

Delivery of ecosystem services from permanent grasslands in Europe: a systematic review

Schils R.L.M.¹, Bufer C.¹, Rhymer C.M.², Francksen R.M.², Klaus V.H.³, Abdalla M.⁴, Milazzo F.⁵, Lellei-Kovács E.⁶, Ten Berge H.¹, Bertora C.⁷, Chodkiewicz A.⁸, Dămătîrcă C.⁷, Feigenwinter I.³, Fernández-Rebollo P.⁹, Ghiasi S.¹⁰, Hejduk S.¹¹, Hiron M.¹², Janicka M.⁸, Pellaton R.⁶, Smith K.E.¹³, Thorman R.¹³, Vanwalleggem T.⁵, Williams J.¹³, Zavattaro L.¹⁴, Kampen J.¹⁵, Derckx R.¹⁶, Smith P.⁴, Whittingham M.J.², Buchmann N.³ and Newell Price J.P.¹³

¹*Agrosystems Research, Wageningen Plant Research, Droevendaalsesteeg 1, 6708 PB Wageningen, the Netherlands;* ²*School of Natural and Environmental Sciences, Newcastle University, United Kingdom;*

³*Department of Environmental Systems Science, Institute of Agricultural Sciences, ETH Zürich, Switzerland;*

⁴*Institute of Biological and Environmental Sciences, University of Aberdeen, United Kingdom;*

⁵*Department of Agronomy, ETSIAM, University of Córdoba, Spain;* ⁶*Institute of Ecology and Botany, Centre for Ecological Research, Hungary;*

⁷*Department of Agricultural, Forest and Food Sciences, University of Torino, Italy;* ⁸*Department of Agronomy, Institute of Agriculture, Warsaw University of Life Sciences – SGGW, Poland;*

⁹*Department of Forestry, ETSIAM, University of Córdoba, Spain;* ¹⁰*Water Protection and Substance Flows Group, Agroscope Reckenholz, Switzerland;*

¹¹*Department of Animal Nutrition and Forage Production, Mendel University, Czech Republic;* ¹²*Department of Ecology, Swedish University of Agricultural Sciences, Sweden;*

¹³*ADAS, United Kingdom;* ¹⁴*Department of Veterinary Sciences, University of Torino, Italy;*

¹⁵*Biometris, Department of Plant Sciences, Wageningen University, the Netherlands;* ¹⁶*Library, Wageningen University and Research, the Netherlands*

Abstract

Permanent grasslands cover 34% of the European Union's agricultural area and are vital for the delivery of essential ecosystem services. Over recent decades, permanent grasslands have suffered a significant decline and land use change continues to threaten their area. We performed a systematic review on the multifunctionality of permanent grasslands in Europe, examining the effects of land use change and management practices on 18 ecosystem service indicators. Based on the evidence in 696 out of 70,456 screened papers, we found that both land use change and intensification decreased multifunctionality. A lower management intensity was associated with benefits for biodiversity, climate regulation and water purification, but had a negative effect on the provision of high-quality animal feed. Increasing the number of species in the sward enhanced multifunctionality of permanent grassland without significant trade-offs such as losses in production. We suggest that a combined approach of protection and management extensification will help secure multiple benefits from permanent grasslands.

Keywords: agro-ecology, land use change, management, multifunctionality

Introduction

Permanent grasslands cover 34% of the European Union's agricultural area and are vital for human wellbeing as they contribute to a wide variety of essential ecosystem services. For centuries, permanent grasslands have been the basis for livestock production on farms all over Europe. However, over the past decades, permanent grasslands have suffered a significant decline and land use change continues to threaten their area (Schils *et al.*, 2020). In addition to the provision of feed, permanent grasslands sustain a broad range of additional ecosystem services, including climate regulation through carbon sequestration, preservation of biodiversity and cultural values, protection against erosion and flooding, and pollination of food crops (e.g. Bengtsson *et al.*, 2019). For European permanent grasslands we have a restricted understanding of land use and management effects on multifunctionality. Here, we analyse the body of, mainly monodisciplinary, studies across Europe in a comprehensive multidisciplinary systematic

literature review with a focus on experimental contrasts in land use and management aspects. Our study addressed two central research questions: first, what are the reported effects of land use change on the delivery of ecosystem services? Second, what are the reported effects of intensification and specific management options on the delivery of ecosystem services by permanent grassland?

Materials and methods

We systematically searched the scientific literature for grassland studies on 18 indicators of ecosystem services in Europe, published in the English language between 1980 and 2019. The indicators were pollinators, threatened species, and plant richness for *biodiversity*; nitrous oxide, methane and carbon dioxide emissions, and carbon sequestration for *climate regulation*; nitrogen, phosphorus in groundwater and surface water for *provision of fresh water*; recreational value and aesthetics for *cultural values*; hydraulic conductivity, bulk density, soil loss and runoff for *erosion and flood control*; energy and protein content, and forage yield for *provision of animal feed*. In our study, permanent grasslands are defined as land used to grow grasses or other herbaceous forages that has not been included in a crop rotation for a duration of five years or longer.

We screened 70,456 papers and retained 696 papers that contained at least one of eight experimental contrasts, either in land use (permanent grassland versus cropland, forest or temporary grassland) or in management options (sward renewal, defoliation frequency, nitrogen input, legume presence, and number of sward species). The 696 papers contained 1,032 eligible experimental contrasts. For each contrast, we registered the outcome, i.e. the effect of the contrast on the value of the ecosystem service indicator: no conclusion, favourable, neutral, unfavourable. For the analysis, outcomes were transformed to numerical values (favourable=1, neutral=0, unfavourable=-1). More details are presented in Schils *et al.* (2022).

Results

Most of the extracted papers included in this review were identified in regions where over 40% of the utilized agricultural area was covered by permanent grasslands. Around two thirds of the extracted papers originated from the Atlantic or Continental biogeographic regions.

We found consistent trade-offs in the reported outcomes between indicators for feed on the one hand, and non-feed ecosystem services on the other, for three management intensity indicators, i.e. nitrogen input, increasing defoliation frequency and grass renewal (Figure 1). The reported outcomes of increased number of species in the sward showed mainly favourable effects on the indicators for *biodiversity*, *cultural values* and *water purification* and mixed effects on *provision of animal feed* (not shown). Grass renewal showed significant favourable effects on forage yield, but no consistent effect on forage quality. In contrast, we found that grassland renewal significantly increased nitrous oxide emissions and nitrogen losses to water. Considering land use change, we found that most studies reported favourable outcomes for maintaining permanent grasslands compared to conversion to croplands across all ecosystem service indicators, apart from forage yield and energy content (not shown).

Discussion and conclusions

The outcomes of our review suggest that, in spite of apparent changes in human dietary preferences, the protection of permanent grasslands in Europe has to be prioritized to prevent further losses of the area and their ecosystem services. At the same time, in view of the need to reduce ruminant livestock's impact on climate change and the apparent benefits of lower management intensity on biodiversity and water quality, the time seems ripe to increase support for a reduced management intensity on existing European permanent grasslands.

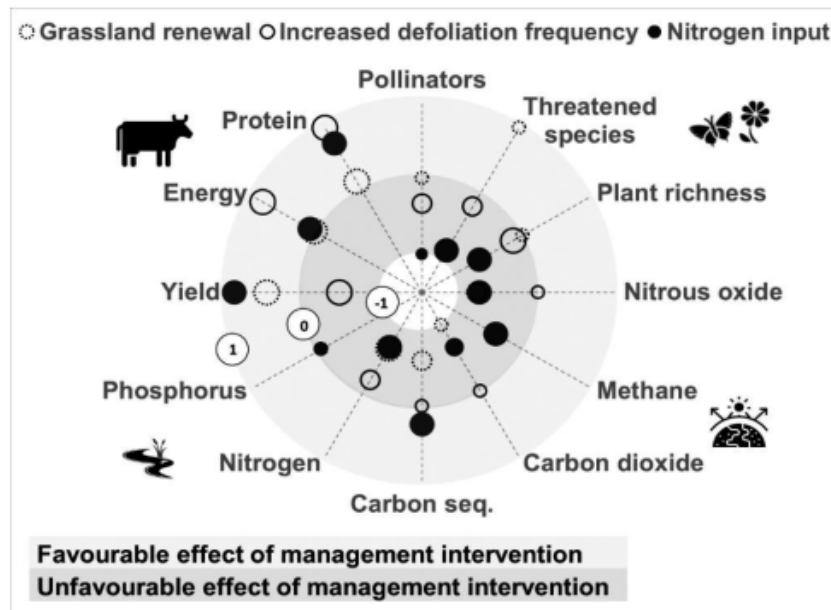


Figure 1. Effects of management intervention on indicators for ecosystem services. The boundary between the shaded zones represents a mean score of 0. Light shaded outer zone represents a favourable score for permanent grassland (moving outwards, the mean score increases from 0 to 1), darker shaded inner zone represents an unfavourable score (moving inwards, the mean score decreases from 0 to -1). Dot size indicates number of underlying cases (small: <5 cases, medium: 5-9 cases. Large: >9 cases).

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