Trade-offs between services rendered by semi-natural grasslands of the Vosges massif (France)

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Abstract

Grasslands are at the heart of multiple expectations on the part of farmers and society. The objective of this study was to assess the services provided by semi-natural grasslands, and the trade-offs between these services. Starting from a survey of 150 grasslands in the Vosges massif, we selected 58 that have been monitored for two consecutive years (2018-2019). Grassland services were assessed through measurements (M) and indicator calculations (IND) including dry matter production (M), feed value and anti-oxidant content of grass (M), physicochemical composition of the soil (M), carbon sequestration (M), floristic biodiversity (M), cost of production and replacement (M), product quality (cheese and meat) (IND), animal health (IND), pollinator value (IND), ecological conservation status (IND). The study of the trade-offs between these services shows that there is no binary opposition between economic value and environmental value. On the contrary, certain environmental services may be associated with the economic interest of livestock farmers.

Keywords: ecosystem service, fodder production, economy, product quality, animal health, biodiversity

Introduction

Semi-natural grasslands can provide many services to farmers and society (Boval and Dixon, 2012), but their economic value and their ability to provide services to society are often considered incompatible. However, many studies show that there may be an economic interest in conserving these species-rich grasslands (Bengtsson *et al.*, 2019; Plantureux, 2020). The analysis of the trade-offs between the services rendered by these grasslands is essential to justify their conservation. In this study, the objective was to study these trade-offs on a large number of services, including fodder production and biodiversity, but also looking at economic aspects, animal health and product quality (milk and meat).

Materials and methods

We surveyed 150 permanent grasslands from the Vosges Mountains (North-Eastern France), and we characterized each grassland using phytosociological and agronomic classifications (Mesbahi *et al.*, 2020). We selected the 20 most important grassland classes, and for each of these we selected about 3 representative grasslands. Elevation ranged from 184 to 1,222 m a.s.l and soil pH from 4.2 to 8, grasslands were cut and/or grazed and N-fertilization varied from 0 to 259 kg ha^{-1} (mineral and organic fertilization, and animal deposition). In 2018 and 2019, we realized botanical relevés within areas with homogeneous vegetation types. Grass samples were taken 4 times per year in six 0.5 m^2 quadrats per grassland, except in the absence of grass growth. Grassland services were assessed through direct measurements or observations (M) and indicator calculations (IND), as detailed in Table 1. Principal Component Analysis (PCA) was performed in order to study the links between services.

Results and discussion

Five groups of variables appeared (Figure 1): Group 1 = grass production (code in Table 1: GP1, GP2) associated with biodiversity (B1, B2) and anti-infective potential (AH1), Group 2 = forage quality (GF1, GF2), Group 3 = product quality (QP1, QP2, QP3, QP4), 4), Group 4 = flexibility (GP3) and oligotrophilous richness (B4), and Group 5 = biodiversity (B3,B6) and production costs (E).

Table 1. Evaluated services.[1]

Service	Evaluation	Code	Abbreviation	Variable
Grass production	M	GP1	Yield	annual dry matter production
	IND	GP2	VP	pastoral value
	IND	GP3	Flexibility	grass production flexibility
	IND	GP4	Earliness	grass production earliness
Grass feed value	M	GF1	UFL	forage energy content
	M	GF2	PDIN	forage protein content
	IND	GF3	Milk_pot	potential milk production
Biodiversity	M	B1	SpecRich	plant species richness
	IND	B2	Shannon	Shannon diversity index
	IND	B3	Conserv_status	ecological conservation status
	M	B4	oligod_sample	oligotrophilous species richness
	M	B5	Family_rich	plant family richness
	IND	B6	ValeurPoli	pollinator value
C sequestration	M	C	SoilCarb_030	C content (top 30 cm soil)
Economy	M	E	Cost/DMT	production cost in €/DM ton
Quality of products	IND	QP1	Aroma	cheese aromatic value
	IND	QP2	Cheese_Texture	cheese texture
	IND	QP3	Cheese_Fat_color	cheese fat colour
	IND	QP4	Meat_antiox	meat antioxidant faculty
	IND	AH1	AnimHealth_antiox	antioxidant value
Animal health	M	AH2	IC50Trol_DPPH	forage antioxidant analysis
	IND	AH3	AnimHealth_antiinf	anti-infection value

[1] M = measured or calculated from observations; IND = indicators.

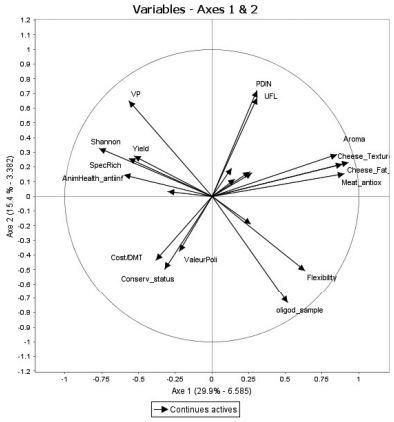

Figure 1. Principal Component Analysis on services rendered by grasslands (n=58) in the Vosges mountains (France). Abbreviations are detailed in Table 1.

It is thus observed that there is no binary opposition between economic and environmental variables. On the contrary, production is associated with specific richness (Group 1), and flexibility with oligotrophilous species richness (Group 4). The opposition between Group 3 (product quality) and Group 5 (biodiversity) is explained by the effect of grazing. This mode of exploitation promotes the quality of the products (favourable impact of fresh grass consumption) but is not favourable to flowering

species. The presence in Group 5 of the cost of production (E) might seem surprising because grazing is known as the least expensive method of harvesting. The variable (E) is calculated by dividing cost by the yield, and pastures are penalized here by their lower yield. As found by Grace *et al.* (2016) we found no relations between biodiversity and forage quality, but our results challenged previous studies highlighting a trade-off between biodiversity and yield (Le Clec'h *et al.*, 2019) possibly due to the larger environmental gradient but smaller number of grasslands we studied.

For each of the 58 grasslands in the sample, a unique combination of services is ultimately observed, with environmental and economic strengths and weaknesses.

Conclusions

The trade-off between the services provided by the permanent grasslands is not limited to an opposition between environmental services and production or economic services. The nature of the trade-offs varies from one grassland plot to another. This observation should encourage the conservation of a diversity of types of grassland within a farm or territory, in order to jointly provide a range of services. However, more studies are needed to generalize our observations to other geographical areas.

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