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Native and non-native herbaceous species dependence on tree cover in grazing systems from northern Chilean Patagonia

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ABSTRACT

Grazing systems that combine grasslands and woodlands represent changes in tree cover that influences herbaceous vegetation and may threaten the native forest flora. We studied these influences in Chilean Patagonia where recent colonization resulted in the fragmentation of the lenga (*Nothofagus pumilio*) forests leading to a mosaic-type landscape. The herbaceous vegetation, transmitted photosynthetically active radiation (PAR) and other forest structure characteristics were sampled in 15 (20 m × 20 m) plots differing in tree cover for two years, while considering the relative position (below or beyond) of tree crowns. Herbaceous species were classified as forest, non-forest, and forest indifferent species according to their preference, rejection or indifference to the forest environment. Species richness decreased with increasing PAR but this was dependent on the response of non-natives. Species composition varied gradually from open grasslands to dense forests, according to transmitted PAR values. Native species were associated to either forests or open areas, but the number of native species did not vary along the tree cover gradient (beyond tree crowns) or even decreased (below tree crowns). Non-native species dominated in the open grasslands and beyond tree crowns and its richness increased with transmitted PAR. The occurrence of grasslands and dense forests within this grazing system is shown to promote higher species richness. Management will consider that dense forest patches are necessary for maintaining a high diversity of native species, since isolated trees or low wooded areas do not guarantee the persistence of all native species associated to the original forests.

1. Introduction

Tree cover has significant influence on the understory vegetation (Scholes and Archer, 1997; Barbier et al., 2008). The variation of tree cover from dense forest to open grassland in the same area (the 'grassland-forest continuum', *sensu* Breshears, 2006) results in a mosaic of environmental conditions that determines the type of vegetation under the canopy. The area of influence of trees can extend beyond the vertical projection of the canopies, due to their effects on the microclimatic conditions, i.e. solar radiation, temperature, wind speed and water availability (Matlack, 1993; Baldocchi et al., 2002; Ovalle et al., 2006) and on the amount of litter and soil nutrients (Facelli and Pickett, 1991; Dorrough et al., 2006; Barnes et al., 2009). Herbaceous plant species respond to this influence, either by restricting its distribution to certain habitats or by showing a wide distribution range (Scholes and Archer, 1997; Gilliam, 2007).

Deforestation for the expansion of agricultural lands and grazing systems has led to many of the tree-grass mosaic-type human-dominated landscapes we see today worldwide (Huston, 2005; Manning et al., 2006), such as silvopastoral systems (*sensu* Nair, 1993). Subsequent changes in tree cover and forest fragmentation entails a remarkable change for the original ecosystems, where the consequences for the herbaceous vegetation and the threat to the native species have been largely overlooked (Honnay et al., 2002; Whigham, 2004; Barbier et al., 2008; Moola and Vasseur, 2008). Moreover, grazing in areas with varying tree cover profoundly alters herbaceous plant communities (Scholes and Archer, 1997; Clarke, 2003; Dorrough et al., 2006; Barnes et al., 2009). The fact that forest herbs account for most of the species diversity in temperate regions (Whigham, 2004; Gilliam, 2007; Moola and Vasseur, 2008) encourages focusing more research attention on the response of the herbaceous layer to changes in tree cover and grazing regime in order to minimize biodiversity loss in recently modified landscapes (Huston, 2005; Pastur et al., 2012).

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The characterization of the response of plant species to tree cover changes and grazing has important implications for the management of landscapes for biodiversity conservation. Globally, conservation of native biodiversity in agricultural landscapes has become a major challenge for both management and scientific research (Manning et al., 2006; Wardle et al., 2011; Balmford et al., 2012). In particular, the introduction and naturalization of exotic (non-native) plant species is long recognized as a major threat for the native flora in a wide range of landscapes (e.g. Moore and Goodall, 1977; Holmgren et al., 2000; Meiners et al., 2002; Domínguez et al., 2006). In this context, silvopastoral systems are worldwide recognized as examples of grazing systems that improve the conservation value of grasslands (Nair, 1993; Ovalle et al., 2006; Le Brocque et al., 2009; Marañón et al., 2009). Remnant trees or forests increase environmental heterogeneity and provide the habitat for survival of native herbaceous species (Manning et al., 2006, 2009). Studies conducted in temperate environments show that tree cover has great influence on the regeneration of tree species (Barbier et al., 2008) and diversity of the understory herbaceous communities (Damascos and Rapoport, 2002; Whigham, 2004; Gilliam, 2007; Lencinas et al., 2008, 2011).

In Chilean Patagonia, the human activity since the early twentieth century resulted in the fragmentation of the vast extensions of 'lenga' (*Nothofagus pumilio* [Poepp. & Endl.] Krasser) forests leading to a mosaic-type landscape with patches of forest fragments and open grasslands (Veblen et al., 1996). The resulting grassland communities are composed by herbaceous species native to Chile and Argentina, and non-native species (mainly European) introduced, deliberately or not, by the settlers for forage production (Silva et al., 1999). The area is usually grazed by wild and domestic herbivores which also have a great influence on the dynamics of natural forest regeneration (Veblen et al., 1989; Cavieres and Fajardo, 2005; Blackhall et al., 2008).

Even though some studies have analyzed the response of the herbaceous communities to varying lenga tree cover by natural forest dynamics or silvicultural practices (Damascos and Rapoport, 2002; Lencinas et al., 2008, 2011), little is known about the consequences for plant species richness of native and non-native species and their dependence on lenga tree cover under a cattle grazing regime. In general, the introduction of domestic cattle in Patagonia is argued to favor non-native herbaceous species and to be detrimental to the native ones (Domínguez et al., 2006). We developed previous research in the study area showing that, along the lenga tree cover gradient, optimal values of herbaceous production and quality are reached at intermediate tree cover, with no significant change in the number of species but a negative linear relationship in the percentage of the natives in the community with decreasing tree cover (Sánchez-Jardón et al., 2010). A better understanding of these novel silvopastoral systems within the mosaic-type landscapes may contribute to improve local plant species richness and native plant conservation, thus enhancing the conservation value of grasslands for livestock production in this region. Moreover, the characterization of the influence of tree cover and grazing on understory plant diversity in Patagonian forests will be useful for both grazing and biodiversity management and would eventually allow to set the scientific basis for ecological restoration of the original forest.

In this study the response of native and non-native herbaceous species along a lenga tree cover gradient and open grasslands was examined in a traditional grazing production system in Chilean Patagonia. The main objectives were (1) to characterize the distribution of herbaceous species to a lenga tree cover gradient, and (2) to analyze the differential response of native and non-native species (abundance and richness) to this gradient.

2. Materials and methods

2.1. Study area

The study was undertaken in central Aysén region, northern Chilean Patagonia, in the original distribution area of monospecific lenga forests at mid-elevations. During colonization in the early 1900s, settlers used fire to transform extensive areas of the original forest into the current mosaic-type landscape (Veblen et al., 1996) and they introduced non-native herbaceous species either deliberately for forage production or accidentally as companion species of the former, that are at present widely naturalized in the area (Silva et al., 1999). Currently, fragments of the original forest remain within the mosaic-type landscape dominated by seminatural, cultivated grasslands for livestock production, where primary forests remain at higher (less accessible) elevations (Fig. 1 in Sánchez-Jardón et al., 2010). The primary land use is extensive cattle grazing with some sheep grazing. Forest fragments are grazed along with the latter, especially during summer months.

The study area was located in Tamel Aike – Institute of Agricultural Research (INIA) station in the Simpson Valley (Coyhaique County, Aysén region, Chile; 45°58′ S, 72°08′ W, 590 m.a.s.l.). The valley represents a typical Chilean Patagonian valley, common in the Aysén region. Mean annual temperature from the closest meteorological station (located in Aerodromo Teniente Vidal, nearby the city of Coyhaique) is 8 °C, mean maximum temperature in January (warmest month) is 19 °C and minimum temperature in July (coldest month) is −0.5 °C. Annual precipitation is 994 mm. This climate limits the growing season to approximately six months, from October to March–April. Differences in temperature and precipitation occurred between the two growing seasons considered in this study, the first (2006–2007) was wetter and cooler than the second (2007–2008). In order to simulate a grazing production system traditional in Chilean Patagonia, one 50 ha sector comprising open grasslands and lenga forest with varying tree cover was delimited within the research station. The sector has been grazed by cattle during summer months for at least 12 years prior to this study. During the study, this sector was grazed from December to April–May by a stock of approximately 20 cows (with calves) following traditional practices.

2.2. Data collection

Fifteen plots (20 m × 20 m) within a gradient of tree cover (from open grassland to dense forest) were distributed in this sector (Fig. 1a). Three of the plots were located in open grasslands and three in dense forests. To characterize the forest structure along the tree cover gradient considered, transmitted PAR – photosynthetically active radiation – and other forest structure variables were measured in each plot. At each plot, PAR was measured at midday on a sunny summer day in 2007 (January 8–10) and 2008 (January 21–23), using a 0.8 m length ceptometer (AccuPAR model PAR-80, Decagon Devices Inc., USA). Measurements were conducted on summer months in order to maximize differences in light transmitted through the canopy of the deciduous lenga trees between plots. Transmitted PAR (%) was calculated at each plot as the mean incident PAR compared to a reference measure of incident PAR recorded every 15 min in a nearby open area (at least 20 meters away from the closest tree). One hundred readings were taken along two diagonal transects in each plot (200 records per plot) in 2007 and following a quadrangular grid (100 records per plot) in 2008. A high correlation was found between transmitted PAR in 2007 and 2008 ($r = 0.99$; $P < 0.001$), indicating that no significant difference existed between years or measuring methods. Additionally, forest structure variables were measured at each plot: number of adult trees, diameter at breast height (DBH) over 10 cm, average