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Livestock grazing affects microclimate conditions for decomposition process through changes in vegetation structure in mountain grasslands

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ABSTRACT

It is often assumed that a change in litter quality is the main driver of alterations in the decomposition process when grazers modify vegetation structure. Soil microclimate is also modified, but this driver of decomposition has been far less studied than litter quality. We analyzed the relationships among vegetation structure, microclimate and decomposition in different mountain grassland types, across a fence-line separating paddocks with different grazing intensity. Along the fence, we selected nine pairs of contrasting grassland types including lawns and tall tussock grasslands, which are associated with high and low local grazing pressure, respectively. At each site ($N = 18$) we estimated growth form composition and vegetation height. During the growing season we recorded soil temperature, soil moisture and the photosynthetically active radiation. Within the same period, we measured the decomposition rate of two common litter substrates. We analyzed the relationships among those variables at the landscape and at the local scale. At the landscape scale we considered the variation across all sites ($N = 18$). At the local scale we considered each pair as a sample ($N = 9$) and the differences between both sides of the fence as the variables to correlate. Our results indicate that when short grasslands are released from grazing and tall grasslands became dominant, temperature and light at the soil level are reduced, while soil moisture tends to increase, enhancing decomposition. Furthermore, these results show that the microclimatic conditions effect can counteract the litter quality effect (reported in previous studies) on decomposition, resulting in increased decomposition rates when grazing is reduced.

1. Introduction

Mountain ecosystems are experiencing land-use changes in an unprecedented way. Pastoral practices have become the main economic activity in these ecosystems in response to the advancement of agriculture on lowlands (Asner et al., 2004). The potential consequences of grazing on litter decomposition through changes in plant biomass quantity and quality as well as dung and urine deposition is well established (Bardgett and Wardle, 2010; Olofsson and Oksanen, 2002; Olofsson et al., 2004; Semmartin et al., 2004, 2010). However, the impact of grazing on changes in soil microclimatic conditions (e.g. soil temperature and moisture) associated with changes in vegetation structure has received little attention, despite their potentially important effects on the decomposition process (Gass and Binkley, 2011; Risch et al., 2007; Stark et al., 2010). Some components of vegetation structure, as dominant growth forms and the quantity of green and standing dead biomass, determine the soil microclimatic conditions. Grazing influences plant community structure and species composition. On the one hand, plant height is reduced by herbivore consumption of aboveground biomass, further leading to a more prostrate growth of dominant plants (Díaz et al., 2007). On the other hand, the consumption of aboveground tissues can promote a replacement of tall by short species, and if grazing persists, it prevents the recolonization of tall species. Vegetation height and aboveground biomass reduction can result in less transpirational surface and a greater soil exposure to radiation and weather elements in grazed areas. Accordingly, LeCain et al. (2000) found higher soil moisture in an ungrazed pasture compared to a grazed one, which was attributed to accumulated litter and standing dead biomass in the ungrazed site. Other authors reported that in woodland systems, grazers may remove the foliage and understory vegetation, leading to an increase in soil temperature concomitant with a decrease in soil moisture (Yates et al., 2000; Xiong et al., 2008). These changes in soil temperature and moisture regimes have important consequences for soil microbial processes by regulating microbial

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activity (Klumpp et al., 2011; Olofsson et al., 2004; van der Waal et al., 2001). In general, high soil temperature combined with enough soil moisture availability enhance microbial activity, but it could be slowed down when soil moisture is limited (Almagro et al., 2009; Voroney, 2007). However, despite the importance of soil temperature and moisture to microbial activities, few studies have analyzed how the changes in vegetation structure induced by grazing could alter litter decomposition processes mediated by changes in soil microclimatic variables.

In the upper belt of the Córdoba mountains in central Argentina, livestock production has been the main economic activity since the beginning of the 17th century (Díaz et al., 1994). Through differential use, domestic herbivores maintain a mosaic of different grassland types including grazing lawns and open and closed tall tussock grasslands (Cingolani et al., 2003, 2010; 2014; Pucheta et al., 1998a). In this system, as in other grasslands, herbivores avoid tall vegetation and strongly select grazing lawns, preventing their conversion into tall tussock grasslands (Cingolani et al., 2003, 2014; Pucheta et al., 1998a, 1998b; von Müller et al., 2017). As predicted by classical theories on the impact of large herbivores in productive systems (Bardgett and Wardle, 2003; Mcnaughton, 1984; McNaughton et al., 1997; Pastor et al., 2006), selective grazing maintain a low input of high quality litter (and hence high decomposability) in lawns, while tussock grasslands receive a high input of low quality litter (Vaieretti et al., 2013). Lawns also receive an important input of dung (Vaieretti et al., 2010; von Müller et al., 2012, 2017), which could contribute to accelerated decomposition rates and nitrogen mineralization (Bardgett and Wardle, 2003). However, despite the differences in the quantity and quality of resources that enter into the soil, in a previous study we found that *in situ* litter decomposition rates were similar in lawns and in closed tussock grasslands, yet lower in open tussock grasslands (Vaieretti et al., 2013).

In that study, we found that *in situ* litter decomposition rates were explained mainly by the microenvironmental conditions (40% of variance, tested by the average of common substrates decomposition rate), while litter decomposability (i.e. decomposition due to litter quality, tested by the average of litter decomposition in a common garden) explained only 15% of variance (see also Poca et al., 2015). These results suggest that some aspects of the microenvironment (the combination of soil physicochemical and biological properties, and microclimate; Eviner and Chapin, 2003) may be the main drivers of field decomposition rates. Considering that in our previous studies (Vaieretti et al., 2010, 2013) soil physicochemical properties were similar across the different grassland types and were not related to differences in decomposition, we hypothesize that it is the microclimate which determine the soil environment effect on decomposition in the field. To test this hypothesis, we here attempted to answer the following questions: (1) How does vegetation structure, as a result of the grazing regime, affect microclimatic conditions? (2) How vegetation structure and microclimatic conditions affect decomposition?

2. Materials and methods

2.1. Study area

The study area is located in a high plateau of Córdoba mountains, in central Argentina (31° 37′S, 64° 48′W). Mean temperatures of the coldest and warmest month are 5.08 °C and 11.48 °C, respectively, with no frost-free period. Mean annual precipitation is 900 mm (1992–2010), mostly concentrated between October and April, which are the warmest months (Colladon et al., 2010). Soils are classified as mollisols, derived from the weathering of the granitic substrate and fine-textured eolian deposits (Cabido et al., 1987). The vegetation of the area is strongly determined by pastoral use and fire events, which in combination with topography result in different landscape units dominated by different plant growth forms (Cingolani et al., 2003, 2004, 2008).

The principal productive activity in the area is livestock raising, which is primarily focused on cattle (mainly Aberdeen Angus breed). Because of the large size of the paddocks, animals can select among different landforms and plant communities (von Müller et al., 2017). At 2000 m s. n.m. three main distinct grassland types can be visually identified: short lawns, open tussock grasslands and closed tussock grasslands. These grassland types are maintained by different local grazing pressure (Cingolani et al., 2003, 2014; Vaieretti et al., 2010, 2013).

Lawns are mainly dominated by annual and perennial grasses and forbs which are highly consumed by herbivores because of their high foliar nutrient content (Pérez Harguindeguy et al., 2000; Pucheta et al., 1998a; Vendramini et al., 2000). These patches have high plant alpha diversity and are associated to high local grazing pressure (Cingolani et al., 2010; Vaieretti et al., 2013; von Müller et al., 2017). Open tussock grasslands comprise a mixture of short plants and tussock species (Cingolani et al., 2003; Pucheta et al., 1998a; Vaieretti et al., 2010). These grasslands in general are dominated by thin tussock grasses such as *Deyeuxia hieronymi* (Hack.) Türpe and several species of *Festuca*, but also present high cover of graminoids and forbs as *Carex* spp. and *Lachemilla pinnata* (Ruiz & Pav.) Rothm. (Vaieretti et al., 2010). Open tussock grasslands are usually associated with high or moderate local grazing pressure (Vaieretti et al., 2013; von Müller et al., 2017). Closed tussock grasslands are strongly dominated by tall tussocks of *Poa stuckertii* (Hack.) Parodi, and other species. This type of grassland is associated to very low or no local grazing pressure (Vaieretti et al., 2013; von Müller et al., 2017). The study was performed in the Quebrada del Condorito National Park and an adjacent area under private ownership. In the section of the National Park selected for this study, livestock was maintained in an attempt to prevent the loss of plant diversity and the excessive accumulation of biomass, which can lead to wildfires (von Müller et al., 2017).

2.2. Experimental design

We selected two adjacent fenced paddocks under different grazing regimes (sustained for at least 15 years). The paddock in the National Park was under continuous stocking density of 0.13 Cattle Equivalents per ha (CE ha^{-1}), which represents low cattle pressure for this grassland system (Cingolani et al., 2014; von Müller et al., 2017), and was characterized by a matrix of closed and open tussock grasslands with some patches of grazing lawns, besides other cover types. The paddock under private ownership was under an average annual stocking density of 0.20 EC. ha^{-1} which represents high cattle pressure, and the vegetation was characterized by a matrix of grazing lawns with some patches of tussocks grasslands, besides other cover types (see Supplementary Material; file S1). We selected nine pairs of sampling sites of contrasting grassland types along the fence. Sites had an area of approximately 100 m^2. The pairs of sampling sites were located at distances of at least 25–30 m to each other (see Supplementary Material; file S1). Two pairs of sites were lawns contrasted with open tussock grasslands, two pairs were lawns contrasted with closed tussock grasslands, and two pairs were open tussock grasslands contrasted with closed tussock grasslands. In all pairs, the site with more open vegetation was located in the high grazing paddock (i.e. the private ownership paddock; Table 1). Additionally, we selected three pairs of sites conformed by the same grassland type at each side of the fence (one pair of each grassland type) which were used as controls (Table 1). The distance among sites of the same pair separated by the fence varied between one and two meters. All pairs of sampling sites were located at similar altitudes (2140–2160 m a.s.l.), at gentle slopes (2–10%) with south-west aspect and slightly variable topographic positions. The fence-line provide a direct comparison, at both sides of each pair, of vegetation structure due to differences in past and present grazing management avoiding differences in topography or pre-existent soil characteristics. Designs like this have been used to analyze the effect of