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Seed rain alteration related to fire and grazing history in a semiarid shrubland

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A B S T R A C T

In arid environments, vegetation is distributed in patches. Herbivory and fires promote changes and seed rain plays a key role in the soil seed bank and the colonization of new spaces. This study focuses on the effect of different land use histories on the spatial and temporal seed rain distribution in Patagonia. We placed traps to capture seed rain of perennial grasses, shrubs and annual forage dicots at five sites with different grazing and fire histories. With grazing and fire seed rain diversity is higher than in absence of disturbances. Functional groups seed rain in vegetation patches did not show differences between sites, but at the interpatch level, grazing increased shrub seed and decreased perennial grass seed in the seed rain. Fire decreased the effects of grazing on shrub seed rain, but did not change its effects on perennial grasses. Shrub species showed a minimum abundance in the seed rain in the undisturbed site. Our results suggest that changes described for vegetative attributes are reflected in the seed rain, and this could reinforce the patch-interpatch pattern; fire did not reduce the grazing effects because it decreased the seed rain of the preferred grasses and increased the less preferred ones.

1. Introduction

In arid environments, the vegetation is distributed in patches immersed in a bare soil matrix ("interpatches") (Aguiar and Sala, 1999). These patches are conformed of phytogenic mounds dominated by shrubs, with grasses, subshrubs, herbs and biological crusts growing under their canopy (Bisigato and Bertiller, 1999; Cecchi et al., 2001). Several mechanisms have been proposed to explain the maintenance of these structures, including a complex balance between competition and facilitation (Caballero et al., 2008). Recently, it has been highlighted that the formation of vegetation patches is a product of grazing in the semiarid regions of the world (Allington and Valone, 2013).

Disturbances, such as herbivory, fire and drought, forge the structure and functioning of grassland ecosystems (Oesterheld et al., 1999). Under grazing conditions, key resources, such as water and nitrogen, are more available in the shrub patches (Allington and Valone, 2013). Also, the importance of the shrub patches as a seed source and trap forms a spatial pattern of the soil seed bank that reinforces this heterogeneous distribution (Caballero et al., 2008). Concentration of defoliation and trampling in the interpatches reduces the cover of the grasses and biological crusts that protect the soil, leading to edaphic changes that decrease nutrient concentration and infiltration, and increase the loss of vegetation cover in these spaces (Allington and Valone, 2013; Fuls, 1992). These losses of vegetation and soil cover may, eventually, result in a partial reduction of the soil seed bank (Caballero et al., 2008). In addition, cattle may indirectly affect pollination levels through modifications in the plant community and between plants and their pollinators (Tadey, 2008; Vázquez and Simberloff, 2004). Once that situation is reached under grazing conditions, the interpatches are seldom revegetated and they become the centers from which the desertification process advances in these systems (Fuls, 1992; Chartier and Rostagno, 2006; Chartier et al., 2011).

In the Patagonia, excessive grazing is one of the main causes of desertification (Bertiller and Bisigato, 1998; León and Aguiar, 1985). Several authors explained how traditional management has caused several changes in the vegetation (e.g., Bär Lamas et al., 2013; Bisigato et al., 2005; Bisigato and Bertiller, 1997; León and Aguiar, 1985; Peter et al., 2012, 2013). Soil erosion is one of the principal processes of degradation in the Monte region (e.g., Chartier et al.,

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2011; Chartier and Rostagno, 2006; Parizek et al., 2002), and its continuous and accelerated advance may cause irreversible changes (Gaitán et al., 2007) limiting perennial grasses establishment (Bisigato and Bertiller, 2004; Chartier and Rostagno, 2006), although in some cases grazing exclusion has allowed the vegetation to recover (Funk et al., 2012).

Fire is a management tool commonly used to foment changes in vegetation that leads to a reduction in the shrub layer and an improvement in the desirable grasses. Several studies have pointed out these changes (Bran et al., 2007; Peláez et al., 2010), but others did not find any evidence to support this practice (Peter et al., 2013). Once fire has occurred, the wind redistributes the nutrients and propagules accumulated under the shrub canopy (Bóo et al., 1996; Ravi & D'Odorico, 2009), homogenizing the distribution of the vegetation (Rostagno et al., 2006).

In grasslands, these disturbances determine the longevity of the soil seed bank (Fenner and Thompson, 2005). In degraded areas of Patagonian Monte, the limiting factors for perennial grass recruitment are the spatial distribution of the soil seed bank and water availability (Bisigato et al., 2009). Seed rain composition and abundance play a key role because they have direct effects on the soil seed bank (Fenner and Thompson, 2005), which is the only source of potential recruiters after a severe fire (Galíndez et al., 2012). So, seed rain and remaining soil seed bank are involved in the colonization of new spaces (Thompson, 2000). Therefore, management practices that tend to sustain and/or increase perennial grass soil seed bank will contribute to their re-establishment (Bertiller and Aloia, 1997). Various studies on seed rain (Bonvissuto and Busso, 2007) and soil seed banks (Bertiller, 1998; Bertiller and Aloia, 1997; Busso and Bonvissuto, 2009; Pazos and Bertiller, 2007) in the Patagonian Monte have already been undertaken.

The findings of Peter et al. (2013) indicated that this semiarid rangeland is resilient to fire, but not to continuous grazing. The objective was to study the effect of different land use histories (involving grazing and fire) on the composition of the seed rain, and its spatial and temporal distribution in northeastern Patagonia. We hypothesized that seed rain responds in the same way as vegetative attributes such as frequency and cover. Therefore, our predictions were that: (1) seed rain diversity will be higher under intermediate disturbance (such as moderate grazing), (2) the abundance of perennial grasses in the seed rain will decrease under grazing conditions, whereas the abundance of shrubs and annual forage dicots in the seed rain will increase, (3) the differences promoted by grazing will decrease in burnt sites, so the heavily-grazed areas that were burnt will be similar to the moderate-grazed unburnt areas.

2. Materials and methods

2.1. Study area

The study area was in Adolfo Alsina (40° 40′ S, 64° 10′ W) department, Río Negro province, Argentina and it is representative of the Patagonian Monte. The climate is dry subtemperate, with warm summers (mean temperature 24 °C) and mild winters (mean temperature 7 °C). Soils are Aridisols; mean annual precipitation is around 255 mm, with high within and between year variability. Moderate northwesterly wind occurs throughout the year (Godagnone and Bran, 2009). Vegetation in the area is characterized by shrubland steppe, corresponding to the Monte Phytogeographical Province, South District, North Patagonia Sub-district (Roig et al., 2009); with a herbaceous layer of predominantly winter-growing grasses. This community is dominated by *Larrea divaricata* Cav., *Chuquiraga erinacea* D. Don and *Condalia microphylla* Cav. in the shrub layer, *and Nassella tenuis* (Phil.) Barkworth in the herbaceous layer. Other shrubs, e.g. *Prosopis flexuosa* var. *depressa* F.A. Roig, *Senna aphylla* (Cav.) H.S. Irwin & Barneby, *Lycium chilense* Miers ex Bertero, *Monttea aphylla* (Miers) Benth. & Hook., *Schinus johnstonii* F.A. Barkley and *Ephedra ochreata* Miers can be found in the area. *Poa ligularis* Nees ex Steud., *Piptochaetium napostaense* (Speg.) Hack., *Jarava plumosa* (Spreng.) S.W.L. Jacobs & J. Everett, *Pappostipa speciosa* (Trin. & Rupr.) Romasch., *Nassella longiglumis* (Phil.) Barkworth (=*Nassella clarazii*), and the annual species *Schismus barbatus* (L.) Thell., *Erodium cicutarium* and *Daucus pusillus* Michx (Cabrera, 1971) are also commonly found in the herbaceous layer. The study area has almost 100 years of grazing history, with an average stocking rate of ≈0.18 sheep ha^{-1} (Peter et al., 2013).

2.2. Sampling design

The area of the study was 30 × 10 km of a vegetation unit which comprised several ranches with different land uses. Five areas with different land-use histories related to grazing and fire were selected using the judgment employed by Peter et al. (2013):

- Heavily-grazed area (HG): site grazed by sheep at an average stocking rate, but situated ≤600 m from the water point.
- Moderate-grazed area (MG): site grazed by sheep at an average stocking rate, but situated ≥2500 m from the water point.
- Ungrazed area (UG): site located near a railway from which domestic livestock had been excluded for over 50 years.
- Burnt ungrazed area (BU): site burnt in 2002 (eight years before sampling) excluded to livestock after the fire.
- Burnt grazed area (BG): site burnt in 2002 (eight years before sampling) which remained grazed by sheep at the average stocking rate, and situated ≤600 m from the water point.

Three years after the fire occurrence, a five year drought event took place, and mean annual rain ranged from 35% to 75% of the average value (Funk et al., 2012). HG and MG were included in the same paddock, but were 2000 m apart from each other. So grazing intensities of these areas were selected using piospheres (Bisigato y Bertiller, 1997), which are radial grazing gradients created in arid lands from the water point. UG was situated at <100 m from MG, and surrounded by a wire fence to exclude it from livestock grazing. The burnt sites (BG and BU) were separated by fence.

At each paddock, five shrubby islands with a diameter greater than one meter were chosen randomly. On each vegetation patch, one seed trap was placed under shrub cover (n = 5) and another at the adjacent interpatch space (n = 5), with a minimum distance of 1 m from the island edge. Seed traps were built with synthetic fabric (wadding), cut in 30 × 30 cm square units and 1.5 cm thick, and attached to the ground with a metal frame and nails. This type of seed trap was considered appropriate due to the density of the wadding material and the anchorage mechanism of the seeds produced by most of the species included in this study (pers. obs.).

The sampling period was one year long, from September 2010 to August 2011. Seed traps were replaced every two month over this period.

2.3. Sample processing

Seed traps were placed in labeled paper bags and subjected to −18 °C for three days to avoid seed predation by insects trapped in the wadding. After this process, samples were kept in a dark dry place. As all propagules found were fruits with one seed we will refer to them as seeds from here on. During the processing of the traps, seeds were manually removed from the wadding, identified to species level (when possible) and counted. A database was created to facilitate species identification, by collecting seeds