

Mixed effects of sward biodiversity and management regime on ecosystem services

Hoekstra N.J.¹, De Long J.R.^{1,2}, Jansma A.P.³, Iepema G.³, Manhoudt A.⁴, van Eekeren N.¹

¹Louis Bolk Institute, Kosterijland 3–5, 3981 AJ Bunnik, the Netherlands; ²University of Amsterdam, Department for Ecosystem and Landscape Dynamics, P.O. Box 94240, 1090 GB Amsterdam, the Netherlands; ³Van Hall Larenstein University of Applied Sciences, 8901 BV Leeuwarden, the Netherlands; ⁴Natuurmonumenten, Stationsplein 1, 3818 LE Amersfoort, the Netherlands

Abstract

Species-rich grasslands provide ecosystem services such as flora and fauna diversity, forage for livestock, carbon sequestration and water regulation. These ecosystem services can be affected by sward botanical composition and management intensity. However, the effects and interactions of these factors to optimise ecosystem services are not fully known. To address this, we established experimental plots with three types of sward with varying levels of diversity: productive monoculture (PM; perennial ryegrass (*Lolium perenne*)), biodiverse (BD) and productive biodiverse (PBD), which were subjected to four management regimes ranging from extensive (i.e., low input, late mowing) to intensive (i.e., high input, early mowing). After three years, we found successful establishment of biodiverse swards with high forb cover, particularly under extensive management. Forage dry matter yield was the highest in BD and intensively managed swards. Forage N concentration was the highest in PBD swards and digestible organic matter was the highest in PM and PBD swards. Treatment effects on carbon sequestration and water regulation were minimal. Collectively, diverse swards, different management regimes and their interactions benefit some, but not all, ecosystem services, and highlight the need for careful consideration of sward species composition and long-term management of biodiverse grasslands to achieve site-specific goals.

Keywords: biodiversity, diverse grasslands, ecosystem services, forage

Introduction

Species-rich grasslands provide ecosystem services such as flora and fauna diversity, forage for livestock, carbon sequestration and water regulation. However, the effects of sward diversity and management intensity (and their interactions) to achieve the above-mentioned ecosystem services are not fully known. To address this, we established experimental plots with three types of sward with different levels of diversity, which were subjected to four management regimes, from extensive to intensive. We hypothesised that sward diversity and management regime differentially affect different ecosystem services.

Materials and methods

The experiment was established in August 2017 on a clay soil at the Dairy Campus Research Facility (WUR) in Leeuwarden, The Netherlands. A detailed description of the experimental design can be found in Hoekstra *et al.* (2023). We established experimental plots (6 m × 10 m) with three types of sward with varying levels of diversity: (1) productive monoculture (PM; perennial ryegrass (*Lolium perenne*)), (2) biodiverse (BD; a species-rich mixture from natural sources aimed at meadow bird conservation, www.biodivers.nl) and (3) productive biodiverse (PBD; i.e., biodiverse mixture with additional species selected to increase the quantity and quality of forage, including *L. perenne*, *Trifolium repens*, *Cichorium intybus* and *C. carvi*). These plots were subjected to four management regimes differing in the date of the first harvest and the timing, type and amount of fertiliser applied (Table 1). The experiment was conducted in four replicate blocks, resulting in a total of 48 plots.

Table 1. Overview of the management regimes

Code	Management regime			Fertilisation				Applied before first cut?
	N fertilisation level	Timing of first cut ¹	cuts/year	FYM (t ha ⁻¹)	CS (m ³ ha ⁻¹)	CAN (kg N ha ⁻¹)	N (kg ha ⁻¹)	
LL	Low	Late	3	18	–	–	115	Yes
ML	Medium	Late	4	–	18	90	162	No
ME	Medium	Early	4	–	18	90	170	No
HE	High	Early	4	–	42	180	378	Yes

CAN, calcium ammonium nitrate; CS, cattle slurry; FYM, Farmyard manure; Late, after the 1st week of June, in line with meadow bird conservation guidelines.

The proportion cover of individual plant species was determined in two 1×1 m quadrats per plot in August 2020. Herbage dry matter yield (DMY) was determined for each harvest using a Haldrup plot harvester and in 2019 all cuts were analysed for total nitrogen and in-vitro digestibility of organic matter. In autumn 2019, soil samples (0–10 cm) were taken in all plots, and analysed for soil organic matter content (EurofinsAgro, Wageningen, the Netherlands). Soil penetration resistance was measured with a penetrometer at a depth of 0–30 cm. The effects of sward type and management and their interaction on ecosystem services were determined using general linear mixed effects models, taking into account the block structure.

Results and discussion

In 2020 the proportion of forb cover (Figure 1a) was the highest for the biodiverse mixture and the lowest for the perennial ryegrass monoculture. In the PBD mixture, the proportion of forbs was lower due to the competitive advantage of perennial ryegrass, particularly at higher levels of N application (significant management (MR)×sward type (ST) interaction $P<0.01$). The proportion of legumes was very low and ranged from 0% in PM to 3% in the PBD and BD mixture under LL management (significant MR×ST interaction, $P<0.05$).

Grasses showed the opposite pattern to forbs. For PM, the main grass was *Lolium perenne*, whereas for BD the main grass species were *Festuca rubra* and *Festuca pratensis*.

Herbage DMY was significantly ($P<0.001$) higher for the BD sward compared to PM and PBD (Fig. 1b). This may be related to the strong growth of grasses such as *Festuca rubra* and *Festuca pratensis* and the relatively strong growth of forbs in the dry conditions prevailing in 2018–2020. There was a strong effect ($P<0.001$) of management regime, and herbage DMY ranged from 10 000 kg ha⁻¹ year⁻¹ for LL to 15 000 kg ha⁻¹ year⁻¹ for HE. Late mowing of the first cut had little or no effect on total herbage DMY (ME vs ML). Intensively managed swards (HE) had higher dry matter yield regardless of the type of sward (MR×ST, $P<0.05$).

Forage crude protein (CP) concentration was highest in the PBD swards (135±18 g kg⁻¹ vs 124±15 g kg⁻¹ for PM and BD) and organic matter digestibility (OMD) was higher in PM (73±8.3%) and PBD (74±4.8%) swards compared to BD (64±7.4%) ($P<0.001$), indicating that productive plant species (mainly *L. perenne*) contributed to the improvement of forage quality in PBD swards. Due to the poor establishment of legumes, they had little or no effect on the herbage N concentrations. Both CP and OMD were significantly ($P<0.001$) higher for the HE compared to the LL management. For CP this could be related to the increased N application rate but not to the mowing date (ME=ML), while for OMD this appeared to be mainly related to the first cut date (ME<ML); data not shown.

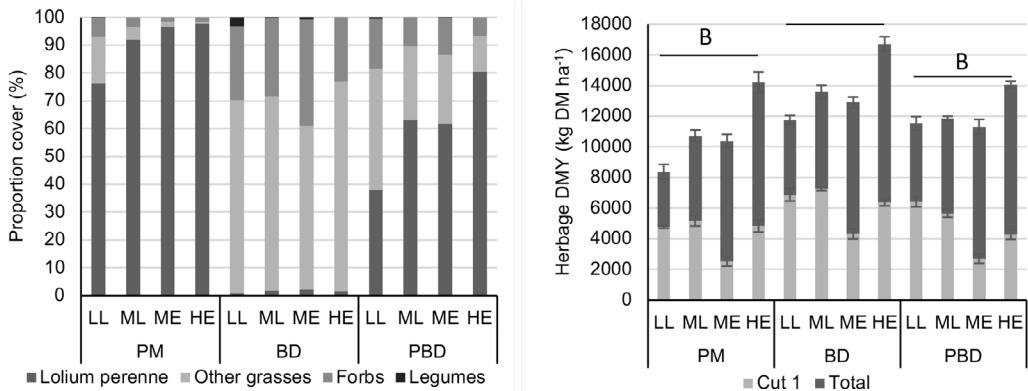


Figure 1. The effect of sward type (PM, productive monoculture; BD, biodiverse; PBD, productive + biodiverse) and management regime (abbreviations see Table 1) on (a) the proportion of grasses, forbs and legumes in autumn 2020, and (b) herbage dry matter yield of the first cut and cumulative cuts in 2020 ($n=4$; error bars, standard error).

Effects of management and sward type on carbon sequestration and water regulation (as indicated by soil penetration resistance) were minimal (data not shown), which may be related to the relatively short interval between sowing (autumn 2017) and measurement (autumn 2019).

Conclusion

The biodiverse mixtures have resulted in a strong increase in the proportion of forbs, particularly in more extensive management regimes. Herbage productivity was the highest in the case of BD swards and intensive management, whereas herbage quality was the highest in the case of PM and PBD swards and intensive management.

Collectively, diverse swards, different management regimes and their interactions benefit some ecosystem services, but may negatively affect others. Taken together, these findings focus attention on the need to carefully consider sward species composition and long-term management of biodiverse grasslands in order to maximise specific ecosystem services depending on the site-specific goals.

Acknowledgements

This research was part of the project ‘Koeien en Kruiden’, which was funded by the Ministry of Agriculture, Nature and Food Quality, the province Friesland, the Dairy Campus Innovatiefonds, the Centre of Expertise Agrodier and the University of Applied Research Van Hall Larenstein. This research was partly funded by the public private cooperation program “Raw forage, soil and circular agriculture” via the Top Sector Agri & Food TKI-AF-15102/15284 LWV190195.

References

Hoekstra N.J., Long J.R., Jansma A.P., Iepema G., Manhoudt A. and van Eekeren N. (2023) Differences in grassland sward biodiversity and management regime lead to mixed effects on ecosystem services. *European Journal of Agronomy*, 149, 126886.

The Netherlands 9-13 June



EGF
2024

Why grasslands?

Edited by

C.W. Klootwijk
M. Bruinenberg
M. Cougnon
N.J. Hoekstra
R. Ripoll-Bosch
S. Schelfhout
R.L.M. Schils
T. Vanden Nest
N. van Eekeren
W. Voskamp-Harkema
A. van den Pol-van Dasselaar



Volume 29
Grassland Science in Europe