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Effects of grazing abandonment on functional and taxonomic diversity of Mediterranean grasslands

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ABSTRACT

This paper analyses changes in species richness and functional trait diversity in response to grazing abandonment in Mediterranean grasslands, for five traits that are well connected to ecosystem function and community assembly: Plant Height, Specific Leaf Area, Seed Mass, Onset of Flowering and Growth Form. The impacts of land-use change on floristic composition and community weighted traits were measured along with soil fertility, bare soil cover and litter cover. Results reveal changes in the community average value of all analysed plant functional traits and a loss of functional diversity after abandonment in two of them, which is not accompanied by a change in species richness, indicating a loss of functional groups and a potential effect on the ecosystem functioning.

Abandonment is accompanied by the disappearance of short species, prostrate or creeper growth forms and early flowering species, while tall species and graminoid forms increase, their greater inflammability predicting an increase in wildfire frequency and intensity. Seed Mass and Specific Leaf Area show a weak but significant signal, with abandonment favoring large-seeded species and small Specific Leaf Area. A decline in soil fertility after abandonment is also detected, probably related to the decreased nutrient recycling rate and litter decomposability.

1. Introduction

In Europe, many agrosystems with high natural values such as semi-natural grasslands, heathlands, arable steppes and agroforestry systems are undergoing complex changes in land use which threaten their biodiversity and the ecosystem services they provide. Most of the studies examining changes in species and functional diversity with respect to land use changes have focused on the impact of intensification processes (Dorrough and Scroggie, 2008; Flynn et al., 2009; Laliberté et al., 2010), while the abandonment of traditional human activities, including extensive grazing, has received less attention (Castro et al., 2010; MacDonald et al., 2000; Pakeman and Marriot, 2010; Peco et al., 2005).

Species diversity, usually measured as species richness, is the most widely studied component of biodiversity (Helm et al., 2006; Krewenka et al., 2011), although in recent years, there has been a proliferation of the focus on functional diversity (Díaz et al., 2007a; Flynn et al., 2009; Laliberté et al., 2010; Tscharntke et al., 2008). The use of species richness is justified by its ease of measurement and the assumption that this component of diversity is well correlated with ecosystem processes and properties, including resource use, biomass production and stability (Balvanera et al., 2006; Duffy et al., 2003; Ives et al., 2000; Mittelbach et al., 2001). Changes in species diversity should be regarded as an outcome of ecological assembly processes, not a causal driver of ecosystem function (Mayfield et al., 2010).

In contrast, functional diversity, which focuses on the functional traits of species in a community rather than taxonomic units, can be a more direct, mechanistic link to ecosystem processes than species richness (Díaz and Cabido, 2001; McIntyre and Lavorel, 2001; Petchey and Gaston, 2006).

Land-use change can affect both species diversity and functional traits. According to the sampling effect hypothesis (SEH), trait states (or values) accumulate with successive additive random draws from a regional species pool, implying a positive relationship between species diversity and functional diversity (Huston, 1997). However, changes in species diversity and functional trait diversity (ΔDSF) can in fact take different paths in response to land-use change, and species diversity–functional diversity are not necessarily correlated (Mayfield et al., 2006, 2010). According to Mayfield et al. (2010), land-use change impacts upon community assembly processes, not species per se, and changes in species diversity should be considered an outcome of ecological assembly processes.

Many attempts have been made to identify grazing-related plant traits, but few general patterns have emerged (see review in Díaz et al., 2007b). Basically, the only generalizations have dealt with

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the encouragement of species with prostrate habits and annuals over perennials, however even these responses seem to be context-dependent (Díaz et al., 2007b). One of the difficulties encountered in the search for relationships between plant functional traits and grazing at a global scale (Díaz et al., 2007b) is that this response depends on the precise level of grazing (Bullock, 1996), the type of herbivory and its selective behavior (Evju et al., 2009), productivity (de Bello et al., 2005; Pakeman et al., 2004; Vesk and Westoby, 2001) and the herbivory history (Díaz et al., 2007b; Milchunas and Lauenroth, 1993). We must therefore define the rules of the response to grazing by the different plant traits for each climatic context and grazing history (Díaz et al., 2007b).

Dehesa grasslands (*Montados* in Portuguese) in the Mediterranean basin have a long history of grazing. The abandonment of long-term grazing does not seem to affect species richness (Peco et al., 2006), while the abandonment of cropping does so (Castro et al., 2010). Grazing abandonment produces an increase in the proportion of taller plants, high leaf dry weight, late flowering species and chamaephytes, as well as species with heavy seeds and fruits with adhesive structures (Peco et al., 2005). The vegetation in abandoned croplands becomes dominated by chamaephytes and nanophanerophytes, and there is an increase in Plant Height, Dry Leaf Matter Content and Seed Mass, while Specific Leaf Area (SLA) decreases (Castro et al., 2010). In addition to changes in the vegetation, changes in the environmental filtering due to abandonment have been documented (Peco et al., 2006). To date, however, no published studies have approached the impact of grazing abandonment on functional diversity in Mediterranean grasslands or the trajectory of species richness in relation to functional diversity (Mayfield et al., 2010).

The main goal of this study is to analyse changes in species richness and functional trait diversity (ΔDSF) in response to grazing abandonment in Mediterranean grasslands for five traits (Plant Height, Specific Leaf Area, Seed Mass, Onset of Flowering and Growth Form) that are well connected to ecosystem function and community assembly. The paper also analyses the impact of change of use on other vegetation descriptors (floristic composition and weighted trait average for individual traits) and the environment (soil fertility, bare soil cover and litter cover), integrating this information to provide an overall assessment of the mechanisms by which land use change influences the system, and the consequences of these changes for its functions.

2. Methods

The study was conducted on the southern slopes of Sierra de Guadarrama (Central Spain) in a 15,000 ha area near San Pedro Peak (40°38′N, 3°70′E). The lithology is silica, predominantly gneis, Precambrian and Palaeozoic granite. The area had a gently rolling relief, mostly between 800 and 1000 m.a.s.l. The climate is continental Mediterranean (mean annual temperature: 13.2 °C; average annual rainfall: 550 mm at Colmenar Viejo station). The predominant soil type is Dystric cambisol.

The fields varied in size between 5 and 20 ha, with stone wall demarcations. Until the middle of the last century, all this area was used for low-density sheep and cattle grazing (around 0.2–0.3 GU/ha) which were moved between fields to make the most of the pastures. Some of these properties were still grazed by livestock, while others had not been grazed for more than 30 years.

Grassland and scattered trees (mainly *Quercus ilex* subsp. *ballota* and *Juniperus oxycedrus*) were the predominant vegetation types. The herbaceous layer mainly consisted of annuals, with a progressive increase in perennials with increasing soil moisture in water discharge areas and valley floors. We selected 19 sites that met the following requirements: (i) on two environmentally similar adjacent properties, one in use and the other abandoned for at least 30 years, separated by a well-preserved stone wall that effectively prevents cattle movement between the two, (ii) on dry slopes of less than 15%, (iii) neither of the sites shared the same stone wall and (iv) at least 500 m from the nearest town. This paired design permitted the analysis of land change use, independently of other environmental factors, and facilitated the use of more powerful statistical techniques.

2.1. Sampling

Two 10 m × 10 m plots were set one on grazed and one on abandoned site per pair, at least 5 m from the property wall. In every plot five 20 cm × 20 cm quadrats were placed, one in the center and the other four in each corner.

All plant species present in each quadrat were recorded in May 2002, yielding a frequency value between 0 and 5 for each species and plot, and a richness value for all five quadrats in the same plot. During the vegetation sampling, we also recorded the bare soil and litter cover in each quadrat using an ordinal scale, ranging from 0 to 5 (0:0, 1:1–12, 2:12–25, 3:25–50, 4:50–75, 5:75–100, intervals commonly used in vegetation studies).

In order to control for the possible effect of productivity on the vegetation response to grazing (de Bello et al., 2005; Pakeman et al., 2004; Vesk and Westoby, 2001), soil fertility was estimated by a bioassay with barley (*Hordeum vulgare*). Four soil cores were collected at random in each plot (5 cm diameter and 10 cm deep), air dried and sieved through 2 mm mesh. The soil samples from each plot were mixed and set in three pots (5 cm square and 6 cm deep), planted with eight barley seeds. The pots were kept in greenhouse conditions for 4 weeks, watered regularly to keep the soil moist. After germination, only two seedlings were left in each cell. The pots were relocated weekly to randomize the possible effect of position. After the bioassay, all plants were collected, cleaned and oven dried for 72 h at 80 °C. We calculated the average dry biomass per plot, which was used as an estimator of the plot's soil fertility.

Five functional traits were measured in the study area, four quantitative (Plant Height, Specific Leaf Area (SLA), Onset of Flowering and Seed Mass) and one qualitative (Growth Form). Plant Height was defined as the distance from the plant base to the highest leaf (excluding reproductive tissue and protruding branches) in ten mature individuals from each species, set at least 25 m apart. SLA was defined as the ratio between leaf area and dry leaf weight, measured by collecting a leaf from each of the ten individuals previously used to measure Plant Height. We chose the youngest fully developed leaves, including the petiole. We scanned the hydrated and expanded leaves, and measured the area of each image with an image analyzer program (Leica Q500 Iw). The same leaves were weighted with a precision balance after oven drying at 60–80 °C for 24 h. Exceptionally, and in the case of small leaf species, we formed ten groups of 5–10 leaves for the surface and weight measurements.

Seed Mass was taken from Azcárate et al. (2002) in most cases. New measurements were also made for some species not included in the latter study, using the same protocol (30 dry seeds per species), 'seed' being defined according to Bekker et al. (1998).

Onset of Flowering was coded by month, from 1 (January) to 9 (September), and treated as a quantitative variable. Growth Form was treated as a qualitative variable, consisting of four categories: *graminoid*, *erect*, *prostrate* and *rosette*. Both traits were taken from specific bibliography on Iberian flora (Castroviejo, 1986–1999; Valdés et al., 1987).

The paucity of some species made it impossible to obtain all five traits for all species recorded in the samples. Species which lacked at least one functional trait were deleted from the analysis of functional traits. All species affected by this problem showed a frequency of less than 10% in the quadrats, in both grazed and