Taxonomic and functional biodiversity positively influence agronomic characteristics of permanent grassland

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Abstract

European permanent grasslands are the main source of livestock fodder and the main hotspot of botanical diversity, but the trade-offs between fodder production and botanical diversity conservation remain debated. This study aims to identify what grassland features influence fodder characteristics and to estimate the direction of correlation between biodiversity and fodder characteristics. We focused on a diverse sample of 58 permanent grasslands from the Vosges Mountains (eastern France). For each grassland, we estimated the quantity and quality of the fodder using 10 fodder characteristics, and extracted 26 grassland features related to management, environment, and taxonomic and functional diversity. We used random forest algorithms to investigate what grassland features best predicted fodder characteristics. Our results showed that fodder characteristics could be well estimated using only 14 grassland features (R^2>0.4) pertaining to management, soil, climate, taxonomic and functional diversity. Diversity was negatively correlated to three fodder characteristics, but positively correlated to six. We conclude that biodiversity is a key predictor of grassland fodder characteristics, and enhances most of them. We argue that conservation of permanent grassland biodiversity and agricultural production can both benefit from synergies.

Keywords: yield, nutritive value, antioxidant, management, environment, ecology

Introduction

Permanent grasslands are the main source of fodder in Europe, and may host a high botanical diversity (Wilson *et al.*, 2012). It is generally considered that there is opposition between fodder production and botanical diversity. This is because intensification of agricultural practices increases yields, but greatly reduces biodiversity (Gaujour *et al.*, 2012). In mature permanent grasslands, studies concluded there are hump-shaped relationships between diversity and biomass production: potential yields are maximized at intermediate levels of biodiversity (Guo, 2007). Effects of diversity on nutritive value differ among studied characteristics, but remain weak or insignificant in sown experiments (Schaub *et al.*, 2020). Here, we aimed to study the effect of taxonomic and functional diversity in permanent grasslands managed by farmers, under environmental and management gradients. We hypothesize that poorly studied nutritive values could be positively related to biodiversity, especially mineral content, antioxidant activity and flexibility of management.

Materials and methods

We studied 58 permanent grasslands from the Vosges Mountains (North-Eastern France). Environmental conditions strongly differed among grasslands: elevation varies from 184 to 1,222 m a.s.l and soil pH from 4.2 to 8.0. Grasslands are cut, grazed, or cut and grazed, and N-fertilization varies from 0 to 259 kg ha^{-1} (mineral and organic fertilization, and animal deposition). In 2018 and 2019, we realized botanical relevés and vegetation samples in six 0.5 m^2 per grassland. Vegetation samples were used to calculate yield (then normalized at 1,100 degree day – base 0 °C from 1st February), pastoral value and flexibility of management, and to measure neutral detergent fibre, acid detergent fibre, acid detergent lignin, crude protein, mineral content, potential milk production and antioxidant activity (i.e. 10 agronomic characteristics). From botanical relevés, we calculated four taxonomic (species richness, Shannon

exponential, inverse Simpson, taxonomic evenness) and four functional (functional richness, functional evenness, functional diversity, Rao's Q diversity) features, as well as Ellenberg indices for fertility and humidity. We extracted 15 more features from farmers' interviews, soil analysis and topographic model, to inform about management and environment.

We used spatial random forest algorithms to investigate what grassland features best predicted agronomic characteristics (Benito, 2021). For each agronomic characteristic, we then selected the few features allowing the best prediction accuracy (R^2). We assume that characteristics were predicted well if their best R^2 was higher than 0.4. Finally, we check for direction of the correlation between agronomic characteristics and their selected features. This statistical approach did not aim to highlight whether there was a relation between grassland characteristics and features, but to highlight the best features for characteristic predictions.

Results and discussion

We could predict all agronomic characteristics correctly: all R^2 are higher than 0.4. Among the 26 grassland features related to management, environment, taxonomic and functional diversity, only 14 were selected for the best prediction of agronomic characteristics. Six out of ten characteristics required biodiversity features to be best predicted. Six correlations between biodiversity and characteristics were positive, and three were negative (Table 1). Ellenberg fertility index was the most important feature, useful for the prediction of eight out of ten characteristics (Pittarello *et al.*, 2020).

The relation between yield and biodiversity were hump-shaped, confirming the conclusion of Guo (2007). However, the results from our large scale study differed from those of Schaub *et al.* (2020) obtained in one experimental station: biodiversity had a mostly positive effect on nutritive value. Similarly to Brun *et al.* (2019), our results highlighted that the relation between biodiversity and agronomic characteristics depends on considering taxonomic or functional diversity, but our study brings new horizons about the relation between biodiversity and nutritive value.

Table 1. Selected features for the prediction of each agronomic characteristics, prediction quality (R^2) and direction of the correlation between features and characteristics (positive, negative or unselected).[1,2]

Agronomic characteristics	R^2	Management					Environment					Biodiversity			
		Ellenberg fertility	LUI	Number of cut	Degree day	Mode of use	Ellenberg humidity	Elevation	Soil sand	Soil pH	Soil depth	Taxonomic richness	Shannon exponential	Functional richness	Rao's Q diversity
Yield (1,100 d.g)	0.68	+		+								-	+		
Pastoral value	0.68	+								+			+	-	
NDF	0.56	+			+	+		-		+					
ADF	0.50	+			+	+	-	-		+					+
ADL	0.45	+	-	-	+	+	-	+							+
CP	0.56	+			-		+								
Mineral content	0.55	+			-		+			+		+	+		
Milk potential	0.45		+		-			+							
Flexibility	0.58	-								-			-		
Antioxidant activity	0.41								-		-				

[1] Unselected features are not shown. 'Mode of use' is the proportion of cut on grassland number of use.

[2] NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin; CP = crude protein.

As hypothesized, mineral content and flexibility of management were influenced by taxonomic diversity, but they were weakly influenced by functional diversity. However, antioxidant activity was weakly sensitive to diversity features, but could be related to water stress (Sairam and Srivastava, 2001).

Conclusions

Only three out of ten agronomic characteristics were negatively related to one biodiversity feature. These promising results highlight that biodiversity conservation and agricultural production can both benefit from synergies. More research is needed to better understand the role of botanical diversity on production and conservation, especially in the face of climate change.

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