Can we deduce general management recommendations from biodiversity-ecosystem functioning research in grasslands?

Author(s):
Klaus, Valentin H.; Gilgen, Anna K.; Lüscher, Andreas; Buchmann, Nina

Publication date:
2019-06

Permanent link:
https://doi.org/10.3929/ethz-b-000353577

Originally published in:
Grassland Science in Europe 24

2019 EGF EUCARPIA

Joint Symposium | Zurich, June 24–27

Improving sown grasslands through breeding and management

Edited by

O. Huguenin-Elie
B. Studer
R. Kölliker
D. Reheul
M. Probo
P. Barre
U. Feuerstein
I. Roldán-Ruiz
P. Mariotte
A. Hopkins

EUCARPIA

EGF

Volume 24
Grassland Science in Europe

Can we deduce general management recommendations from biodiversity-ecosystem functioning research in grasslands?

Klaus V.H.[1], Gilgen A.K.[1], Lüscher A.[2] and Buchmann N.[1]
[1]Institute of Agricultural Sciences, ETH Zürich, Universitätstr. 2, 8092 Zürich, Switzerland; [2]Agroscope, Forage Production and Grassland Systems, Reckenholzstr. 191, 8046 Zürich, Switzerland

Abstract

Experiments using grassland model systems have increased our theoretical understanding of linkages between biodiversity and ecosystem functioning. Nowadays, there is strong interest in using beneficial biodiversity effects for more sustainable land use. Therefore, we performed a restricted review on published papers to evaluate whether existing biodiversity-ecosystem functioning literature enables us to make recommendations on how to use plant diversity to improve grassland management for forage production. Among the screened studies, many reported positive effects of 'higher plant diversity' of mixtures on, e.g. productivity, weed suppression and further production-related functions. However, it was difficult to extract clear recommendations, as many experiments were of purely scientific design and data analysis did not directly address agronomic questions. Still, we also found studies with clear implications for grassland management, indicating that biodiversity is still an underestimated production factor. Besides intensive outreach activities to communicate these results to farmers, novel experiments should directly address agronomic questions such as the practical use and long-term maintenance of biodiversity effects for forage production.

Keywords: biodiversity, ecosystem services, productivity, mixtures, ecosystem functioning

Introduction

Many experiments have progressed our fundamental understanding of the linkage between biodiversity and ecosystem functioning, most of them in grassland-like model systems (e.g. Finn *et al.*, 2013; Weisser *et al.*, 2017). Recently, there is strong interest in utilising beneficial biodiversity effects on ecosystem functioning for more sustainable land use. Furthermore, governments and institutions have integrated the idea of mutual benefits for ecosystem services and biodiversity into their planning and decision-making.

Materials and methods

We reviewed published papers and datasets to assess whether current biodiversity-ecosystem functioning research enables us to deduce recommendations on how to use plant diversity to improve forage production. In this summary paper, we refer to a selection of papers with the aim of covering both extensive and intensive grasslands, including the two largest European biodiversity experiments in extensive grasslands (the *Jena Experiment*; Weisser *et al.*, 2017) and in intensive (temporary) grasslands (the *Agrodiversity Experiment*; Finn *et al.*, 2013).

Results

We found a number of interesting and relevant research results reporting positive effects of species mixtures on many functions and services such as productivity, weed suppression and other ecosystem services such as reduced risk of nitrate leaching (Table 1).

Despite 25 years of biodiversity-ecosystem functioning research in grasslands, it was surprisingly difficult to extract clear recommendations from the many published studies on how to improve grassland management. The reasons for this were manifold. Study results were either not directly meaningful to

Table 1. Effects of plant diversity on grassland functioning and their practical relevance in extensive and intensive grasslands. Note that all results come from either temporary or long-term sown experimental grasslands.

Biodiversity effect	Management intensity	Direct practical relevance	Design of experiment/study	Comments
Plant species richness in mixtures increases yield compared to average monoculture yield (simple overyielding)	intensive	*low*	Ten different experiments with grassland model communities with one to 64 species; management with up to 200 kg N ha^{-1} a^{-1} (Craven *et al.*, 2016; Weigelt *et al.*, 2009)	Simple overyielding of minor agronomic relevance; effect often saturates at low diversity; partly unrealistic species combinations, treatments and management
	extensive	*low*	Different experiments with grassland model communities with one to 64 species; no fertiliser addition (Cardinale *et al.*, 2012; Weigelt *et al.*, 2009)	Simple overyielding of minor agronomic relevance; partly unrealistic species combinations and treatments
Plant species richness in mixtures increases yield compared to yield of best performing cultures (transgressive overyielding)	intensive	*high*	31 replicated experiments; temporary swards with one to four species; different clover proportions; up to 450 kg N ha^{-1} a^{-1} (Finn *et al.*, 2013; Nyfeler *et al.*, 2009)	Wide agro-environmental gradient; directly applicable to high yielding temporary grasslands; biodiversity effect exceeds fertilisation effect; only four species involved
	extensive	*high*	Field trial of establishing grasslands on ex-arable sites using seed mixtures of 25-42 plant species; no fertiliser addition (Bullock *et al.*, 2007)	Results close to practice with economic assessment of the biodiversity effect; implications also for grassland restoration
Effects of plant species richness on grassland yield persist under drought conditions	intensive	*high*	Two experiments with temporary swards with one to four species; different clover proportions; up to 200 kg N ha^{-1} a^{-1}; rainout shelters (Hofer *et al.*, 2016; Finn *et al.*, 2018)	Implications meaningful for practice; importance under future climatic conditions; biodiversity benefits were larger than drought impairment; only four species involved
	extensive	*medium*	Six experiments with grassland model communities with one to 64 species; drought induced by different methods such as shelters (Craven *et al.*, 2016)	Effects on mean yield of minor agronomic relevance (simple overyielding); importance under future climatic conditions
Plant species richness reduces the abundance or biomass of unsown species (weed suppression)	intensive	*high*	31 replicated experiments; fertilised temporary swards with one to four species, different clover proportions (Connolly *et al.* 2018)	Results directly applicable to temporary grasslands; only four species; specification of weed species unclear (includes unsown but valuable species)
	extensive	*medium*	Experiment with grassland-like model communities ranging from one to 64 species; no fertiliser addition (Roscher *et al.* 2009)	Partly unrealistic composition of species; effect saturates at relatively low diversity; weed species unclear (may include unsown but valuable species)

farmers, as they have been analysed in a purely scientific way and do not report relevant information such as the effect of a mixture compared to the best monoculture (transgressive overyielding). Another problem with application to farm conditions is the sometimes quite artificial treatment of the plots (weeding) to keep the planted diversity levels. Nevertheless, a number of studies could be found where clear practice-oriented recommendations on how to utilise beneficial effects of plant diversity for grassland management could be extracted (Table 1).

Conclusion

Besides a gap between purely scientific research projects and the requirements for practical implementation, this review found consistent evidence of positive effects of functional plant diversity on forage production in both intensive and extensive grasslands. Thus, the number of functionally relevant plant species has to be acknowledged as an important pillar for sustainable forage production. On the contrary, it remains doubtful if the use of biodiversity effects can also safeguard high diversity of native plants in today's grasslands. To achieve a broad adoption of plant diversity effects in grassland production systems, we identified several requirements that should be considered such as the need for intensive outreach activities, the development of ready-to-be-used seed mixtures (e.g. Suter *et al.*, 2019) and the exploration of how the desired plant diversity can be maintained under intensive management.

References

Bullock J.M., Pywell R.F. and Walker K.J. (2007) Long-term enhancement of agricultural production by restoration of biodiversity. *Journal of Applied Ecology* 44, 6-12.

Cardinale B.J., Duffy J.E., Gonzalez A., Hooper D.U., Perrings C., Venail P., ... and Naeem S. (2012) Biodiversity loss and its impact on humanity. *Nature* 486, 59-67.

Connolly J., Sebastià M.T., Kirwan L., Finn J.A., Llurba R., Suter M., ... and Lüscher A. (2018) Weed suppression greatly increased by plant diversity in intensively managed grasslands: A continental-scale experiment. *Journal of Applied Ecology* 55, 852-862.

Craven D., Isbell F., Manning P., Connolly J., Bruelheide H., Ebeling A., ... and Beierkuhnlein C. (2016) Plant diversity effects on grassland productivity are robust to both nutrient enrichment and drought. *Philosophical Transactions of the Royal Society B* 371, 20150277.

Finn J.A., Kirwan L., Connolly J., Sebastià M.T., Helgadottir A., Baadshaug O.H., ... and Lüscher A. (2013) Ecosystem function enhanced by combining four functional types of plant species in intensively managed grassland mixtures: a 3-year continental-scale field experiment. *Journal of Applied Ecology* 50, 365-375.

Finn J.A., Suter M., Haughey E., Hofer D. and Lüscher A. (2018) Greater gains in annual yields from increased plant diversity than losses from experimental drought in two temperate grasslands. *Agriculture, Ecosystems & Environment* 258, 149-153.

Hofer D., Suter M., Haughey E., Finn J.A., Hoekstra N. J., Buchmann N. and Lüscher A. (2016) Yield of temperate forage grassland species is either largely resistant or resilient to experimental summer drought. *Journal of Applied Ecology* 53, 1023-1034.

Nyfeler D, Huguenin-Elie O, Suter M, Frossard E., Connolly J. and Lüscher A. (2009) Strong mixture effects among four species in fertilized agricultural grassland led to persistent and consistent transgressive overyielding. *Journal of Applied Ecology* 46, 683-691.

Roscher C., Temperton V.M., Buchmann N. and Schulze E.D. (2009) Community assembly and biomass production in regularly and never weeded experimental grasslands. *Acta Oecologica* 35, 206-217.

Suter D., Kessler W., Thomet E., Frick R. and Lüscher A. (2019) Grass-clover mixtures in practice: key-factors of success. *Grassland Sciences in Europe* 24 (this volume).

Weigelt A., Weisser W.W., Buchmann N. and Scherer-Lorenzen M. (2009) Biodiversity for multifunctional grasslands: equal productivity in high-diversity low-input and low-diversity high-input systems. *Biogeosciences* 6, 1695-1706.

Weisser W., Roscher C., Meyer S.T., Ebeling A., Luo G., Beβler H., Barnard R., Buchmann N., ... and Eisenhauer N. (2017) Biodiversity effects on ecosystem functioning in a 14-year grassland experiment: patterns, mechanisms, and open questions. *Basic and Applied Ecology* 23, 1-73.