SOWING LEGUME-RICH PASTURES MAKE COMPATIBLE AN INCREASE IN PRODUCTION WITH THE CONSERVATION OF PLANT DIVERSITY OF MEDITERRANEAN DEHESAS

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Abstract

Improvement in forage production and soil quality achieved by sowing legume-rich mixtures in managed grasslands is a reality; however, the compatibility of these kind of pastures with biodiversity conservation it is not so evident. The aim of this study is to evaluate the accuracy of sowing legume-rich pastures in the dehesa from an environmental point of view, by evaluating the changes on the plant community diversity in the medium-long term. Our results show that biodiversity can be sustained while increasing productivity and profitability of the farms through legume-rich pastures, thus they can be considered a suitable option in Iberian dehesas and in all probability, in other Mediterranean silvopastoral systems.

Keywords: legume-rich pastures; pasture biodiversity; species richness; scattered trees; silvopastoral systems.

Introduction

Dehesas, Mediterranean wooded pasturelands, cover around 3.5 million hectares of the south-western Iberian Peninsula, forming one of the largest agroforestry systems in Europe (Den Herder et al. 2017). Dehesas are included in the EU habitat directive as a habitat with community-wide interest (Díaz et al. 2013) and qualified as biodiversity hotspots (Myers et al. 2000; López-López et al. 2011). Due to their shallow depth, and water and nutrients scarcity, fertility is low, thus, native pastures are poor in terms of productivity and quality. Attending to the well-known N limitation in the dehesa, it is essential to find a N self-sufficiency strategy, and sowing legume-rich pastures appear to be part of it. These multi-species pastures show high environmental plasticity. Each species can exploit different ecological niches, increasing the productivity, the production stability and also the pasture lifetime. However, it is still essential to improve our information about the persistence of legumes and the possible influence on biodiversity at pasture level.

Materials and methods

Study area

The study area is characterized by two fundamental features: The Mediterranean character of the climate (dry summers and cold winters) and the low fertility of the soil, particularly P and Ca. The soils are mainly acid varying among Eutric and Distric Cambisols and Luvisols. The *experimental design* was conducted in 2016 and 2017 on seven dehesa farms in Extremadura (West of Spain) where a mixture of forage legume seeds (20 kg seed ha^{-1}) had been sown in different years, following a chronosequence. In each farm, 3-5 different ages (years of sowing) were identified besides a control plot (parcel that has never been sown). The different plot ages were grouped for plotting and some analyses into Control plots, Young plots (0 to 5 years), Mature plots (6 to 10 years) and Old plots (11 to 15 years). In total, 33 plots were monitored, with year of sowing ranging from 2002 to 2015. The plots were representative of the vegetation in the area in terms of botanical composition and phenology.

Regarding sowing, in November, a mixture of legumes was sown. The mixture of *Rhizobium*-inoculated seeds was composed of *Trifolium subterraneum* (61%) (different subspecies as *brachycalycinum* and *yaninnicum*) with other forage legumes: *T. michelianum var balansae* (7%), *T. vesiculosum* (3%), *T. resupinatum* (6%), *T. incarnatum* (8%), *Ornithopus sativus* (12%) and *T. glanduliferum* (3%). Superphosphate was applied as fertilizer in the sown parcels with different frequency among farms. Two microhabitats were clearly defined in each of the 33 plots: beneath oak canopy and outside tree canopy.

Sampling protocol

Botanical composition was determined with the Point Transect method (Southwood and Henderson 2000), noting the species present every 100 cm in eight random 25 m transects. Annual inventory included 264 transects (7 seven farms (*33 plots) · 4 transects ·2 microhabitats*) and a total 6864 individual plants.

Statistical analysis

Statistical analyses were performed with R Software (R Foundation for Statistical Computing, Vienna 2017). Differences in age (quadratic adjustment) and habitat among values of yield, species richness and biodiversity indexes were compared by mixed effects models (LMMs) using the “nlme” package, considering “farm” as random factor and “age” nested in farm. A summary of the statistical considerations and results of the mixed effects models applied is shown in Table 1 and 2. Rarefaction curves were calculated with “vegan” and “iNEXT” packages.

Results

Plant diversity

As said before, plant diversity of dehesas is usually high, and our results in the control unsown plots confirm this statement (*Shannon index value*: 2.744 (beneath) and 2.528 (outside). *Simpson index value*: 0.889 (beneath) and 0.847 (outside)). The mean number of species recorded in each sampling plot was almost 40 species on average (α diversity) and the total number of species recorded per habitat (ϒ diversity) was over 150 species both beneath canopy and out of canopy, with species richness slightly higher in the latter. These differences in richness (Figure 1) are not significant with age; however, depending on the sampling year, habitat becomes significant (Table 1).

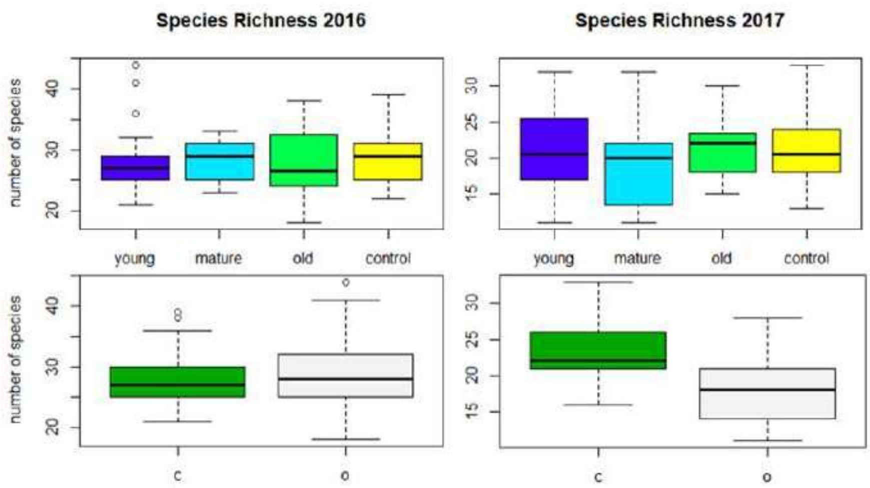

Figure 1: Species Richness in 2016 (left) and 2017 (right) in the studied plots grouped by age, and in the two microhabitats (under canopy (**c**) and out of tree canopy (**o**)).

In the initial years after sowing legume-rich pastures (young pastures in Figure 2), mean species richness per sample decreased slightly both beneath and outside the tree canopy. This loss of α diversity persisted in mature and old plots. However, species richness at higher spatial level (ϒ diversity) did not differ significantly for any of the age groups of the sown pastures with respect to the control unsown plots, indicating that the loss of α diversity in sown pastures is compensated by the high β diversity.

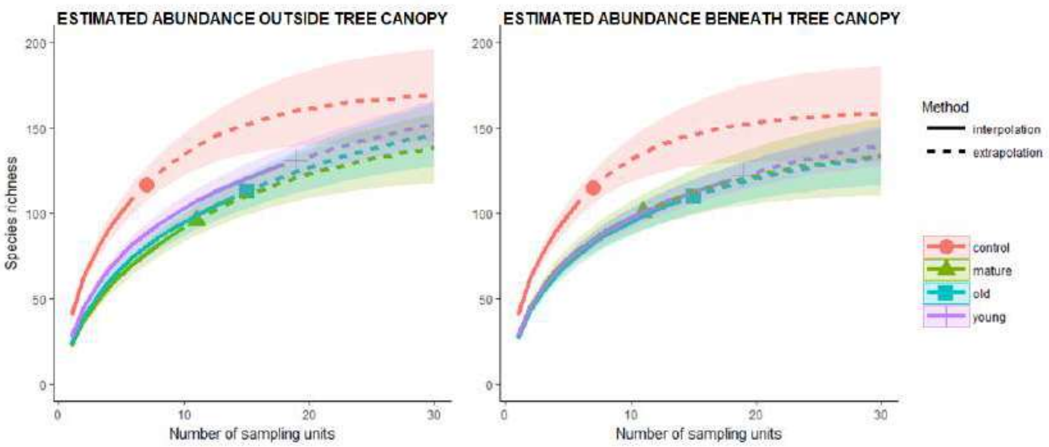

Figure 2: Estimated species richness by accumulation curves (±95 % C.I.) in pastures grouped by age. Solid lines and symbols represent recorded data while dashed lines represent the species richness estimated following the extrapolation (prediction) approaches proposed by Chao (2005) and Colwell et al. (2012) to make comparable values produced with different sampling efforts.

Table 1: Significance (p) effects of LMM to explain variations on α diversity in two consecutive years. Fixed factors were "habitat" (beneath and outside of canopy), "age" of sown legume-rich pastures (year from sowing) and their interaction (age x habitat). Farm was included as a random factor (age is nested in farm). The model included a quadratic term in age.

Year of sampling	Biodiversity measurements	Significance (p) fixed effects			R^2 Model
		age	habitat	age*habitat	
2016	Simpson	0.5472	0.9862	0.3978	0.3154
	Shannon	0.7396	0.9499	0.5226	0.3508
	Species Richness	0.5563	0.0388*	0.6313	0.1540
2017	Simpson	0.7375	0.0013**	0.4213	0.3444
	Shannon	0.7734	4.99e-05 ***	0.2792	0.3881
	Species Richness	0.7838	1.35e-05 ***	0.0564	0.4221

Table 2: Species richness in the considered habitats and groups of age considering the two sampling years of the study (2016 and 2017). It can be observed that Richness is higher beneath the tree canopy when weather is adverse (2017 sampling).

Sampling year	Age of sown pastures	Mean Species Richness by habitat ± s.e	
		Beneath canopy	Outside canopy
2016	control	36.896 ± 6.590	47.054 ± 14.44
	young	36.496 ± 10.432	48.119 ± 18.380
	mature	37.69 3± 7.966	44.357 ± 10.839
	old	37.895 ± 7.857	70.777 ± 43.181
2017	control	34.584 ± 9.293	29.588 ± 13.964
	young	35.581 ± 10.889	20.254 ± 3.288
	mature	38.677 ± 17.579	18.542 ± 5.881
	old	34.045 ± 12.034	24.024 ± 5.879

Pasture production

Yield increased significantly (p=0.018 beneath and p=0.0003 beyond tree canopy) after sowing legume-rich pastures. Mean production for control plots was 1586 kg ha^{-1} ± 132 $CI_{95\%}$ one year after the sowing was almost tripled 4762 kg ha^{-1} ± 389 $CI_{95\%}$. Production decreased gradually in the following years, but maintaining noticeably higher levels than unsown plots.

Discussion

The desirable positive effect in productivity that motivates the sowing of legume-rich pastures was significant and stronger beyond than beneath tree canopies of legume-rich pastures was achieved, with an improvement in yield of more than 200 % over the control levels. This increase in production may be due to the interaction among N_2-fixing and non-fixing-plants (Temperton et al. 2007; Nyfeler et al. 2009) and the mixed-pastures long-lasting character together with the high number of plant species with diverse functions (Fornara and Tilman 2009). The increased yield and legume proportion on the farms (data not shown) appear to justify the sowing of legume-rich pastures. However, the appropriateness of commercial seed mixtures has been seriously questioned by some authors because of their excessive competitiveness or invasive character (Driscoll et al. 2014). In contrast, our biodiversity results indicate unproblematic coexistence of both native and sown legumes, agreeing with Proença et al. (2015). In fact, native *Trifolium* such as *T. striatum, T. stellatum* and *T. glomeratum* were among the most abundant legumes on the study farms.

The response of pasture biodiversity over the years seem to be influenced by the weather, thus, with the habitat. In 2017, pastures experienced unusually high temperatures and scarce rainfall in early spring and species richness was higher beneath the canopy, whereas in 2016, with more favourable climate conditions, species richness was more abundant outside the canopy (See Table 2). We could say that beneath the tree canopy, especially in climatically adverse years, species richness is significantly higher than outside due to the tree "nurse" effect. Taking the increasing recurrence of heat/dry events in the spring/growing season into account, this could be a support to the implementation of sown pastures rich in legumes in silvopastoral systems as dehesa.

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