Changes in the vegetation of hay meadows under an agri-environment scheme in South Belgium

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SUMMARY

We monitored five-year changes in the vegetation of 31 hay meadows under an agri-environment scheme in Wallonia, Southern Belgium. Management included delayed mowing (in July) and fertilizer prohibition. It resulted in increasing cover of characteristic forbs (such as *Leucanthemum vulgare*, *Lotus corniculatus*, *Centaurea jacea*) and oligotrophic grasses (*Avenula pubescens*, *Festuca rubra*), while the competitive grasses, such as *Holcus lanatus*, *Phleum pratense* and *Alopecurus pratensis*, tended to decrease. We interpreted this as a vegetation shift from typical hay meadow to oligotrophic grasslands due to soil impoverishment following the current management. Both habitats are of conservation value. Despite these changes in the meadow plant communities, only one of the four criteria used by the Walloon administration to indicate hay meadow conservation status changed significantly over the six-year period. This was a decrease in the cover of species indicating high grazing intensity. The number and cover of characteristic plant species, and the cover of nitrophilous species, did not change significantly.

BACKGROUND

After World War II, agriculture in Western Europe has seen major changes. This included mechanization and the subsequent increase in parcel size, as well as increasing use of pesticides and chemical fertilizers. This had the laudable aim of increasing yields in order to ensure European food self-sufficiency. However, this had several environmental consequences, including dramatic loss of biodiversity in agroecosystems (Batáry *et al.* 2015). In grassland regions one major driver of biodiversity loss was grassland improvement or conversion to arable land. This led to the dramatic decline of several semi-natural ecosystems, such as traditional hay meadows and calcareous grasslands (Piqueray *et al.* 2011).

As a consequence, as early as 1992, several of these grassland ecosystems were protected by the EU Habitats Directive (92/43/EEC), being listed in Annex I and requiring designation as Special Areas of Conservation. EU member states are required to take measures in order to preserve or improve the conservation status of these ecosystems at the national level, notably through the Natura 2000 network of protected areas. However, this directive does not include a direct financing mechanism. The objectives must therefore be fulfilled using other funds, including agri-environment schemes (AES), part of the second pillar of the Common Agricultural Policy. Due to the mobilization of public funds, there is a need to demonstrate the effectiveness of the measures regarding their objective of ecosystem preservation, which has not so far been shown (Batáry *et al*. 2015).

ACTION

In Wallonia, South Belgium, the AES dedicated to grassland conservation is the *Grassland with High Biological Value (MC4)* scheme. Its general aim is to maintain or improve the biological conservation status of grasslands, or of animal species linked to grassland ecosystems. The non-profit association Natagriwal has been placed in charge of the implementation of this measure, by making contact with farmers and establishing management plans. Management plans can depend on the targeted habitat or species. Natagriwal thereafter advise and support farmers in the implementation of the management plan and conduct biological monitoring in order to evaluate the measures. Each year a sample of grassland is subject to a vegetation survey.

The present study shows the results obtained for a set of 31 hay meadows (habitat code 6510, “Lowland hay meadows” in the EU Habitats Directive) in the Famenne region, Wallonia, Belgium. Famenne is a 15 km-wide Devonian shale belt running from southwest to northeast through Wallonia. All 31 meadows fell under AES in 2006. Management plans included absence of fertilization, pesticides or any other improvement. Hay mowing had to occur in July, with a 10% refuge zone left unmown. A second cut or late season grazing was allowed, but was not an obligation.

The vegetation was first monitored in 2006, at the beginning of the five-year contracts, and again in 2011 at their end. Vegetation monitoring was done in 1 m radius circular vegetation plots. Between two and eight plots were surveyed in each meadow, depending on its area. In 2006, plot coordinates were taken using a GPS, so recording might be repeated at approximately the same place in 2011. In each plot, in both years, plant species were recorded and their abundance was estimated using the Van der Maarel (1979) scale of plant cover-abundance. Van der Maarel values were converted into percent (class median) prior to analyses. Plots from the same meadow in the same year were combined to give the mean cover of each species, resulting in a single vegetation measure at the meadow scale for each monitoring year. In both years, monitoring occurred from late May to early July. All the data were collected by the same person (S. Rouxhet), therefore avoiding observer effects (Couvreur *et al*. 2015).

In order to analyze vegetation changes during AES contracts, a principle coordinate analysis (PCoA) was

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Table 1. Species lists used for determining 'Lowland Hay Meadows' habitat conservation status in Wallonia.

Species list	Species
Species list 1: habitat characteristic species	*Anthriscus sylvestris, Arrhenatherum elatius, Avenula pubescens, Centaurea gr. jacea, Crepis biennis, Daucus carota, Galium mollugo, Geranium pratense, Heracleum sphondylium, Knautia arvensis, Leontodon hispidus, Leucanthemum vulgare, Pimpinella major, Rhinanthus angustifolius, Rhinanthus minor, Tragopogon pratensis, Trisetum flavescens*
Species list 2: other indicators of habitat quality	*Briza media, Bromus erectus, Campanula rapunculus, Colchicum autumnale, Lathyrus pratensis, Lotus corniculatus, Sanguisorba minor, Saxifraga granulata*
Species list 3: nitrophilous species	*Alopecurus pratensis, Bromus hordeaceus, Cirsium vulgare, Phleum pratense, Poa trivialis, Rumex obtusifolius, Urtica dioica.*
Species list 4: high grazing intensity species	*Bellis perennis, Cynosurus cristatus, Lolium perenne, Poa annua, Ranunculus repens, Rumex crispus, Rumex obtusifolius, Taraxacum sp., Trifolium repens*

performed, based on Bray-Curtis distances using the R-package 'Vegan'. We then compared habitat conservation status between the two dates using paired t-tests. Several indicators were considered: i) species richness, ii) plant community, using mean Ellenberg N-index weighted by species cover, (the scale gives a value from 1 for plants preferring the most oligotrophic conditions to 9 for plants of the most eutrophic conditions for all species recorded: see Ellenberg *et al*. (1992)), and iii) the four criteria used by the Walloon administration for the six-yearly EU reporting on the 'Lowland Hay Meadows' habitat conservation status (Tables 1 and 2). These criteria, associated species lists, and thresholds for conservation status levels are used by the Department for Nature and Agriculture Study of the Walloon administration in the six-yearly Natura 2000 evaluation.

Table 2. Criteria and thresholds for the determination of 'Lowland Hay Meadows' habitat conservation status in Wallonia. A: Very good, B: Good to medium, C: Degraded, D: Not a lowland hay meadow.

Criterion*	Conservation Status			
	A	B	C	D
Criterion 1: number of characteristic species (list 1)	≥ 7	4-6	3	<3
Criterion 2: cover of characteristic species + other indicators of habitat quality (lists 1 and 2)	≥ 50%	25-50%	10-25%	<10%
Criterion 3: cover of nitrophilous species (list 3)	≤ 10%	10-30%	≥ 30%	
Criterion 4 : cover of high grazing intensity species	< 40%	40-60%	≥ 60%	

*See species lists in Table 1

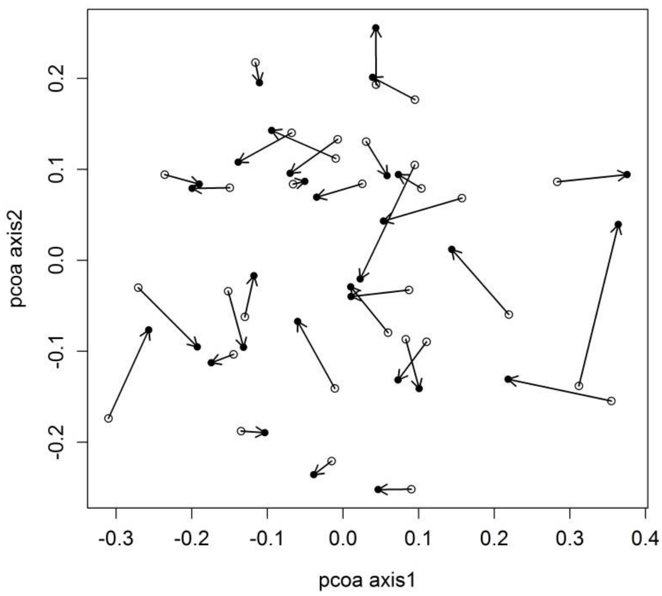

Figure 1. PCoA of the 31 hay meadows, based on species presence-absence data. White dots are the 2006 survey, black dots are the 2011 survey. Full arrows link the same meadow at the two different dates. Closest dots in the graph exhibit the most shared species.

CONSEQUENCES

PCoA based on presence-absence data (Figure 1) revealed few changes between the two dates, with no general tendency across the different meadows. This indicates that, for the most part, the same species were observed in 2006 and 2011 in a given meadow. No species had a tendency to appear or disappear over the five years of management throughout the 31 monitored meadows. Conversely, PCoA based on cover data revealed that vegetation changes were relatively large between the beginning and the end of the five-year contracts. Indeed, between-year variation was as large as between-meadow variation (Figure 2a). There was a general trend towards negative values on axis 1 and positive values on axis 2 (Figure 2a). This corresponded to increased cover of some characteristic forbs (e.g. *Leucanthemum vulgare*, *Lotus corniculatus*, *Centaurea jacea*) and oligotrophic grasses (*Avenula pubescens*, *Festuca rubra*), while competitive grasses such as *Holcus lanatus*, *Phleum pratense* and *Alopecurus pratensis* tended to decrease (Figure 2b).

However, paired t-tests did not support this finding. They clearly confirmed that species typical of high intensity grazing

Table 3. Paired t-tests comparing conservation indicators of the 31 hay meadows between 2006 and 2011.

Conservation indicators	Mean (2006)	Mean (2011)	p
Species richness	31.6	31.2	0.611
Mean Ellenberg N-index	5.8	5.6	0.003
Number of characteristic species	5.0	5.2	0.501
Cover of characteristic species + other indicators of habitat quality [%]	41.9	48.5	0.084
Cover of nitrophilous species [%]	21.2	22.7	0.697
Cover of high grazing intensity species [%]	32.1	20.6	0.004

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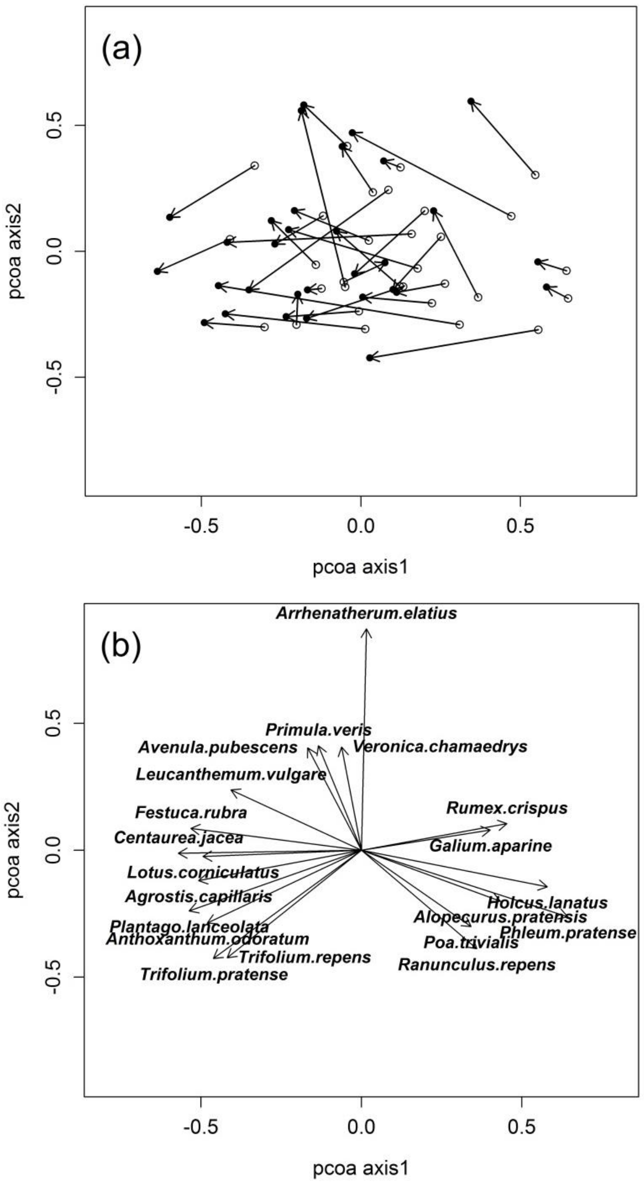

Figure 2. PCoA of the 31 hay meadows, based on species cover data. (a) White dots represent the 2006 survey, black dots the 2011 survey. Arrows link the same meadow at the two different dates. Closest dots in the graph exhibit closest vegetation characteristic (species composition and cover). (b) Projection, in the same plane, of well correlated species (correlation with PCoA plane > 0.5). The length of the arrows indicate the degree to which an increase in cover by the plant species tended to occur.

(see list 4 in Table 1), including *Rumex crispus* and *Ranunculus repens*, globally decreased in cover between 2006 and 2011 (32.1% to 20.6%, p = 0.004, Table 3). Also, mean Ellenberg N-index decreased significantly (*P*=0.003), suggesting a shift towards oligotrophic species over the management period. Cover of indicators of habitat quality (lists 1 and 2 in Table 1) slightly increased, although this change was not significant (Table 3). All other indicators exhibited no significant change between 2006 and 2011 (Table 3).

Some meadows did not exhibit expected changes. In particular the two most degraded meadows in 2006, at the extreme right in Figure 2a, did not change much after five years. Conversely, some other meadows experienced positive changes, shown in Figure 2a by long arrows toward the left of the diagram. These were mainly meadows with intermediate conservation interest in 2006, and therefore located in the mid-right part in Figure 2a. Only one meadow had an arrow toward the right in Figure 2a, suggesting a degradation.

Most of the measures used to determine the conservation status of the meadows were relatively stable between 2006 and 2011 (Table 4). We observed more degradations than improvements in the number of characteristic hay meadow species (8 and 5 respectively), resulting in a decrease in the number of meadows with a very good status. For the other three indicators, we observed an inverse pattern (Table 4).

DISCUSSION

PCoA revealed changes in the vegetation of hay meadows under an agri-environment scheme. It is worth noting that even meadows that were already in a good condition in 2006 (i.e. in the left part of the chart at Figure 1) exhibited changes. The most degraded meadows at the beginning of the contract did not change a lot within five years. These were in fact particular cases, as they were included in the AES because they sheltered a threatened bird species (red-backed shrike *Lanius collurio*), but their vegetation was typical for improved meadows. However, one might expect that adapted management would contribute to restore lowland hay meadow habitat. This was not always the case in our study. This is in agreement with the conclusions of Critchley *et al*. (2003) that AES with single management prescriptions are more effective at maintaining existing habitats than at restoring new ones. The greatest changes occurred in meadows with medium conservation status. One of these meadows exhibited degradation, but this was likely due to management problems (it remained unmown for two consecutive years). This suggests that the most added-value of AES can be obtained in meadows of intermediate conservation value.

Changes in the vegetation were mainly due to changes in species cover, rather than to species turnover. Indeed both total species richness and the number of characteristic species remained relatively stable between monitoring dates. This statement is also supported by the low between-date changes

Table 4. Evolution of the conservation status of the 31 hay meadows, in relation to the criteria and thresholds showed in Table 2. '--': 2- or 3-levels degradation; '-': 1-level degradation; '0': stable; '+': 1-level improvement; '++': 2- or 3-levels improvement.

Conservation status criteria	--	-	0	+	++	Status 'A' in 2006*	Status 'A' in 2011*
Number of characteristic species	0	8	18	4	1	10	7
Cover of characteristic species + other indicators of habitat quality [%]	2	3	15	9	2	10	13
Cover of nitrophilous species [%]	1	5	16	8	1	10	12
Cover of high grazing intensity species [%]	0	2	22	6	1	22	26

* Status A is defined in Table 1

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observed in Figure 1 (based on species presence-absence data) compared to those observed in Figure 2a (based on species cover). This is consistent with the fact that both species extinction and colonization may be delayed following environmental changes in grassland ecosystems (Piqueray *et al*. 2011).

It is worth noting that observed vegetation changes, although they are considered positive from a conservation point of view, did not always correspond to a better hay meadow conservation status with respect to the criteria used for six-yearly Natura 2000 evaluation. Notably, it was frequently observed that some typical species for this habitat, such as *Arrhenatherum elatius*, *Trisetum flavescens* or *Heracleum sphondyllium* tended to decrease. They were mainly replaced by *Anthoxanthum odoratum* and *Festuca rubra*, which are not considered habitat specialists. This suggests a vegetation shift from typical hay meadow to oligotrophic grasslands, likely due to soil impoverishment following hay removal. This shift might be avoided by authorizing a slight fertilization (compost during two years of the five-year contract has now been proposed in Wallonia). However, oligotrophic grasslands, although not covered by the EU habitat directive, also have a high biodiversity conservation value, sometimes higher than hay meadows, as they may shelter rare oligotrophic species. Therefore a choice has often to be made between two conservation options. The occurrence or absence of rare oligotrophic species in the parcel vicinity should be the basis of this choice, due to the low dispersal ability of the majority of grassland species (Edwards *et al*. 2007).

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REFERENCES

Batáry P., Dicks L.V., Kleijn D. & Sutherland W.J. (2015) The role of agri-environment schemes in conservation and environmental management. *Conservation Biology*, **29**, 1006-1016.

Couvreur J., Fiévet V., Smits Q. & Dufrêne M. (2015) Evaluation of the " observer effect " in botanical surveys of grasslands. *Biotechnologie, Agronomie, Société, Environnement*, **19**, 132-142.

Critchley C.N.R., Burke M.J.W. & Stevens D.P. (2003) Conservation of lowland semi-natural grasslands in the UK: a review of botanical monitoring results from agri-environment schemes. *Biological Conservation* **115**, 263-278.

Edwards A.R., Mortimer S.R., Lawson C.S., Westbury D.B., Harris S.J., Woodcock B.A. & Brown V.K. (2007) Hay strewing, brush harvesting of seed and soil disturbance as tools for the enhancement of botanical diversity in grasslands. *Biological Conservation* **134**, 372-382.

Ellenberg H., Weber H.E., Düll R., Wirth V., Werner W. & Paulißen D. (1992) Zeigerwerte von Pflanzen in Mitteleuropa. *Scripta Geobototanica*, **18**, 3-258.

Piqueray J., Cristofoli S., Bisteau E., Palm R. & Mahy G. (2011) Testing coexistence of extinction debt and colonization credit in fragmented calcareous grasslands with complex historical dynamics. *Landscape Ecology*, **26**, 823-836.

van der Maarel E. (1979) Transformation of cover-abundance values in phytosociology and its effects on community similarity. *Vegetatio*, **39**, 97-114.

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