and grazing periods (1997–2001) in 30 sample plots. During the mowing period, the number of grassland species increased, but the change was unfavourable for the original dry grassland community. The results indicated that the aggressive growth of clovers (increase in 19 plots/decrease in 0 plots), *Trifolium medium* in particular, reduced the abundance of dry grassland species (6/13). Simultaneously both forest species (10/1) and overgrowth species (7/0) increased. During the grazing period, species turnover was lower and the growth of *T. medium* was reduced (6/8), but the invasion of clovers was continued by *T. repens* (11/1). Changes in species composition, including a decreased abundance of weeds (1/17), during grazing was more favourable for the grassland vegetation.

Key words: changed management, clover, grazing, mowing, vegetation, semi-natural grassland

Introduction

Mowing and grazing are traditionally used as complementary methods in grassland management (Simán & Lennartson 1998), but nowadays the two methods often constitute alternatives (Marttila *et al*. 1999). In Finland, grazing is nowadays increasingly difficult to arrange for practical and economic reasons, due to the steadily decreasing number of cattle farms.

The effects of grazing on the vegetation, including selective defoliation, dung, trampling and an increase in bulk density, are more complicated than the effects of mowing (e.g. Dormaar *et al*. 1989, Orodho *et al*. 1990, Hæggström 1990, Putman *et al*. 1991). The two methods also differ in regard to the frequency and intensity of disturbance. In Finnish semi-natural grasslands, it is recommended to cut hay in late July or early August (Heritage landscapes working group 2001), which allows the vegetation to grow taller than in pastures, where grazing often starts almost two months earlier.

Changes in the management usually result in changes in the species composition (Kirkham *et al*. 1996, Pykälä 2001, Fischer & Wipf 2002).

Grassland vegetation benefits from both kinds of management, but at the species level mowing is more disadvantageous for some species and grazing for others (Tamm 1956, Simán & Lennartson 1998, Schläpter *et al.* 1998). For example, grasses have better tolerance to trampling than herbs and shrubs (Yorks *et al.* 1997) and continuous consumption of vegetation may increase the abundance of species with vegetative reproduction due to flowering being hindered (Fischer & Wipf 2002).

Comparative studies on the effects of mowing and grazing in the same or adjacent areas with similar environmental conditions are rare (e.g. Steen 1976, Wahlman & Milberg 2002). The results are often contradictory when the species composition is compared in differently managed sites. Due to the dynamic nature of grassland vegetation and species sensitivity to different environmental conditions and local practices, both mowing (Tamm 1956, Pykälä 2001, Wahlman & Milberg 2002) and grazing management (Londo 1990, Schläpter *et al.* 1998) is preferred. In this paper, the development of the vegetation was followed over a period of a decade in a dry semi-natural grassland. After abandonment, the site was managed in two different periods allowing a comparison to be made of the effects of mowing and grazing on the vegetation.

Material and methods

The dry grassland (50 m × 60 m) was located on a gentle south facing slope in Joutseno, SE Finland. The site formed part of an old, low intensively used hayfield, which was occasionally grazed by sheep until its abandonment in the early 1970s. In the 1980s, large areas of the upper slope were densely covered by *Lychnis viscaria*, while overgrowth became apparent, especially in the southernmost corner of the site. The grassland was restored by removing tree saplings and shoots of *Rubus idaeus* in 1990. The species-rich grassland was classified in national inventories as a valuable traditional rural biotope (Haapanen & Heikkilä 1993, Marttila *et al.* 1999). The growth of trees in the surrounding areas gradually isolated the grassland from other open cultural biotopes.

The management of the grassland can be divided into two periods. During the first period, the grassland was raked in May 1990–1994 and hay was cut in late July or early August in 1992–1995 (Berg *et al.* 2001). The mown hay was removed from the site during the following week. The second management period included sheep grazing (1997–2001). In order to protect species (e.g. insects) against the effects of overgrazing, the slope was divided into two equal sections. The eastern part was grazed by 3–5 animals in odd years (1997, 1999) and the western part by the same number of animals in even years (1998, 2000). The grazing periods were in late June to July (12–34 days) and in early August (6 days in 1999, 11 days in 2000).

The data of the vegetation was collected on 30 sample plots (1 × 1 m) in 1990, 1996 and 2001, starting on 26–27 June in each year (effective thermal sum 408–436). Plots were located systematically along a permanent grid of five lines (distance 14 m) and 3–8 rows (distance 5 m). The abundance of each taxon in the plot was estimated by projection cover using a percentage scale (0%–100%).

The data were collected by different persons in each study year. In order to decrease estimation errors caused by the observer (Kennedy & Addison 1987, Økland 1990), percentages were rescaled to five abundance classes (1 = 0.25%–1%, 2 ≥ 1%–10%, 3 ≥ 10%–40%, 4 ≥ 40%–80%, 5 ≥ 80%–100%). Due to the incomplete identification of some non-flowering grasses in 1990, all but *Elymus repens* were excluded in further analysis. *Achillea millefolium*, usually found as rosettes, was also excluded because the estimations of the species were apparently too high in 1996 compared with the other study times and the vegetation inventory for the site (Marttila *et al.* 1999).

The plant community includes species groups with different ecological properties, relevant for explaining community patterns during management periods. Seven groups of taxa (*see* Appendix) were formed based on habitat preference and ecological function (Ellenberg 1988, Hämet-Ahti *et al.* 1998, Pykälä 2001): (1) dry grassland species (DRYG), (2) general grassland species (GENG), (3) ruderal species constantly inhabiting, e.g. road-sides and yards (RUDE), (4) weed species inhabiting fields and field margins

(WEED), (5) overgrowth species including tall indicators of nutrient enrichment (OVER), (6) forest species including tree saplings and forest herbs (FORE), and (7) clovers (CLOV). The taxonomy is according to Hämet-Ahti *et al.* (1998). Three taxa (*Alchemilla*, *Hieracium*, *Taraxacum*) were not identified at species level, but they are treated and called as species in the text. The mean number of species in the groups in the study years were compared using the paired *t*-test (1990–1996 and 1996–2001).

A turnover index (T) was used as a measure of changes in species composition between the mowing and grazing periods. The index was calculated as $T = (A + D)/n$, where A is the number of new species in a plot during a period, D is the number of species that have disappeared and n is the total number of species at the beginning of the period (Berlin *et al.* 2000). The difference between the mean turnover rates was tested using the paired *t*-test.

Changes in the occurrence and abundance of single species and species groups in the management periods were compared using the two-tailed sign test. Positive changes (i) in the sample plots included both the establishment of new species and increases in species abundance (classes 1–5), and negative changes (d) disappearances and decreases in species abundance. A test was performed using species for which $i + d > 4$ plots.

Relationships between species groups were analysed using the Spearman rank correlation test. Changes in abundance classes during mowing and grazing period were used for the calculations.

Results

The mean number of all vascular plant species in plots increased in the mowing period (Table 1). The turnover index of herbs (74 species) was significantly ($p < 0.001$) higher in the mowing period 1990–1996 (mean ± SD = 1.09 ± 0.50) than in the grazing period 1996–2001 (0.65 ± 0.24). The mean number of grasses (12 species) in plots varied from 1.3 (1990) to 1.9 (1996) and 1.8 (2001).

During the mowing period, the number of grassland and overgrowth species increased (Table 1). The species of the latter group were found in only 1–5 plots, whereas the increase in grassland species such as *Campanula patula* and *Pilosella cymosa* coll. was more considerable (Table 2). The abundance of clovers increased

Table 1. Changes in the number and abundance of species in groups of dry (DRYG) and general grassland species (GENG), ruderals (RUDE), weeds (WEED), forest species (FORE), overgrowth indicators (OVER) and clovers (CLOV). *See* appendix for species included in the groups. m = mean number of species in plots, i = number of plots where species was either established or increased, d = number of plots where species either disappeared or decreased.

	Number of species					Abundance of species					
	1990	1996	2001	1990–1996	1996–2001	1990–1996			1996–2001		
	m	*m*	*m*	p^a	p^a	*i*	*d*	p^b	*i*	*d*	p^b
DRYG	1.40	1.53	1.50	0.564	0.881	6	13	0.167	7	7	1.000
GENG	2.93	4.70	5.33	0.000	0.079	11	5	0.210	4	9	0.266
RUDE	0.70	0.77	0.97	0.601	0.086	12	6	0.238	6	12	0.238
WEED	1.10	1.20	0.60	0.501	0.000	10	7	0.630	1	17	0.000
OVER	0.37	0.53	0.57	0.023	0.662	7	0	0.016	4	5	1.000
FORE	0.27	0.43	0.50	0.096	0.489	10	1	0.012	2	4	0.688
CLOV	0.50	0.67	1.03	0.043	0.005	19	0	0.000	13	8	0.384
Total*	9.8	13.3	14.0	0.000	0.563						

[a] p *t*-test, [b] p sign test
* ungrouped species included

in 19 plots (Fig. 1). The group included four *Trifolium* species, of which *T. medium* was found, and increased, in 17 plots. The increase in clovers had a negative correlation with dry grassland species ($r = –0.540$, $p < 0.01$) (Table 3). The abundance of dry grassland species decreased in 11, and increased in three, plots where *T. medium* was present (both occupied in 14 plots). The corresponding relationship in declined species was 6/2 for *Lychnis viscaria* (10 plots), 3/1 for *Potentilla argentea* (6 plots) and 5/2 for *Hypericum maculatum* (7 plots).

The most characteristic feature for the grazing period (1996–2001) was a decrease in the occurrence and abundance of weeds. *Elymus repens* disappeared from 12 plots. The clovers continued to spread, but the increasing species changed to *Trifolium repens* (Table 4). The abundance of *T. repens* increased in 11 plots, in most of which *T. medium* was never found (5, 10, 20–21, 23, 26–27, 30 in Fig.1). Other increased species were dry and general grassland species, such as *Rumex acetosella* and *Leucanthemum vulgare*. However, *Lychnis viscaria* and *Potentilla argentea* continued to decline. During the period, increase in clovers had a negetative correlation with dry grassland species ($r = –0.417$, $p < 0.05$).

Discussion

Mowing caused more changes in species composition than grazing, but some changes probably took place due to management being resumed following two decades of abandonment. Spring raking during the first few years most likely stimulates germination and seedling establishment by removing litter and opening up the soil surface (Parr & Way 1988, Pykälä 2001). The high species turnover might be partly a result of the slightly different location of the sample plots, because the accurate positions of these could not be ensured in the second study period as precisely as in the third one. However, the number of species is known to increase, especially when management is resumed (e.g. Bobbink & Willems 1993) and the species composition in grasslands varies even if the management continues without changes (Stampfli 1995, Berlin *et al.* 2000).

Despite the increasing number of grassland species, vegetation development during the mowing period was unfavourable for maintaining the original dry grassland community. Dry grassland species decreased slightly and species indicating more luxuriant habitat, in general, increased their abundance. For *Lychnis viscaria*

Table 2. Changes in species occurrence and abundance between 1990 and 1996 (species, which $i + d > 4$ and $p < 1$). n = number of inhabited plots, i = number of plots where species was either established or increased, d = number of plots where species either disappeared or decreased. Group abbreviations are explained in Table 1.

		1990	1996	1990–1996		
	Group	*n*	*n*	*i*	*d*	*p*†
Trifolium medium	CLOV	14	17	17	0	0.000
Campanula patula	GENG	4	18	15	1	0.001
Pilosella cymosa	GENG	8	16	10	2	0.039
Stellaria graminea	GENG	9	15	10	2	0.039
Leucanthemum vulgare	GENG	6	12	10	4	0.180
Hieracium spp.	–	2	8	7	2	0.180
Prunella vulgaris	GENG	2	7	5	1	0.219
Elymus repens	WEED	18	20	9	5	0.424
Myosotis arvensis	WEED	2	6	5	2	0.453
Taraxacum spp.	RUDE	18	17	11	8	0.648
Equisetum arvense	WEED	6	7	4	2	0.688
Hypericum maculatum	GENG	11	9	6	10	0.454
Potentilla argentea	DRYG	8	5	2	5	0.453
Lychnis viscaria	DRYG	16	17	5	9	0.424

†*p* sign test

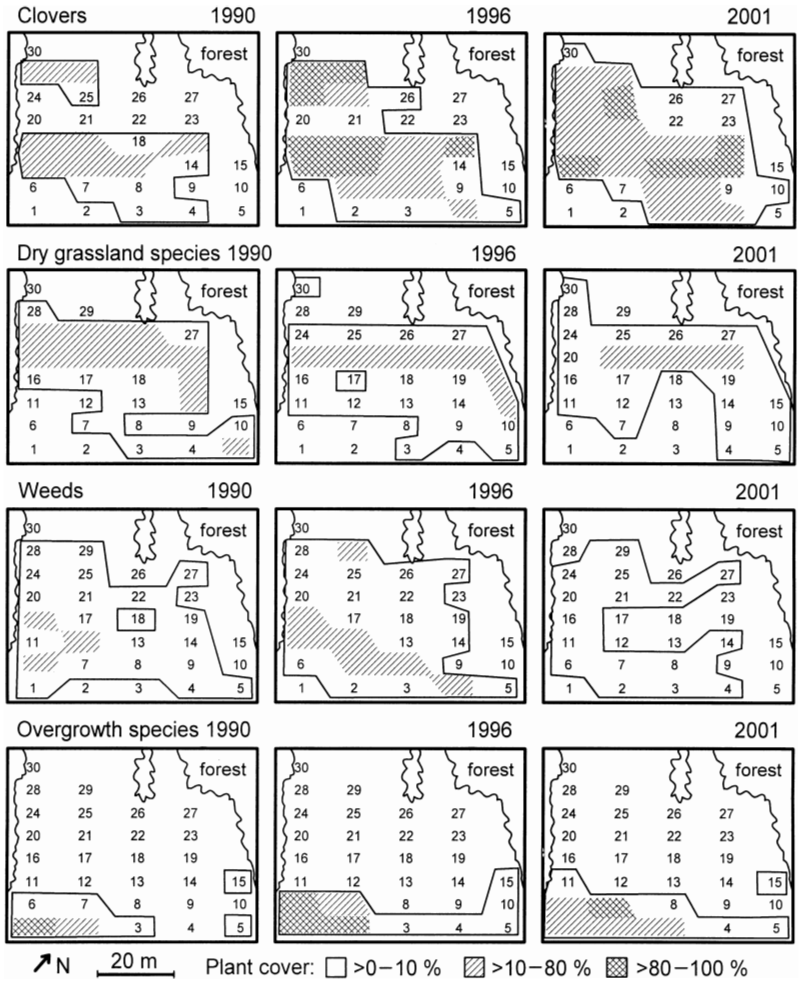

Fig. 1. Distribution and cover of clovers, dry grassland species, weeds and overgrowth species in a dry grassland before management (1990), after a mowing period (1996) and after a grazing period (2001). Species included in the groups are given in the appendix.

the visual change shown in the photograph from 1985 (Berg *et al*. 2001) was more remarkable than the decrease observed in the plots.

Species reducing diversity in grassland plant communities are usually considered to be tall and broadleaved (e.g. Ekstam *et al*. 1988, Johansson & Hedin 1991), but a vigorous growth of legumes can also be deleterious for other species (Chapman & Younger 1995). The nitrogen fixing ability of legumes provides a competitive advantage in nutrient poor soils (Crawford 1989, Schwinning & Parsons 1996) such as in the sandy soil of the study site. On soil of higher nitrogen availability, such as in fertilised pastures, the advantage usually shifts to grasses due to their efficient nitrogen uptake ability (Nesheim & Boller 1991, Schwinning & Parsons 1996). In the present case, the unexpected invasion of *Trifolium medium* seemed to have a detrimental effect, especially on dry grassland species.

During the grazing, the turnover rate of species was reduced and the changes were mainly favourable towards the continuity of a grassland community. Species remaining from the habitat's earlier use as a hay field decreased. The growth of *Trifolium medium* was also reduced either as a result of grazing or because the species had reached the limits of its distribution. *Trifolium repens*, however, continued the invasion by clovers. This stoloniferous, low-growing clover probably benefited from the earlier removal of overshadowing vegetation and the shoots were not damaged by trampling as much as the erect *T. medium*. Although *T. repens* is well adapted

to grazing (Ellenberg 1988), the growth of the plant can be restricted in particular by continuous sheep grazing (Chapman *et al*. 1996, Nolan *et al*. 2001).

Several species increased during the first period and decreased during the second. This can be a result of the earlier start and longer duration of annual disturbance, trampling and selective defoliation by grazing. When the vegetation was cut to a standard height by mowing, tall herbs with rosettes such as *Campanula patula, Leucanthemum vulgare* and *Hieracium* spp. increased, but *Hypericum maculatum* which lacks a rosette, declined. During the grazing *Hypericum* increased, but the changes in the others probably varied due to foodplant selection, a feature especially typical to sheep (Hæggström 1990). *Leucanthemum vulgare* is associated with mowed grasslands (Wahlman & Milberg 2002), but it can also be abundant in pastures because cows usually avoid eating this plant (Howard & Williams 1968). Sheep and horses may eat *L.*

Table 3. Significant Spearman rank correlations between the changes in the abundance of species groups during a mowing period (upper right corned) and a grazing period (lower left corner). Group abbreviations are explained in Table 1.

	DRYG	GENG	RUDE	WEED	OVER	FORE	CLOV
DRYG		–	–	–	–	–	–0.540**
GENG	–		–	–	–0.373*	–	–
RUDE	–	–		–	–	–	–
WEED	–	–	–		–	–	–
OVER	–	–	–	–0.365*		–	–
FORE	–	–	–	–0.421*	–0.430*		–
CLOV	–0.417*	–	–	0.553**	–	–	

** $p < 0.01$, * $p < 0.05$

Table 4. Changes in species abundance between 1996 and 2001 (species, which $i + d > 4$ and $p < 1$). n = number of inhabited plots, i = number of plots where species was either established or increased, d = number of plots where species either disappeared or decreased. Group abbreviations are explained in Table 1.

		1996	2001	1996–2001		
	Group	*n*	*n*	*i*	*d*	*p*†
Trifolium repens	CLOV	3	11	11	1	0.006
Rumex acetosella	DRYG	7	11	9	1	0.022
Leucanthemum vulgare	GENG	12	18	12	3	0.036
Hypericum maculatum	GENG	9	16	10	2	0.039
Ranunculus acris	GENG	7	13	8	3	0.227
Knautia arvense	GENG	5	7	6	2	0.289
Trifolium medium	CLOV	17	18	6	8	0.791
Hieracium spp.	–	8	5	4	6	0.754
Myosotis arvensis	WEED	6	4	2	4	0.688
Lychnis viscaria	DRYG	17	17	7	10	0.629
Stellaria graminea	GENG	15	14	5	8	0.581
Equisetum arvense	WEED	7	6	1	4	0.375
Viola canina	GENG	4	1	1	4	0.375
Taraxacum spp.	RUDE	17	19	8	14	0.286
Potentilla argentea	DRYG	5	2	1	5	0.219
Elymus repens	WEED	20	8	2	17	0.001

†*p* sign test

vulgare, but the plant is probably among the less palatable species, as is *Hypericum maculatum* (Bílek & Žáková 1998).

The continuous decline of *Lychnis viscaria* and *Potentilla argentea* implied other reasons such as changes in interspecific competition and microclimate on the soil surface due to the more dense vegetation (Ellenberg 1988, Crawford 1989). The clovers, as well as the overgrowth species, expanded their distribution and simultaneously reduced the area suited to dry grassland species.

The two management methods had a different impact on the vegetation although some changes were probably caused by the resumed management and would have taken place at some level under any management at all. During the whole study period, both positive and negative changes in the vegetation occurred. The number of grassland species increased and most of the non-typical grassland species decreased, or the increase was at least halted by sheep grazing. The overall development of the vegetation implied that the grassland type was turning into a more luxuriant one. The dense *Lychnis viscaria* population was probably only a short successional phase, which began to change before the resumption of the management, and the management was not able to halt this tendency. The intensity of management was rather low and it is possible that better results would have been achieved, if the vegetation had been cut twice a year in the area of luxuriant vegetation, as recommended when grasslands are restored (Johansson & Hedin 1991, Bobbink & Willems 1993).

The study revealed the importance of the follow-up after reorganised management. Simple mowing or grazing management does not necessarily ensure the maintenance of the grassland community but it can cause negative, or even irreversible, changes in the species composition.

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Appendix. Species of the study site divided into seven groups, based on their habitat preference and ecological function (Ellenberg 1988, Hämet-Ahti *et al.* 1998, Pykälä 2001).

Dry grassland species (DRYG)
Arabidopsis suecica
Arabidopsis thaliana
Campanula rotundifolia
Dianthus deltoides
Epilobium collinum
Erigeron acer
Hieracium umbellatum
Hypericum perforatum
Knautia arvensis
Lychnis viscaria
Plantago lanceolata
Potentilla argentea s.lato
Ranunculus polyanthemos
Rumex acetosella

General grassland species (GENG)
Alchemilla spp.
Campanula glomerata
Campanula patula
Centaurea jacea
Fragaria vesca
Galium album
Galium uliginosum
Gnaphalium sylvaticum
Hypericum maculatum
Leucanthemum vulgare
Luzula multiflora
Luzula pallidula
Pilosella cymosa coll.
Pimpinella saxifraga
Prunella vulgaris
Ranunculus acris
Rumex acetosa
Stellaria graminea
Veronica chamaedrys
Veronica officinalis
Vicia cracca
Vicia sepium
Viola canina

Ruderal species (RUDE)
Artemisia vulgaris
Barbarea vulgaris
Leontodon autumnalis
Linaria vulgaris
Ranunculus repens
Taraxacum spp.

Weeds (WEED)
Cirsium arvense
Elymus repens
Equisetum arvense
Galeopsis bifida
Galeopsis speciosa
Myosotis arvense
Viola arvensis

Overgrowth species (OVER)
Aegopodium podagraria
Angelica sylvestris
Anthriscus sylvestris
Epilobium angustifolium
Pteridium aquilinum
Rubus idaeus

Forest species (FORE)
Luzula pilosa
Melampyrum pratense
Pinus sylvestris
Populus tremula
Solidago virgaurea
Sorbus aucuparia
Trientalis europaea
Viola riviniana

Clovers (CLOV)
Trifolium aureum
Trifolium medium
Trifolium pratense
Trifolium repens

Ungrouped species
Achillea millefolium
Achillea ptarmica
Agrostis capillaris
Agrostis gigantea
Anthoxanthum odoratum
Dactylis glomerata
Deschampsia flexuosa
Festuca ovina
Festuca pratensis
Festuca rubra
Hieracium spp.
Melica nutans
Phleum pratense
Poa nemoralis
Poa pratensis