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Research Letters

# Effect of shrub encroachment on vegetation communities in Brazilian forest-grassland mosaics

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A B S T R A C T

Woody vegetation encroachment in natural grasslands is a concern in many parts of the world. We evaluated the effect of *Baccharis uncinella* (Asteraceae) encroachment on grassland vegetation in southern Brazil, in terms of plant composition and richness. We conducted a vegetation survey in 12 plots of 10 × 10 m. The study site was a forest-grassland mosaic where management practices have been excluded since 1994. Six plots were located in areas without *B. uncinella* and the remaining six in different densities of it. Within each plot, we randomly placed three subplots of 1 × 1 m where we identified plant species and estimated their cover. Vegetation height, total plant cover and standing dead biomass were also estimated. We recorded 46 species belonging to 15 families; 34 of them were in plots with *B. uncinella* (29% grasses, 44% shrubs, 24% forbs and 3% trees) and 37 in plots without it (27% grasses, 35% shrubs and 38% forbs). *B. uncinella* affected grassland community by reducing total plant richness and decreasing the number of forb species. *B. uncinella* may alter the availability of resources, affecting the ability of forbs to establish and grow. The capacity of *B. uncinella* to occupy adjacent open-canopy ecosystems and to suppress grassland plants indicates that, without any management practice, plant richness in Brazilian highland grasslands may decrease. This study presents empirical data that may contribute to conservation efforts of forest-grasslands mosaics in southern Brazil.



## Introduction

The encroachment of woody vegetation in open-canopy ecosystems, *i.e.* grasslands and savannas, has been observed in many parts of the world (Archer, 1990; Bond and Midgley, 2000; Bond et al., 2003; Duarte et al., 2006). This process can be defined as increasing density, cover and biomass of trees and/or shrubs species in open-canopy ecosystems (Van Auken, 2000). The causes are mainly related to changes in climatic variables (*i.e.* warmer and more humid conditions), land use modifications and decreased frequency or cessation of disturbance regimes, resulting herbaceous species being replaced by tussock grasses, shrubs and/or trees (Hobbs and Mooney, 1986; Overbeck et al., 2005).

Woody encroachment often presents conservation concerns (Van Auken, 2000; Overbeck et al., 2007), as it modifies functions and processes of open-canopy ecosystems (Eldridge et al., 2011), such as total primary productivity, decomposition rates, nutrient availability and soil carbon dynamics (Lett and Knapp, 2003). As a result, these modifications could facilitate the growth of other woody species, for example some trees acting as nurse plants (*e.g.* Duarte et al., 2006), creating a positive feedback that might result in an irreversible woody encroachment process (Callaway and Davis, 1998; Barnes and Archer, 1999). Consequently, community and environmental changes can modify resource availability below some species requirements and thus, result in certain species being suppressed (Hobbs and Mooney, 1986). In this way, herbaceous plant cover and productivity may be reduced, which often results in significant decreases in grassland species richness and diversity (Hobbs and Mooney, 1986).

In the southernmost state of Brazil, Rio Grande do Sul, highland grasslands occur in the *Mata Atlântica* biome, within shrubby and forest physiognomies belonging to *Araucaria* pine tree and seasonal forests. Fire and cattle grazing are thought to be responsible for the maintenance of these forest-grassland mosaics under a climate more suitable for forest development (Pillar and Quadros, 1997). Vegetation composition and structure have changed over the last millennia, and it is known that woody species have increased in density and cover, mainly due to climate change and lack of

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management regimes (*i.e.* fire and grazing suppression) (Behling and Pillar, 2007; Overbeck et al., 2007; Andrade et al., 2015, 2016). *Baccharis uncinella* D.C. (Asteraceae) is one of these woody species, with spontaneous occurrences found in southern and southeastern regions of Brazil. In Rio Grande do Sul state, it is considered an endemic shrub of the "*Campos de Cima da Serra*" region. This region is characterized as a high altitude humid grassland region in forest-grassland mosaics (Andrade et al., 2016). Although *B. uncinella* encroachment is a recognized process in Brazilian grasslands-forest mosaics (Duarte et al., 2006), there is a lack of information about its effects on grassland vegetation. *B. uncinella* expansion could have important implications for forest-grassland mosaics conservation, as it may represent the initial stage of grassland conversion to forest. Currently, there is a debate about the best approach to conserve forest-grasslands mosaics in southern Brazil (see Pillar and Vélez-Martin, 2010; Luza et al., 2014; Carlucci et al., 2016; Overbeck et al., 2016). By gaining an understanding of the impacts *B. uncinella* could have on grassland ecosystems, conservationists would acquire important information about the encroachment process.

The aim of this study was to evaluate the effect of *B. uncinella* performance in a forest-grassland mosaic in southern Brazil. Management practices, *i.e.* fire and cattle grazing, were excluded from the study area since 1994. Specifically, we evaluated the influence of *B. uncinella* on grassland plant composition and richness, and whether this influence affects certain life forms (*i.e.* shrubs, grasses and forbs). Previous studies conducted in this region have shown changes in grassland species composition and richness when disturbance practices are excluded, mainly by increasing tussock grasses and shrubs cover (Oliveira and Pillar, 2004; Overbeck et al., 2005; Andrade et al., 2016). Thus, we expect the encroachment of *B. uncinella* to affect grassland community vegetation, promoting not only differences in species composition but also reducing the richness of typical grassland plants.

## Methods

### *Study site*

The study site is located in the Center for Research and Conservation of Nature (CPCN) Pro-Mata (29°28′S, 50°30′W), in São Francisco de Paula, southern Brazil. The altitude ranges between 600 and 1000 m a.s.l. and the predominant climate is the Cfb type (Köppen classification). Mean annual temperature is approximately 15.1 °C, with freezing temperatures occurring from April to November. Mean annual rainfall is 2086 mm, equally distributed throughout the year (Hijmans et al., 2005).

The regional landscape is composed of grassland mosaics interspersed with *Araucaria* and seasonal forests, resulting in a unique vegetation type with high diversity in the *Mata Atlântica* biome. Boldrini (2009) reported 1161 plant species, of which 107 are considered endemic to the region. Many of these species are endangered due to the rapid conversion of grasslands to other land uses, such as agriculture and forestry (Pillar and Vélez-Martin, 2010; Andrade et al., 2015). Fire and grazing practices have contributed to the persistence of grassland vegetation and differential forest expansion patterns, which may result in forest-grasslands patches (Pillar and Quadros, 1997; Oliveira and Pillar, 2004). Thus, the exclusion of cattle grazing and manmade fire in the study area, since 1994, promoted the growth of tall and dense grassland matrix composed of caespitose grasses (*e.g. Andropogon lateralis* Nees) and shrubs (*e.g. B. uncinella*, *Calea phyllolepis* Baker) (Oliveira and Pillar, 2004).

### *Data collection*

Vegetation surveys were carried out in January 2013 in 12 plots of 10 × 10 m. Six plots were established in areas without *B. uncinella*, and at least 30 m from the forest edge, while the other six plots were established in areas with different densities of *B. uncinella*. Within each plot, we randomly placed three subplots of 1 × 1 m where we (i) identified all plant species and estimated each species cover, (ii) measured mean vegetation height, (iii) total plant cover and (iv) standing dead biomass cover. Cover assessments were based on visual estimation of above-ground cover. We used a modified scale of Londo (1976), which varied from 0.1 to 10 (0.1: <1%; 0.2: 1–3%; 0.4: 3–5%; 1: 5–15%; 2: 15–25%; 3: 25–35% and so on). In each plot with *B. uncinella*, we recorded total number of individuals, mean diameter (at breast level from five random individuals) and mean height.

### *Data analysis*

We tested for differences in species composition (using species cover per plot matrix) between grassland communities with and without *B. uncinella*. For that, we performed a Principal Coordinate Analysis (PCoA) as an explanatory analysis, and used MANOVA with permutation test for evaluating significant differences between both groups.

We tested for the effect of *B. uncinella* performance in total species richness, and also separately for each life form, including shrubs, grasses and forbs, with simple linear regressions. *B. uncinella* performance ($P$) per plot was estimated as: $P = I \times D \times H$, where $I$ is the number of *B. uncinella* individuals, $D$ is the mean diameter, and $H$ is the mean height. We also evaluated the effect of *B. uncinella* performance on vegetation mean height, total cover and dead standing biomass using simple linear regressions.

For all analyses we used the software MULTIV (http://ecoqua.ecologia.ufrgs.br) with 10,000 permutations.

## Results

We recorded 46 plant species in total, belonging to 15 families (see Appendix S1). The most common families were Asteraceae (28%), Poaceae (20%) and Melastomataceae (15%). Grass species had the highest percentage of vegetation cover in both situations, with (67%) and without (64%) *B. uncinella*. Among the 46 recorded species, 34 of them (12 exclusive) were recorded in plots with *B. uncinella*; 29% of them grasses, 44% shrubs, 24% forbs and 3% trees. *Trachypogon montufarii* (Kunth) Nees (10%) and *Baccharis trimera* (Less.) DC (9%) were the most frequently occurring species in plots with *B. uncinella*. Moreover, 37 species (9 exclusive) were recorded in plots without *B. uncinella*, where 27% of them were grasses, 35% shrubs and 38% forbs. *Axonopus siccus* (Nees) Kuhlmand and *Schizachyrium tenerum* Nees, both caespitose grasses, were the most frequently occurring species (10%) when *B. uncinella* was absent.

Despite the exploratory analysis (PCoA) showing a tendency of distinct composition between communities with and without *B. uncinella* (Fig. 1), we did not find significant differences in species composition between both groups ($p = 0.47$).

Species richness in grassland communities showed a negative significant relationship with *B. uncinella* performance ($R^2 = 0.36$; $p = 0.04$; Fig. 2A). Regarding plant life forms, forb was the only group that showed a significantly negative relationship with *B. uncinella* performance ($R^2 = 0.43$; $p = 0.017$; Fig. 2D). Shrub and grass species also showed a negative trend, but these relationships were not significant (Fig. 2B and C). Moreover, vegetation height ($R^2 = 0.004$; $p = 0.85$), total vegetation cover ($R^2 = 0.125$; $p = 0.25$) and standing dead biomass ($R^2 = 0.139$; $p = 0.23$) did not show significant relationships with *B. uncinella* performance.

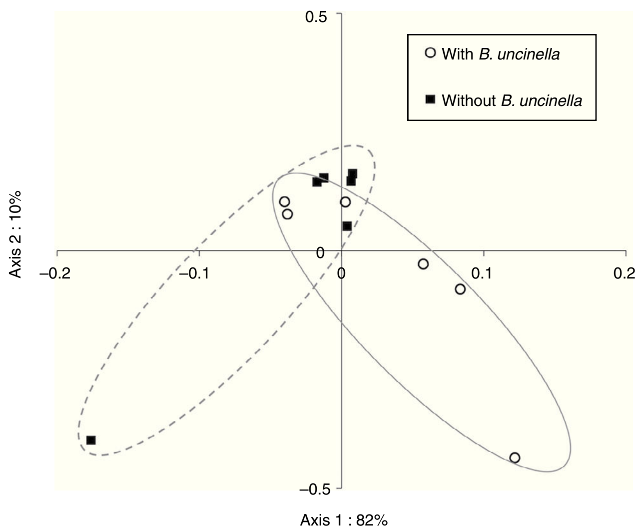


**Fig. 1.** Diagram of the distribution of the plots with and without *Baccharis uncinella*, according with the PCoA of the species cover matrix.

## Discussion

Shrub encroachment in southern Brazilian grasslands as a result of management suppression (*i.e.* cattle grazing and fire) deserves particular attention in the *Mata Atlântica* biome, where current temperature and precipitation conditions favor forest expansion, reducing native grassland vegetation (Oliveira and Pillar, 2004; Pillar and Vélez-Martin, 2010; Andrade et al., 2016; Overbeck et al., 2016). Our study contributes to understanding one of the main concerns about Brazilian forest-grassland mosaics conservation, an important and uniquely biodiverse ecosystem that is currently threatened by global climate change and inadequate local management practices (Oliveira and Pillar, 2004). We showed that *B. uncinella* encroachment had a significant effect on grassland community, reducing native plant richness, and particularly the number of forbs species. However, our results suggested that the presence of *B. uncinella* does not affect the richness of other life forms.

The encroachment of shrubs in natural grasslands could alter resource availability (*e.g.* light interception and soil moisture), affecting the ability of some species to establish and grow (Lett and Knapp, 2003). Our results suggest that some forbs species were mainly observed growing in plots without *B. uncinella*, such as *Galium hirtum* Lam., *Lucilia* sp. Cass, *Polygala brasiliensis* L. and *Sysirinchium* sp. L. Therefore, the presence of *B. uncinella* would lead to a reduction of certain species, such as forbs, which exhibit morphological, life history and ecophysiological traits that contrast sharply with those of the dominant $C_4$ tussock grasses. These traits may limit certain plants ability to obtain resources, mainly light, beneath a *B. uncinella* canopy. The shrubs canopy would decrease light interception, which could mainly affect forbs species due to their shorter height and different specific leaf area without conferring any advantage to caespitose grasses. Previous studies which evaluated the effect of shrub encroachment in open-canopy ecosystems, *i.e.* grassland with no or few trees, reported significant community changes. Such changes were mainly related to a reduction in herbaceous species due to alterations in resource availability (Hobbs and Mooney, 1986; Lett and Knapp, 2003).

In Brazil, conservation efforts are primarily focused on forest ecosystems with grasslands receiving less attention (Overbeck et al., 2007). Nevertheless, woody encroachment in open ecosystems is well documented for many parts of the world (Archer,

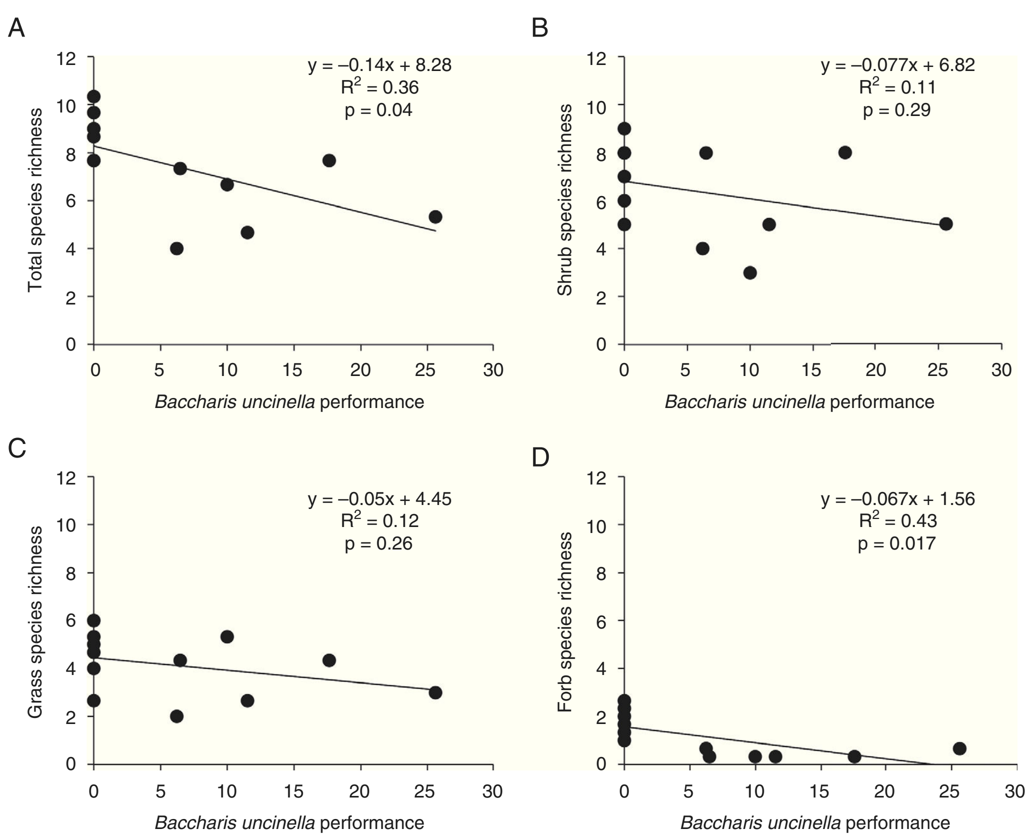


**Fig. 2.** Relationship between community species richness and *B. uncinella* performance per plot (10 × 10 m; *n* = 12). (A) Relationship between total species richness and *B. uncinella* performance. (B) Relationship between shrub richness and *B. uncinella* performance. (C) Relationship between grass richness and *B. uncinella* performance. (D) Relationship between forbs richness and *B. uncinella* performance.

1990; Bond and Midgley, 2000; Van Auken, 2000; Bond et al., 2003; Duarte et al., 2006). As other studies in southern Brazil have suggested (*e.g.* Oliveira and Pillar, 2004; Overbeck et al., 2005; Blanco et al., 2014; Andrade et al., 2016), we observed that the exclusion of disturbances regimes in forest-grassland mosaics would initially result in grassland species loss, mainly due to the encroachment of woody species, such as *B. uncinella*. The presence of such woody species may lead to competitive exclusion of subordinate plants (*e.g.* forbs). Therefore, studies with management practices that reconcile the maintenance of forest-grassland mosaics as a whole are urgently needed. For example, grassland patches can be conserved with adequate fire and grazing regimes to prevent woody expansion and corresponding reduction in grassland species richness. However, these management practices should be avoided inside woody patches to maintain tree recruitment. Longer-term studies are required to evaluate the response of each vegetation type to different management practices, and therefore, to decide which strategies are more appropriate for forest-grassland mosaics conservation.

In our study site, vegetation composition was homogeneous, a few native caespitose grasses dominated the community (*e.g. A. lateralis* and *A. siccus*), and populations of *B. uncinella* seem to be expanding into the open-canopy ecosystem. The capacity of *B. uncinella* to occupy adjacent open ecosystems and to reduce its richness indicates that grassland vegetation is being suppressed in the absence of management practices. However, our study is a first step to understand more about the effects behind *B. uncinella* expansion. Longer-term studies on the causes and mechanisms of this encroachment process are needed; as such encroachment has important implications for Brazilian forest-grassland mosaics conservation.

## Conflicts of interest

The authors declare no conflicts of interest.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.pecon.2016.11.002.

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