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Research Letters

Effects of initial disturbances and grazing regime on native grassland invasion by *Eragrostis plana* in southern Brazil

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ABSTRACT

Extensive invasion of the Campos grasslands of southern Brazil by the South African grass, *Eragrostis plana*, is a serious conservation problem due to its low palatability and ability to quickly spread. Here, we experimentally evaluated the effects of grazing management and initial disturbance on invasibility of native grassland community by *E. plana*. The experiment, a split-plot complete block design with three replications, was established in 2004 in non-invaded native grassland. Grazing management treatments were assessed in main plots (continuous grazing, rotational grazing, and grazing exclusion). The initial disturbance treatments (light grazing, heavy grazing, and heavy grazing plus soil scarification) were applied in subplots before the sowing of standard amounts of *E. plana* seeds. The initial disturbances heavy grazing and heavy grazing plus soil scarification simulated the introduction of exotic forage species. We monitor plant species composition and diversity along six years after the experiment starting. The effects of grazing management and initial disturbance on community invasibility were significant and showed interaction. Heavy grazing plus soil scarification increased the rate of *E. plana* invasion and produced more pronounced changes in species composition than the other treatments. Plots under grazing exclusion, rotational or continuous grazing without soil scarification had low levels of invasion (<10% cover). But exclusion also changed community composition and decreased diversity, while rotational and continuous grazing maintained community structure. The invasion can be largely prevented on undisturbed grassland by employing either rotational or continuous grazing management. If the livestock producers want to introduce another forage species in their natural grasslands and, at the same time, do not run the risk of opening space for *E. plana* should avoid the use of soil scarification.

Introduction

Biological invasions by exotic species around the world have increased during the recent decades perhaps due to the increase of global trade and the opening of new markets (Pyšek et al., 2010). Invasion by *Eragrostis plana* (lovegrass), a South African native species locally known as *capim-annoni*, has been causing damage to native grasslands, affecting the grasslands since community composition, structure, diversity, forage quality, and social systems in southern Brazil (Medeiros et al., 2009). *E. plana* is widely spread in this region mainly along roadsides and in compacted soil areas. This species also has some features that give it competitive advantages in relation to native species as the high production of small viable seeds presenting dormancy (Medeiros et al., 2014), development even under low levels of soil nutrients due to its photosynthetic efficiency and anatomical features, high levels of lignin, which makes it unpalatable for cattle, and the ability to store starch on roots (Favaretto et al., 2015a). By 2004, it was estimated that over one million hectares had been already invaded by *E. plana* mainly in the native grasslands of southern Brazil (Medeiros and Focht, 2007). However, bioclimatic modelling of the habitat suitability in South America has predicted that the occupied region may greatly increase (Barbosa et al., 2013).

The southern Brazilian Grasslands (Campos) are native ecosystems holding high species richness (Boldrini, 2009), where disturbances by grazing and/or fire are essential under present

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climatic conditions to maintain the physiognomy and plant diversity (Overbeck et al., 2007). These ecosystems feature a long history of coevolution between plant species and large grazers until the extinction of the latter by the end of the Pleistocene (Cingolani et al., 2005; MacFadden, 2000). Thereafter anthropogenic fire played a key role in maintaining open vegetation until the introduction of cattle and horses at the 18th century (Behling et al., 2007; Müller et al., 2012). Since 1970, these grasslands have been strongly affected by land use changes leading to increased conversion into annual croplands (mainly soybean and rice), forest plantations, planted pastures with exotic species (Overbeck et al., 2007) and invasion by *E. plana* (Guido et al., 2016; Medeiros et al., 2009).

Livestock producers manage natural grasslands through different ways, mostly manipulating the grazing intensity and introducing exotic species in order to increase the forage productivity. The intensity of grazing is recognized as a regulator of the competition processes in grasslands plant community, altering vegetation structure parameters such as species richness and evenness. In moist pastures, such as those found in the southern Campos, it is common to find intensely grazed areas with greater richness of species, benefiting forbs and grasses species with physiological and morphological adaptations to survive under intense grazing (Cingolani et al., 2005). At lower intensities, there is a tendency to decrease plant richness and predominate species with greater competitive potential, such as caespitose grasses, greatly reducing species evenness (Hendon and Briske, 2002; Škornik et al., 2010). Therefore, by manipulating the intensity of grazing, livestock producers influence local resource availability and the balance of structuring community processes (Davis et al., 2000). Other management strategy used by livestock producers is the introducing of exotic forage species aiming the increase of forage amount in winter when native grassland species are less productive. This strategy is often accompanied by soil disturbance or heavy grazing, which breaks with the coverage structure of the communities, altering light availability, exposing bare soil and nutrients, and weakening local species (Hobbs and Huenneke, 1992). Therefore, both management actions modify the resources availability and the balance of competition and facilitation interactions (Bruno et al., 2003) and thus they can change the invasibility of the grassland communities (Hobbs and Huenneke, 1992).

Disturbances largely influence community assembly and invasibility of ecosystems (Davis et al., 2000; Colautti et al., 2006). In general, invasion processes are determined by several factors that co-vary in space and time, including climate (Parepa et al., 2013), community structure (Tilman, 2004; Fargione and Tilman, 2005), disturbances (*sensu* Hobbs and Huenneke, 1992) in different scales (Stohlgren et al., 2006), resource availability (Davis et al., 2000), propagule pressure (Colautti et al., 2006) and related with ecosystem processes (Moles et al., 2012). Endogenous community factors are considered to define the resistance of communities to invasion and they may be biotic or abiotic. Biotic resistance is the reduction in the success of the invasion caused by competition or disease (Levine et al., 2004; Kuebbing and Nuñez, 2015), while abiotic resistance is when the invader does not tolerate a given habitat condition (Davis et al., 2000), such as the restriction of a given species to a climatic condition. Yet, since abiotic conditions influence the biota and vice versa, the interaction of both sources of resistance should be considered when assessing invasion processes.

Here we report results of a six-year experiment assessing the effects of grazing management (rotational grazing, continuous grazing and grazing exclusion) combined with different types of initial disturbance (two levels of grazing intensity and soil scarification) on plant community dynamics and invasion by *E. plana* during this period. *E. plana* was sowed at high seed density. We assessed species composition, richness, evenness and diversity of plant communities during six years after the starting of the experiment, as well as the amount of *E. plana* coverage. We hypothesized that the treatments that simulate conditions for forage species introduction, i.e. those that first alter the community structure with heavy grazing with or without soil scarification, will result in invasion by *E. plana* contrasting with the treatment of light grazing. The greater change in the initial conditions (i.e. heavy grazing with soil scarification), more intensive will be the invasion. We even predict that such initial changes will influence community structure parameters, leading to differences between treatments concerning diversity, evenness, and species composition trajectories along the observed period. Moreover, we expected changes in community structure due to differences on simulations of grazing management. Rotational regime would allow a plant community with greater resistance to invasion by *E. plana* due to higher diversity and evenness, while grazing exclusion will promote unevenness communities, with low invasion rates, but with a very distinct trajectory characterized by low richness and tussock grasses dominance.

Methods

Study area

The experiment was established in a native grassland paddock (31°5′53.83″S, 54°57′37.44″W) with 8100 square metres, located at *Estância Upacaraí* farm, municipality of Dom Pedrito, Rio Grande do Sul, Brazil (see Focht and Borges de Medeiros, 2012 for more details). The area has been grazed by cattle and horses since the 17th century, when grazers were introduced in the region. *E. plana* was absent in the experimental site, but was present in nearby paddocks and roadsides. The climate type is Cfa (Köppen classification) with 1430 mm annual mean precipitation and frequent water deficits during summer (Alvares et al., 2013). The annual mean temperature was 20.2 °C, while the average temperature of the warmest month and the coldest month was 24 °C and 12.4 °C, respectively. The soil corresponds to Chernozems (IUSS Working Group, 2015).

Experimental design

The experiment was a split-plot design with three complete 30 × 90 m blocks (Appendix S1). Three grazing treatments were applied to the main plots (30 × 30 m): (1) continuous grazing by cattle (*Bos taurus*), (2) rotational grazing and (3) grazing exclusion. Further, before the sowing of *E. plana*, three disturbance treatments were applied once to the subplots (30 × 10 m) within each main plot in July 2004: (1) light grazing that left an aboveground biomass residue of ca. 10 cm height (LG); (2) heavy grazing that left and aboveground residue of ca. 5 cm height (HG); and (3) heavy grazing that left and aboveground residue of ca. 5 cm height plus soil scarification by rotatory tilling to 10 cm depth (HG + SC). Treatments (HG) and (HG + SC) also included the sowing of a seed mixture with *Lolium multiflorum* (25 kg ha^{-1}), *Lotus corniculatus* (6 kg ha^{-1}), and *Trifolium repens* (2 kg ha^{-1}), which are forage species commonly used in winter pastures regionally.

The continuous grazing treatment was applied according to the local farm management regime by allowing free cattle access into the assigned main plots. The mean stocking rate in this treatment was 0.7 animals ha^{-1} (280 kg live weight of cattle ha^{-1}), aiming at maintaining the sward height at ca. 5 cm (recorded mean was 6.14 ± 1.6 cm). The main plots assigned to the rotational grazing treatment were fenced and temporarily grazed about eight times per year by cows that were fasted during the previous night. Cows were maintained in each plot until sward height was reduced to ca. 10 cm (recorded mean was 11.37 ± 3.7 cm). This rotational grazing treatment was maintained until mid 2007 (34 months