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Original article

Changes in plant cover and functional traits induced by grazing in the arid Patagonian Monte

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ABSTRACT

Grazing disturbance may affect the structure and functioning of arid rangelands. We analyzed the changes in plant cover and plant functional traits (plant height, SLA, N in green leaves) at the community, morphotype and species level in relation to grazing disturbance in arid ecosystems with more than 100 years of sheep grazing history. We identified two grazing areas and within each area we selected two representative and homogeneous sites located far (low grazing disturbance) and near (high grazing disturbance) from the single permanent watering point. We evaluated the plant cover at community, morphotype (evergreen tall shrubs, deciduous shrubs, dwarf shrubs, perennial herbs and perennial grasses) and species level at each site and randomly selected three individuals of modal size of each species to evaluate at them the selected plants traits. Plant cover was reduced by grazing disturbance at the community level. The cover of perennial grasses and evergreen tall shrubs decreased and that of dwarf shrubs increased with increasing grazing disturbance. Increasing cover of dwarf shrubs did not compensate the cover reduction of the other morphotypes. In contrast, plant height, SLA and N in green leaves were not affected by high grazing disturbance at community level as a consequence of positive and negative changes in these traits at morphotype and species levels induced by high grazing disturbance. We concluded that cover was the trait most affected by high grazing disturbance and positive and negative changes in other traits at plant morphotype or species level did not affect community attributes related to resistance against herbivory.

1. Introduction

Changes in plant species composition and functional traits as responses to disturbances are central topics in basic plant ecology as well as in rangeland management (Niu et al., 2010; Vesk and Westoby, 2001). In the last decades, there has been an ongoing effort to identify plant functional types and traits related to tolerance and avoidance of environmental stresses and how they respond to disturbances for the purpose of predicting vegetation dynamics and ecosystems functioning in changing environments (e.g. Bertiller et al., 2006; Díaz et al., 2007; Vesk and Westoby, 2001; Westoby, 1998). In arid ecosystems, the extreme dry conditions exert a strong selective pressure on plant morphological and life history traits (Bertiller and Bisigato, 1998; Noy Meir, 1973). Most of these ecosystems are dominated by shrubs and perennial grasses (Whitford, 2002) and have been extensively grazed with domestic herbivores (Defossé et al., 1990). Selective domestic grazing induces strong changes in the relative abundance of plants species with different morpho-physiological traits thus producing important impacts on ecosystem structure and functioning (Bertiller and Bisigato, 1998; Cruz et al., 2010; Díaz et al., 2001; Milchunas and Lauenroth, 1993). The most conspicuous changes induced by domestic grazing are related to the shifting of perennial grasses by long-lived evergreen shrubs and replacements among shrubby species (Bertiller and Bisigato, 1998; Reynolds et al., 1997). Both life forms differ in structural and physiological traits (Bertiller et al., 1991; Carrera et al., 2009; Sala et al., 1989). Shrubs usually produce thick green leaves with large amount of secondary compounds (such as lignin, tannins, or soluble phenolics) protecting them against desiccation, herbivores, pathogens, and radiation effects, while perennial grasses produce leaves of short lifespan, with low protection against abiotic factors and herbivores (Aerts and Chapin, 2000; Campanella and Bertiller, 2008; Carrera et al., 2009).

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Several plant functional traits were proposed to summarize the major dimensions of variations in plant ecological strategies and to understand the main opportunities and selective forces that shape life histories, architectures, growth allocations, and physiologies of plants (Lambers et al., 2000; Westoby et al., 2002). Among them, specific leaf area (SLA), plant height at maturity and seed size are considered key predictors of the response of species abundance to disturbance. In general, the relative abundance of tall plants with high SLA should decrease while that of short plants with low SLA should increase due to herbivore selection under low or moderate grazing disturbance (Cingolani et al., 2005; Díaz et al., 2001; Westoby et al., 1999). However, selective grazing is not only dependent on plant morphological and functional traits (Day and Detling, 1990; Huntly, 1991) since grazing could also affect these traits (Briske, 1996). This codependency could generate feedback cycles between both vegetation structure and biochemistry, and nutrient cycling and storage (Díaz et al., 2007). Although several studies associated changes in relative abundance of plant species with a set of plant functional traits (Díaz et al., 2004, 2007; Golodets et al., 2009; Vesk and Westoby, 2001), few of them evaluated whether mean values of functional traits of plant species and morphotypes (e.g. plant height, SLA and N concentration in green leaves) would change with disturbance such as that induced by domestic grazing in arid ecosystems (Díaz et al., 2001; Niu et al., 2010; Vesk et al., 2004).

The objective of this study was to analyze the changes in plant cover and plant functional traits (plant height, SLA, N in green leaves) at the community, morphotype and species level in relation to grazing disturbance in arid ecosystems of the Patagonian Monte submitted to sheep grazing for more than 100 years. We hypothesized that grazing disturbance affects plant cover and functional traits (height, SLA and N concentration in green leaves) at community, morphotype and species level. We expected that plant cover, height, SLA and N concentration in green leaves will be reduced at the community level under grazing disturbance. These changes will be the consequence of both changes in the dominance of plant morphotypes (i.e. reduced cover of tall plant morphotypes and/or morphotypes with high SLA and N concentration in green leaves and increased cover of dwarf shrub morphotypes with low SLA and N concentration in green leaves) and changes in functional traits within morphotypes and species (i.e. reduced plant height, SLA, and N concentration in green leaves).

2. Materials and methods

2.1. Study site

The study was carried out in northeastern Patagonia (Patagonian Monte). Mean annual temperature is 13 °C and mean annual precipitation is 188 mm (Barros and Rivero, 1982). Soils are a complex of Typic Petrocalcids-Typic Haplocalcids (del Valle, 1998; Soil Survey Staff, 1998). Vegetation corresponds to the shrubland of *Larrea divaricata* Cav. and *Stipa* spp., characteristic of the southern portion of the Monte Phytogeographic Province (León et al., 1998). The Patagonian Monte occupies flat landscapes and it is the most homogeneous floristic environment in Patagonian ecosystems (León et al., 1998). In the Patagonian Monte, sheep grazing was introduced at the beginning of the past century and was typically organized in ranches of about 4 paddocks of 2500 ha each sharing a single permanent watering point. This in turn led to the formation of extended piospheres (1500–2000 m) around watering points where the spatial pattern of plants, some traits of plant communities and upper soils are modified by the frequent visit of grazers (Ares et al., 2003; Bertiller et al., 2002; Bisigato and Bertiller, 1997; Bisigato et al., 2005; Carrera et al., 2008; Larreguy et al., 2012). Our study was conducted in two homogeneous (vegetation, soils, and relieve) and representative areas of the Patagonian Monte of about 10.000 ha each: La Elvira (43° 8′52.0″S, 65° 42′49.6″W; 157 m a.s.l.) submitted to sheep grazing with a stoking rate of 0.11–0.14 sheep ha^{-1} since the beginning of the last century, and La Esperanza (42° 12′13.7″S, 64° 58′55.6″W; 92 m a.s.l.) that was submitted to the same stocking rate up to the year 2003 when this area was converted to a wildlife refuge and the stocking rate was gradually reduced (0.01 sheep ha^{-1} per year) up to the year 2008 when all domestic herbivores were retired. Within each area, we selected one paddock of about 2500 ha with an extended piosphere (Ares et al., 2003) and delimited two sites (3 ha each, minimal area *sensu* Mueller-Dombois and Ellenberg, 1974) located far (low grazing disturbance) and near (high grazing disturbance) from the single permanent watering point (separated at least 1500 m from each other). Vegetation is characteristic of shrubland of *Larrea divaricata* Cav. and *Stipa* spp., relieve is flat (León et al., 1998) and soil texture is sandy or loamy sand at the four sites (Instituto Nacional de Tecnología Agropecuaria, 1990; Rossi and Ares, 2012). Faeces counts and density of sheep paths (Bisigato and Bertiller, 1997; Pazos et al., 2007), vegetation structure assessed by remote sensing (Ares et al., 2003) as well as to reductions in soil organic carbon with increasing grazing (Carrera et al., 2008; Prieto et al., 2011) are usually indicators used to confirm the existence of areas affected by grazing disturbance around watering points (piospheres).

2.2. Indexes of grazing disturbance

We collected 30 soil cores (8 cm diameter and 2 cm depth) from random locations within each site and counted the number of faeces. Additionally, we randomly extracted eight soil samples with a metallic tube (5 cm in diameter, 30 cm depth) to assess soil organic carbon. Soil was air-dried, sieved to 2 mm and analyzed for soil organic carbon by wet combustion (Nelson and Sommers, 1982). Means per site of both attributes were used as indexes of grazing disturbance.

2.3. Plant cover

We evaluated the total plant cover and the absolute and relative plant species cover along four randomly located 25-m linear transects by the line intercept method (Mueller-Dombois and Ellenberg, 1974) at each site and area in August 2010. We further assigned each species to one of the following plant morphotypes: evergreen tall shrubs, shrubs more than 30 cm tall with evergreen leaves; deciduous shrubs, shrubs more than 30 cm tall with drought deciduous leaves; dwarf shrubs, shrubs less than 30 cm tall; perennial herbs, plants with leaves that die at the end of the growing season but the living underground stems lay dormant until the next growing season; and perennial grasses (Supplementary material table 1).

2.4. Plant traits

We randomly selected three individuals of modal size (most frequent crown diameter and height) of each perennial plant species and registered the plant height excluding the reproductive structures, in the case to be present (Laughlin et al., 2010), at each site and area in summer 2010–2011. The number of three replicates per species and site fulfilled the requirement of a level of accuracy $\leq$0.15 (Milner and Hughes, 1970). Then, we collected fully expanded young to medium age leaves (Bertiller et al., 2006) from three branches of the external canopy crown (sunny and partially sunny leaves) of each shrub and herb individual, and three tillers of each perennial grass bunch. Collected leaves were air dried and stored at