

HIGHLAND GRASSLANDS AT THE SOUTHERN TIP OF THE ATLANTIC FOREST BIOME: MANAGEMENT OPTIONS AND CONSERVATION CHALLENGES

Bianca O. Andrade ^{1*}, Camila L. Bonilha ¹, Pedro Maria A. Ferreira ², Ilsi I. Boldrini ^{1,3} & Gerhard E. Overbeck ^{1,3}

¹ Universidade Federal do Rio Grande do Sul (UFRGS), Institute of Biosciences, Graduate Program in Botany. Av. Bento Gonçalves, 1500, Porto Alegre, RS, Brazil. CEP: 91.501-970

² Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS), Faculdade de Biociências. Av. Ipiranga, 6681, Porto Alegre, RS, Brazil. CEP 90619-900

³ Universidade Federal do Rio Grande do Sul (UFRGS), Department of Botany. Av. Bento Gonçalves, 1500, Porto Alegre, RS, Brazil. CEP 91501-970

E-mails: andradebo@gmail.com, bonilhacamila@hotmail.com, pedro.abreu@pucrs.br, ilsi.boldrini@ufrgs.br, gerhard.overbeck@ufrgs.br

ABSTRACT

The natural vegetation in the highlands of the southernmost state of Brazil, Rio Grande do Sul, is characterized by extensive grasslands in mosaics with Araucaria forests, usually under cattle grazing. Plant species diversity and endemism in these grasslands is high, though poorly recognized in conservation policy and the general public, and conversion rates into other land uses are high. In this paper, we give an overview of principal biological features of grassland vegetation in the South Brazilian highland region (plant species richness and diversity) and initiate a debate on conservation possibilities and challenges. We use data from four sites of the Long-Term Ecological Research program (LTER/PELD) *Campos Sulinos* situated in the highland region of the state, where we explore the effects of different types of grassland management (grazing and grazing exclusion) on vegetation structure and composition. Our data give insight into high species richness on both the plot and site scale. Overall, the results indicate the importance of adequate management for the maintenance of grassland vegetation and its characteristic biological features. In theory, grazing or fire can be employed in grassland management, but specific effects of these two types of management need to be considered, as each type of management has distinct effects. We discuss the question of active nature management in conservation units and highlight the importance of research on restoration of degraded grassland areas. Even though grasslands make up the smaller portion of the South Brazilian Atlantic Forest region, their ecological uniqueness calls for specific conservation policy.

Keywords: Campos Sulinos; grazing; restoration; Rio Grande do Sul; vegetation dynamics.

INTRODUCTION

The term *Campos de Altitude* (Highland Grasslands) is generally used for grasslands situated at an altitude above 1.500 or 1.800 m a.s.l. in south-eastern Brazil, from the state of Santa Catarina to the states of Minas Gerais and Espírito Santo, namely in the *Serra do Mar* and *Serra da Mantiqueira* mountain ranges (e.g. Safford 1999, Martinelli 2007, Vasconcelos 2011). These grasslands form isolated patches within a forested landscape, under climatic conditions quite distinct from those of the larger parts of the Atlantic Forest range situated at higher latitudes. Often, grasslands are found at sites with a rugged, spectacular topography. They have attracted botanical and ecological research for a long time,

and attention has been brought, specifically, to the similarities to Andean vegetation in terms of physiognomies and floristic patterns (Safford 1999) and to adaptations of plants to stressful environmental conditions (Rizzini 1997, Scarano 2007). Differences between these grasslands and the *Campos Rupestres*, situated in Mantiqueira, Espinhaço and associated mountain ranges in central Brazil, at somewhat lower altitudes, have been recently discussed in considerable detail (Alves & Kolbek 2010, Vasconcelos 2011). In contrast to the *Campos Rupestres*, which are found mostly on quartzite rocks, sometimes also on ironstone and granitic gneiss, the *Campos de Altitude* in southeastern Brazil are found on granite rocks or Nepheline-syenite (Alves & Kolbek 2010 and references therein).

Further to the south of the *Campos de Altitude* thus defined, in northeastern Rio Grande do (RS) and southeastern Santa Catarina (SC), we find ourselves in a region dominated by grasslands in mosaics with *Araucaria* forests, at altitudes around 800 to 1,000 m, with the highest peaks above 1,800 m (Pico do Montenegro, RS: 1,398 m; Morro Bela Vista do Ghizoni, SC: 1,823 m; Morro da Boa Vista, SC: 1,827 m). These 'Mountain grasslands' ('*Campos de Cima da Serra*', as called in the region), are not included within the 'Highland Grassland' complex mentioned above in most of the literature (but see Longhi-Wagner *et al.* 2012). Definitions of mountain areas are unavoidably arbitrary (Faria 2010), and the lower altitude in most of this region may have been one of the reasons why the grasslands on the South Brazilian Plateau have not been included into the *Campos de Altitude*. Other reasons may be the geographical location of these grasslands, further south to the areas studied by researchers working on the highland grasslands as defined above or clear differences in vegetation physiognomy to grasslands further to the north. Alves & Kolbek (2010) explicitly state that they did not include data from the grasslands in Paraná (PR), SC and RS in their analysis of floristic differences between the *Campos Rupestres* and *Campos de Altitude* because of lack of data and because they considered these grasslands as a blocked successional phase towards forest vegetation.

In fact, although a good number of studies on different aspects of composition and ecology of *Campos de Altitude* and *Campos Rupestres* is available, the highland grasslands in southern Brazil have been rather poorly studied so far. Heringer & Jacques (2002) analyzed floristic composition of grasslands under different types of management. Oliveira & Pillar (2004) studied successional processes at an abandoned grassland site, however without taking a detailed look at the herbaceous layer (see Overbeck *et al.* 2005 for some general results from the same site). General knowledge on floristic composition, however, is well-established for the region: Boldrini *et al.* (2009) presented a species list of vascular grassland plants for the *Campos de Cima da Serra* region, acknowledging the presence of 1161 plant species. Iganci *et al.* (2011) used the high number of endemic species

found in the region – 25% of their total flora (equivalent to 4% of endemics of the Atlantic Forest biodiversity hotspot as a whole) – to discuss distinctiveness of the grasslands in the region compared to other vegetation types. Few studies have looked at floristic similarities or affinities of the highland grasslands in RS and SC with the *Campos de Altitude* or *Campos Rupestres* (e.g. Almeida *et al.* 2004 using Eupatorieae, Longhi-Wagner *et al.* 2012 using Poaceae), and these studies likewise suggest a clear distinctiveness of grasslands in the three regions.

Ongoing research now allows for a more detailed presentation and analysis of the grassland vegetation in the highlands of southern Brazil, based on quantitative composition data. The aim of this paper is to give an overview on principal features of the highland grasslands in northeastern Rio Grande do Sul and southeastern Santa Catarina, focusing on plant communities. We consider the plateau region delimited by the municipalities of São Francisco de Paula (RS), Vacaria (RS) and Lages (SC), and start with a brief description of geology and climate, as well as broad scale vegetation patterns. Then, we show compositional patterns under different grazing management, based on data sampled at four sites that are part of the Long-Term Ecological Research (LTER/PELD) *Campos Sulinos*. We conclude with a discussion of conservation challenges and options. We hope that this paper will stimulate research on floristic composition and ecology of these grasslands, as well as on the floristic affinities to other grassland regions in South America. Apart from the necessity to close knowledge gaps and improve our understanding of the ecology of these grasslands, it is urgent to advance in the conservation of these grasslands that are highly threatened by land conversion, just like open vegetation types in other subtropical and tropical regions (e.g. Overbeck *et al.* 2013, Parr *et al.* 2014, Overbeck *et al.* 2015).

THE CAMPOS DE CIMA DA SERRA REGION

The *Campos de Cima da Serra* region (Figure 1) is a plateau formed by basalt, rhyolite and rhyodacite rocks of the Serra Geral formation, originating from lava flow between 135 and 120

Ma. years ago, associated to the Gondwana break-up and the South Atlantic Ocean opening. Due to high silica content of these rocks, they are highly resistant to weathering, resulting in a plateau landscape which is interrupted only by the rivers dissecting the region (Almeida 2009). Altitudes decrease from east to west. In the southern part of the region, the eastern edge is characterized by steep canyons up to 900 m high ('Aparados da Serra'), consequences of tectonic movements. On basaltic rock, mainly in the Vacaria region, the most important soil type is Humic Hapludox (Latosolo Bruno), sometimes associated to Ultisols (Nitossolos Háplicos). In the other parts of the region, soils are Inceptisols (Cambissolos), usually associated to Lithic Udorthent (Neossolos Litólicos) on steeper slopes and Ultisols (Nitossolos Háplicos) on colluvia (Almeida 2009). As a consequence of the particular climatic conditions of the region, notably the high precipitation, soils are overall characterized by a high organic matter content, low pH, and low fertility.

Climate in the region is oceanic with temperate summers and no dry season (Köppen's Cfb climate). In Brazil, Cfb climate occurs from southern Minas Gerais (Serra da Mantiqueira) and parts of Rio de Janeiro and Espírito Santo states to RS state, in regions where altitudes (or temperature) limits presence of Cfa climate. Cfb climate includes the coldest regions in Brazil, *i.e.* the peaks with altitudes above 1,800 m in Santa Catarina state (Alvares *et al.* 2013). Annual mean temperature ranges from 14°C in the east to 18°C in the west and precipitation ranges from 1,800 in the east to 1,600 mm in the west (Matzenauer *et al.* 2011). Periods of soil water deficit are rare (Pillar & Quadros 1997). The potential evapotranspiration rises towards the west, ranging from 700 mm to 820 mm (Matzenauer *et al.* 2011).

Natural vegetation of the region is characterized by the coexistence of grasslands and Araucaria forest, together with a minor contribution of other vegetation types, such as wetlands and peat bogs (Figure 2; see Figure 1 for distribution of grassland vegetation in the region). The region is inserted in the southern limit of the Brazilian Atlantic rainforest biome (Figure 1). Grasslands and forests occur in large patches, with forests often situated along rivers, and sometimes

smaller forest patches inserted in the grassland or some single trees colonizing grasslands, especially *Araucaria angustifolia*. Based on palynological data, we know that grasslands are much older than the forests in the region. Cold and dry glacial and dry Early Holocene climates favored the predominance of grasslands over forest, forming a grassland continuum from south to southeast Brazil, with trees restricted to river valleys (Behling 2002). After 10000 years BP, under warmer temperatures, Atlantic forest *sensu stricto* (Atlantic rainforest) started to migrate southwards along the coast. Araucaria forest, on the other hand, started its expansion from deep river valleys where it had remained only from 4000 years BP on, when climate became more humid. Only about 1.550 years BP did this forest expansion over grasslands increase in speed (Behling *et al.* 2005). Based on the presence of charcoal particles in the peat profiles, we know that fire increased in frequency from about 10000 years on, likely in consequence of both presence of human populations and a more seasonal climate (Behling *et al.* 2005). From the 17th century on, cattle were present in the region, and cattle ranching became an important economic activity throughout the region, with the natural grassland as forage source. As stocking rates are rather low, fire has traditionally been used as a management tool to remove dry biomass and permit resprouting at the end of the winter (Boldrini *et al.* 2009), although its use has been discussed rather polemically over the past years (Pillar & Vélez 2010). The fact that these grasslands are – and have been for centuries – under cattle grazing, often with the use of fire, certainly distinguishes them from most of the *Campos de Altitude*, and implications of this for conservation will be discussed further on.

MATERIAL AND METHODS

Study sites

The LTER/ PELD *Campos Sulinos* project consists of a larger number of grassland sites in RS; for the present study, only the four sites situated in the plateau region are considered. The project aims at analyzing long-term vegetation dynamics under different types of grassland management,

considering both taxonomic and functional diversity, among other objectives. In this paper we focus on species richness and dominance of the sites in the *Campos de Cima da Serra* region. Three of the four sites where we collected data are located within conservation units, namely Aparados da Serra National Park (APA; Cambará do Sul, RS; 29°08'10"S, 50°09'21"W), Aratinga Ecological Station (ARA; São Francisco de Paula, RS; 29°23'31"S, 50°14'30"W) and Tainhas State Park (TAI; Jaquirana, RS; 29°05'40"S, 50°22'03"W),

and the other on a private property in the Vacaria municipality (VAC; Vacaria, RS; 28°11'09"S, 51°01'52"W). The sites have been established in 2010 and plant species composition is being monitored annually, with exception of VAC, where the plots were established only in 2013.

Experimental and sampling design

Each site comprises an experimental block with three plots of 0.5 ha under different

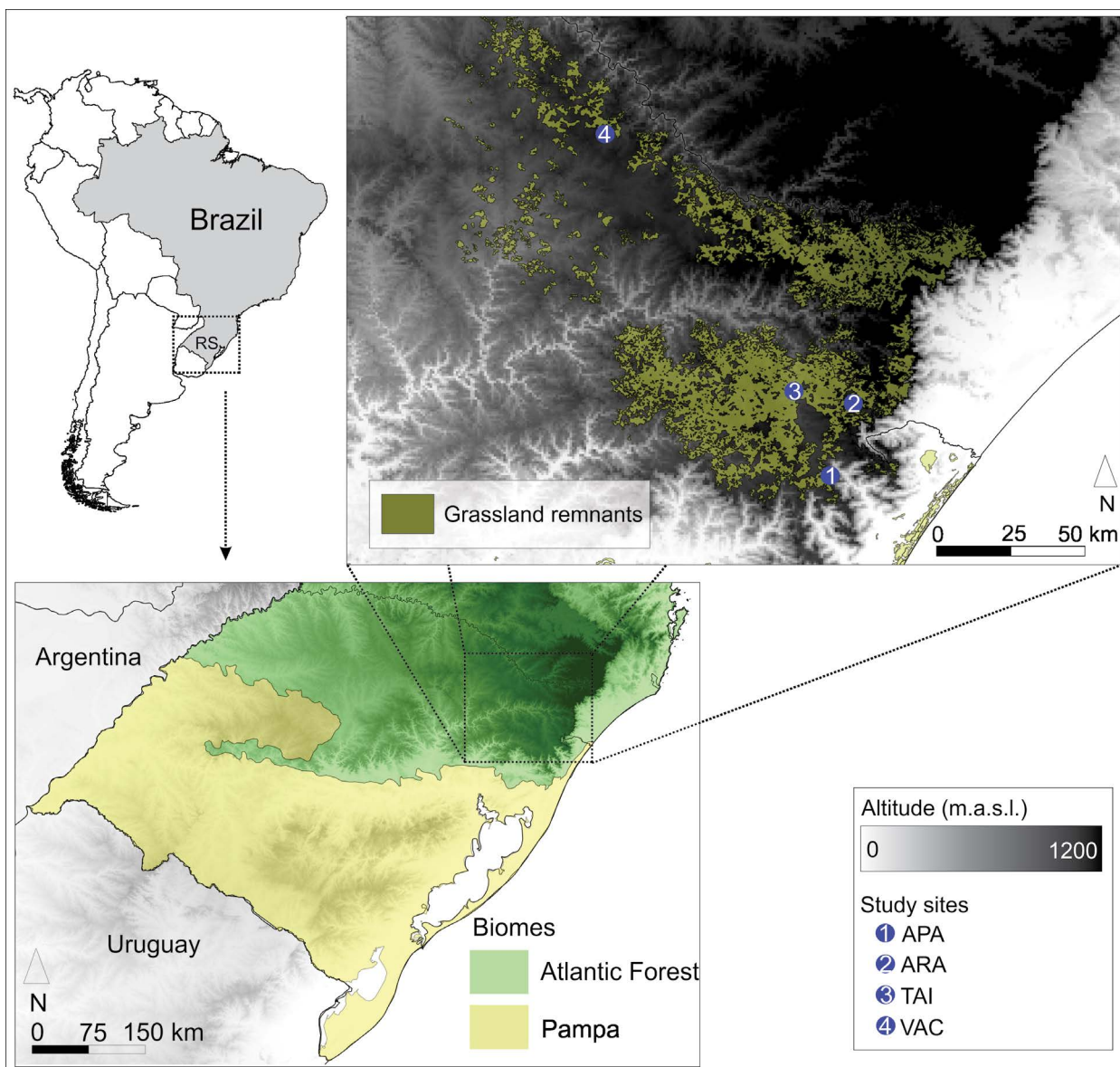


Figure 1. Location of LTER/PELD *Campos Sulinos* study sites in the south Brazilian highland grasslands (Campos de Cima da Serra region). Biome delimitation according to IBGE (2004). Delimitation of grassland remnants modified from Cordeiro & Hasenack 2009). Study sites: Aparados da Serra National Park (APA), Aratinga Ecological Station (ARA), Tainhas State Park (TAI), Vacaria municipality (VAC).

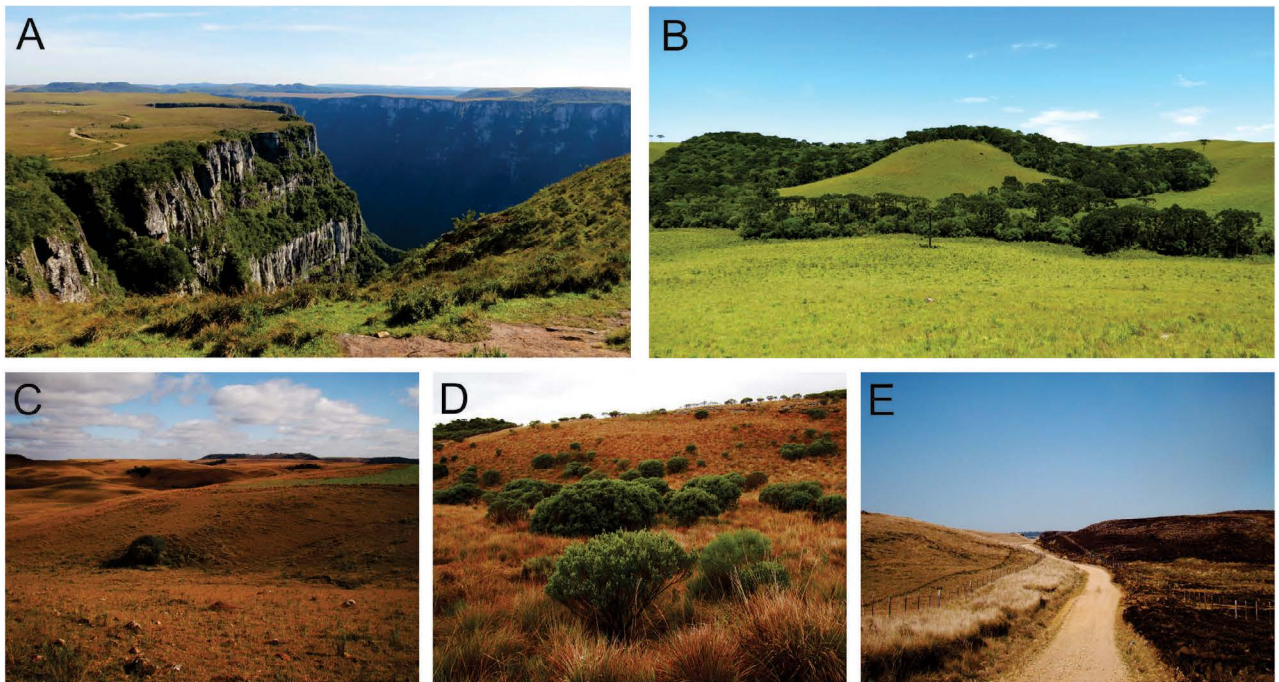


Figure 2. Grassland physiognomy and structure in the South Brazilian highlands. A. Grassland at the border of the South Brazilian Plateau, with forests on the steep hillsides; B. Grassland in contact with a fragment of Araucaria forest; C. Continuous grassland area under relatively high grazing pressure; D. Grazing-excluded grassland (ca. 15 years), with shrub encroachment; E. Grassland recently submitted to fire management (right side of the road) and unburned grassland (left side of the road).

management types: (1) ‘Conventional grazing’, in which we maintained grazing pressure as traditionally used at a given site, (2) ‘Conservative grazing’, where cattle is being allowed into the plot in a simulation of rotational grazing regime, with overall lower grazing pressure in comparison with conventional grazing, and (3) ‘Grazing exclusion’. Plots were established in 2010, and the first sampling was conducted in this year, when all experimental units were still under the same treatment (‘Conventional grazing’, exception: Vacaria, where the first year of sampling was 2013). We estimated grazing pressure in each site in animal units (AU – 450 kg of live weight) per hectare: APA = 0.9 AU/ha, ARA = 0.6 AU/ha, TAI = 0.45 AU/ha and VAC = 1.1 AU/ha.

In each of the 0.5 ha plots, nine 1m² permanent sampling units (SU) were systematically arranged along a grid, with distance of 17 m between them. Sampling of community composition in these plots is conducted annually in Southern hemisphere spring/summer, and we present data from spring/summer 2010/2011 to spring/summer 2013/2014

for APA, ARA and TAI, and summer 2014 for VAC. Sampling was conducted between December and February, *i.e.* in late spring or early summer. In each sampling unit we surveyed all plant species that were present and estimated their cover using a decimal scale (*i.e.* a scale estimating plant cover in 10% intervals, with the first interval being divided into 3 subclasses: < 1%, 1 - 5%, 5 - 10%). Additionally, we measured vegetation height at five points per SU, and also estimated percentage of bare soil, litter, rock outcrops and overall vegetation cover.

Data analysis

In this paper, we aim at (1) characterizing vegetation patterns in general and (2) showing general trends of the two most contrasting treatments – ‘Conventional grazing’ and ‘Grazing exclusion’ – over the four-year period for which data is available.

For the first objective, we used data from the first sampling (2010 for TAI, APA and ARA and

2014 for VAC), using all three plots per site, at that time under the same management ('Conventional grazing'), as well as the complete data set. Data from the SU was pooled to the plot level, square-root transformed and submitted to principal coordinates analysis (PCoA) based on chord distance as a resemblance measure between plots in order to visualize the floristic patterns among sites, using the software MULTIV (Pillar 2011). In addition, we compiled data from all sample dates and create a unified floristic list. To quantify compositional variation, we calculated Sorensen's index among all pairs of sites, using the full species list. Similarity among sites was further depicted in a Venn diagram.

For the second objective, data from the SU was also pooled to the plot level, so that we had three replicates for each of the two treatments 'Conventional grazing' and 'Grazing Exclusion' (one per site, excluding VAC) to be able to present data and dynamics of species richness and diversity along time. We estimated plant diversity using Simpson's Index (Magurran & McGill 2011).

RESULTS

Grassland characterization

Grasslands at all sites were characterized by dominance of perennial grass species in terms of cover and by high overall species richness (APA: 166 species, ARA: 129, TAI: 178, VAC: 123; data from all sampling dates). The families Poaceae and Asteraceae showed the highest species richness, with Cyperaceae or Fabaceae on the third place, depending on site (Table 1). Across sites, we found a total of 306 plant taxa distributed in 43 families. Only 38 species occurred at all four sites (Poaceae: 17 spp., Asteraceae: 11 spp., Cyperaceae: 2 spp., 8 spp. from other families) (see Appendix 1; Figure 3), mostly with low cover values (on average 1% cover per SU). Examples include *Axonopus siccus*, *Baccharis crispa*, *Baccharis pentodonta*, *Hydrocotyle exigua*, *Paspalum polyphyllum*, *Tibouchina gracilis*, all present in all plots of 0.5 ha. *Schizachyrium tenerum*, also found in all plots, was an exception, with a medium dominance (on average 20% cover per SU) at TAI and VAC. Eight

species found are endemic to the South Brazilian highland grasslands. Four species were classified as threatened by extinction according to the recently published list of endangered species of RS state (FZB/RS 2014): *Agrostis lenis*, *Parodia haselbergii*, *Parodia ottonis* and *Piptochaetium alpinum*, found mainly in TAI and APA. Mean species number per sampling unit varied from 22 (ARA) to 36 (VAC; Table 1). Sampling from the three following years yielded 53 (APA), 41 (ARA) and 54 (TAI) species that had not been sampled in the first year.

The vegetation structure at APA, ARA and TAI was determined mainly by the tussock grass *Andropogon lateralis*, which formed a rather uniform layer of about 30 cm height. Average vegetation height in VAC was less than half in comparison with the other sites (Table 1). In VAC, *Mnesithea selloana*, *Paspalum notatum*, *Piptochaetium montevidense* and *Schizachyrium tenerum* were the grass species with the highest cover values. Here, *Andropogon lateralis* was not found in the sampling units, even though present in the region in general. Only three exotic species were found, with low cover value (1% cover in only one SU): the grass *Lolium multiflorum* (found in ARA), a European forage grass often overseeded in grasslands in southern Brazil; and the forbs *Cerastium commersonianum* (found in APA, ARA and TAI) and *Cerastium humifusum* (found in ARA).

The study sites clearly formed groups along the first two ordination axes, separating VAC from the other sites along the first axis, and TAI along the second axis. These first two axes accounted for 67% of overall variation (Figure 4). *Andropogon lateralis* – absent in sampling units at VAC – had a high positive correlation to the first ordination axis, while *Andropogon ternatus*, *Chevreulia sarmentosa*, *Dichantheium sabulorum*, *Eragrostis lugens*, *Ichnanthus procurrens*, among others, showed a strong negative correlation, *i.e.* characterized the vegetation at VAC.

Corresponding with the results of the ordination analysis, similarity in terms of floristic composition, measured by Sorensen's index, was highest between APA and ARA, and lowest between VAC and APA, ARA and TAI, in this order (Table 2).

Table 1. General features of the grassland plant communities at the four LTER/PELD *Campos Sulinos* sites in the *Campos de Cima da Serra* region. Study sites: Aparados da Serra National Park (APA), Aratinga Ecological Station (ARA), Tainhas State Park (TAI), Vacaria municipality (VAC).

Characteristics	APA	ARA	TAI	VAC
Altitude (m a.s.l.) *	924	900	843	932
Mean annual precipitation (mm) *	1898	2002	1931	1732
Mean annual temperature (°C) *	15.2	15.1	15.7	16.2
Mean species number per SU (1m ²) (first year) **	25	22	26	36
Mean vegetation cover (%) **	92	92	90	87
Mean vegetation height (cm) **	24.7	24.0	34.1	11.5
Total number of species (3 plots with 9 SUs) ***	166	129	178	123 **
Total number of families ***	33	28	26	30 **
C3/C4 metabolism (Poaceae) ***	16/32	13/31	23/38	9/28
Poaceae species ***	48	44	61	37
Asteraceae species ***	32	31	36	31
Fabaceae species ***	12	3	21	11
Cyperaceae species ***	15	13	17	4

* ‘WorldClim’ database during 1950 – 2000 period; 1 km spatial resolution (Hijmans *et al.* 2005).

** from first year data set; VAC – only one sampling date.

*** all four sampling dates.

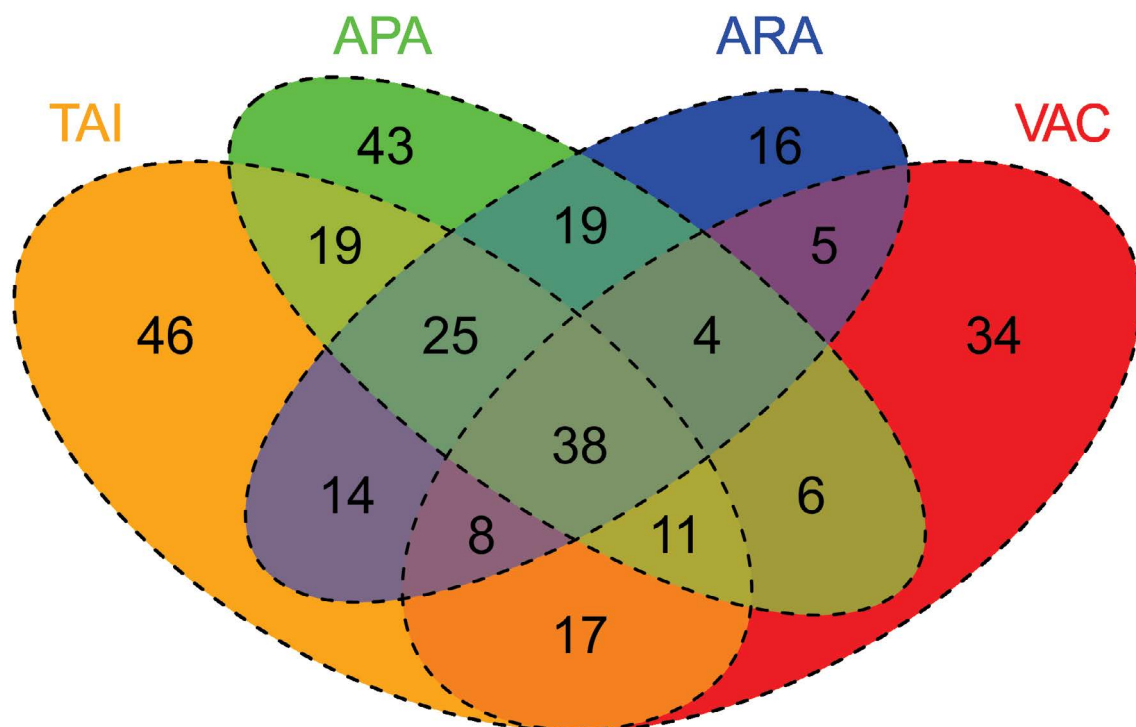


Figure 3. Number of shared species among the four study sites (data from 2010 to 2013). Study sites: Aparados da Serra National Park (APA), Aratinga Ecological Station (ARA), Tainhas State Park (TAI), and Vacaria municipality (VAC).

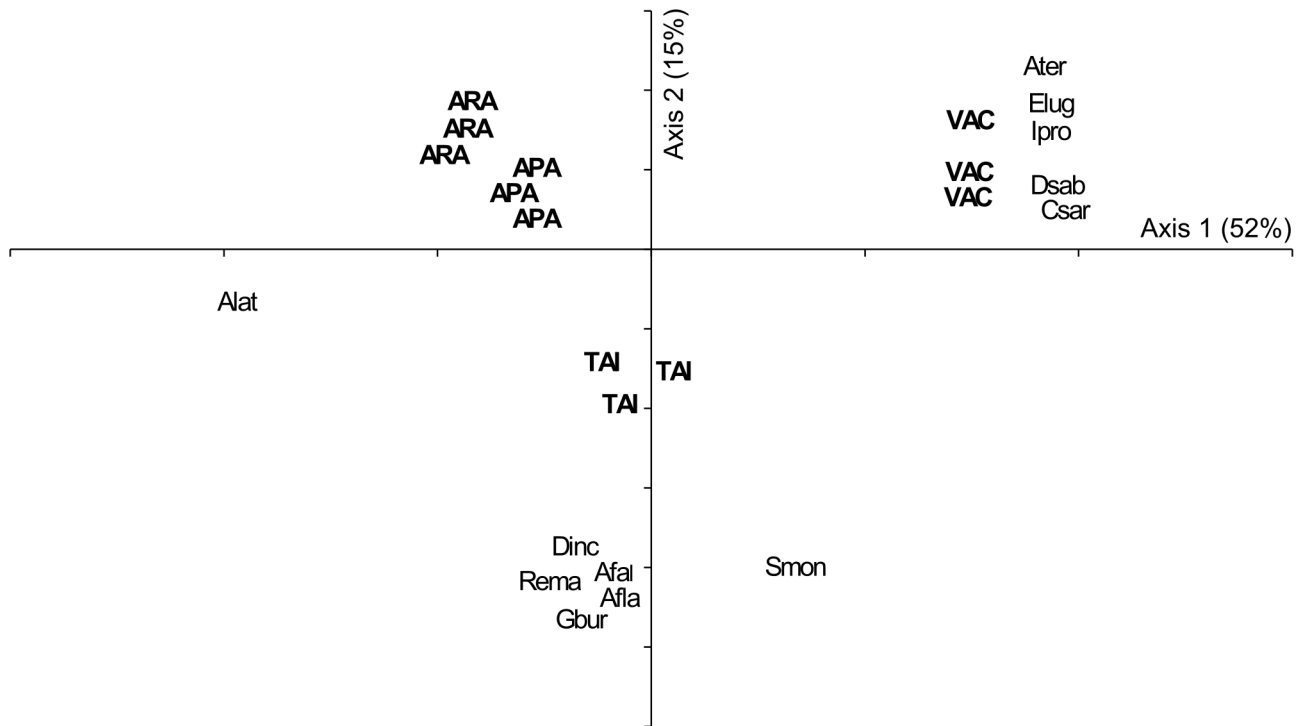


Figure 4. Ordination Diagram (Principal Coordinate Analysis) of the four grassland communities (three plots per site) described by 242 variables (plant species) using the first year data set (2010 for APA, ARA and TAI; 2013 for VAC), all under grazing (*i.e.*, three replicate plots per site). Afal (*Aeschynomene falcata*), Alat (*Andropogon lateralis*), Ater (*Andropogon ternatus*), Afla (*Aristida flaccida*), Csar (*Chevreulia sarmentosa*), Dinc (*Desmodium incanum*), Dsab (*Dichantheium sabulorum*), Elug (*Eragrostis lugens*), Gbur (*Gymnopogon burchellii*), Ipro (*Ichnanthus procurrens*), Rema (*Rhynchospora emaciata*), Smon (*Stylosanthes montevidensis*). Study sites: Aparados da Serra National Park (APA), Aratinga Ecological Station (ARA), Tainhas State Park (TAI), Vacaria municipality (VAC).

Table 2. Sorensen’s similarity coefficient between the study sites Aparados da Serra National Park (APA), Aratinga Ecological Station (ARA), Tainhas State Park (TAI), and Vacaria municipality (VAC).

	TAI	VAC	APA	ARA
TAI	1			
VAC	0.49	1		
APA	0.54	0.41	1	
ARA	0.55	0.44	0.59	1

Diversity increased in the first year after exclusion in comparison to the grazed plot, had the same value in both treatments after two years and decreased in the third year (Figure 5). This change in diversity in the fourth year is the consequence of increased abundance of the dominant tussock grasses, such as *Sorghastrum pellitum* in detriment of the previously dominant *Andropogon lateralis* (Figure 6). After four years, plots under conventional management showed higher species richness than those under grazing exclusion.

DISCUSSION OF THE CASE STUDY

Effect of management on grassland vegetation over time

The exclusion of grazing for a period of three years led to clear changes in species richness and in the relative abundance of dominant species.

At all four study sites, plant species richness was high on the sampling unit and plot scale, comparable to results found in other grassland regions in southern Brazil (*e.g.* Ferreira *et al.* 2010, Dresseno & Overbeck 2013). VAC clearly

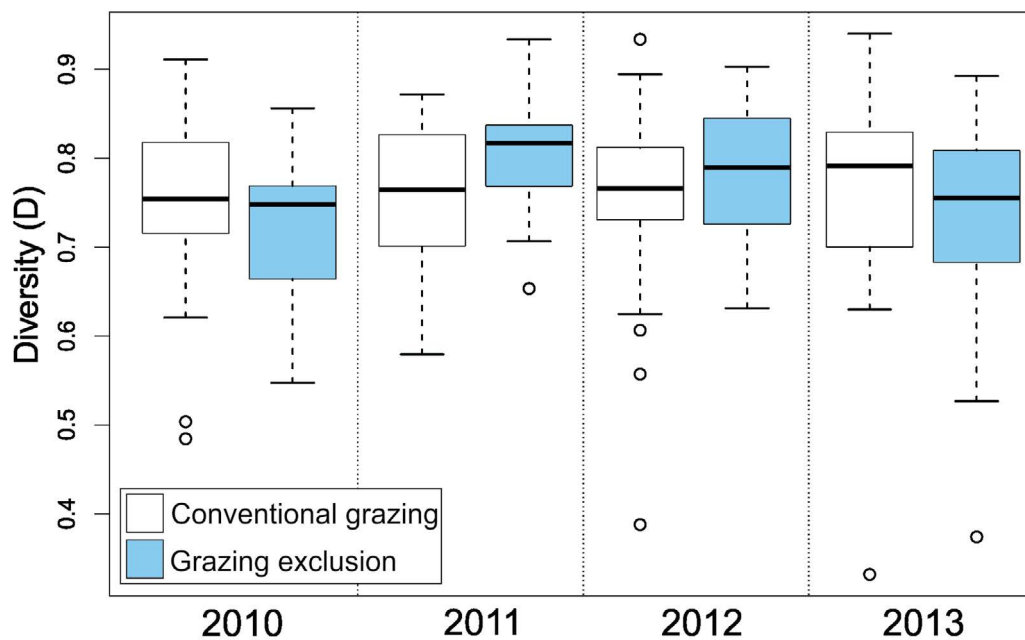


Figure 5. Variation of species diversity (D) among sampling dates and treatments ($n = 216$; 27 1m^2 plots per treatment in each year; pooled data from APA, ARA and TAI). Study sites: Aparados da Serra National Park (APA), Aratinga Ecological Station (ARA), Tainhas State Park (TAI), Vacaria municipality (VAC).

showed the highest species richness on the 1m^2 scale. The almost complete lack of exotic species (only three naturalized species which are not invasive) highlights the good conservation status of these grasslands. The number of endangered and endemic species found (four and eight, respectively) seem rather low at first glance, but it needs to be reminded that the study did not involve sampling of large areas, but looked essentially at four different points, with only 1,5 ha each.

Compositional differences between VAC and the other sites (Table 2; Figure 4) may be a consequence of two factors: first of all, lower contribution of grasses with the C3 photosynthetic pathway indicates somewhat less temperate climatic conditions that find their expression in the plant community. Secondly, differences in management and management history play an important role. Throughout the region, grasslands have been under cattle grazing for the past centuries. However, in the region of APA, ARA and TAI, fire has been traditionally used as part of grassland management: burns at the end of winter are used to remove excess biomass that had not been consumed by cattle and to stimulate resprouting. Even though fire has not been employed any more in the past years,

as sites are situated in conservation units, long-term management will still influence the extant vegetation, as it selected for species adapted to this disturbance, especially tussock grasses. Tussock grasses are not affected by burning as their buds are protected by basal leaf sheaths, or underground (Sarmiento 1992). Especially *Andropogon lateralis* dominated the vegetation at APA, ARA and TAI, in contrast to VAC, where fire is not part of traditional grassland management, and the species had a low contribution. Additionally, stocking rates are higher in VAC, as evidenced by the lower average vegetation height, another factor that may influence species composition and richness, as this leads to reduction of dominance, thus increasing diversity (Overbeck *et al.* 2005, Nabinger *et al.* 2009).

Abandonment of grasslands, *i.e.* exclusion of grazing and fire, led to clear changes in physiognomy and species composition. While diversity increased at first after abandonment, it was lower in abandoned than in grazed plots already in the fourth year of sampling. This reflects increased dominance and cover of tussock grasses such as *Sorghastrum pellitum*. This process leads to competitive exclusion of subordinate species (Overbeck *et al.* 2005) and thus losses in species

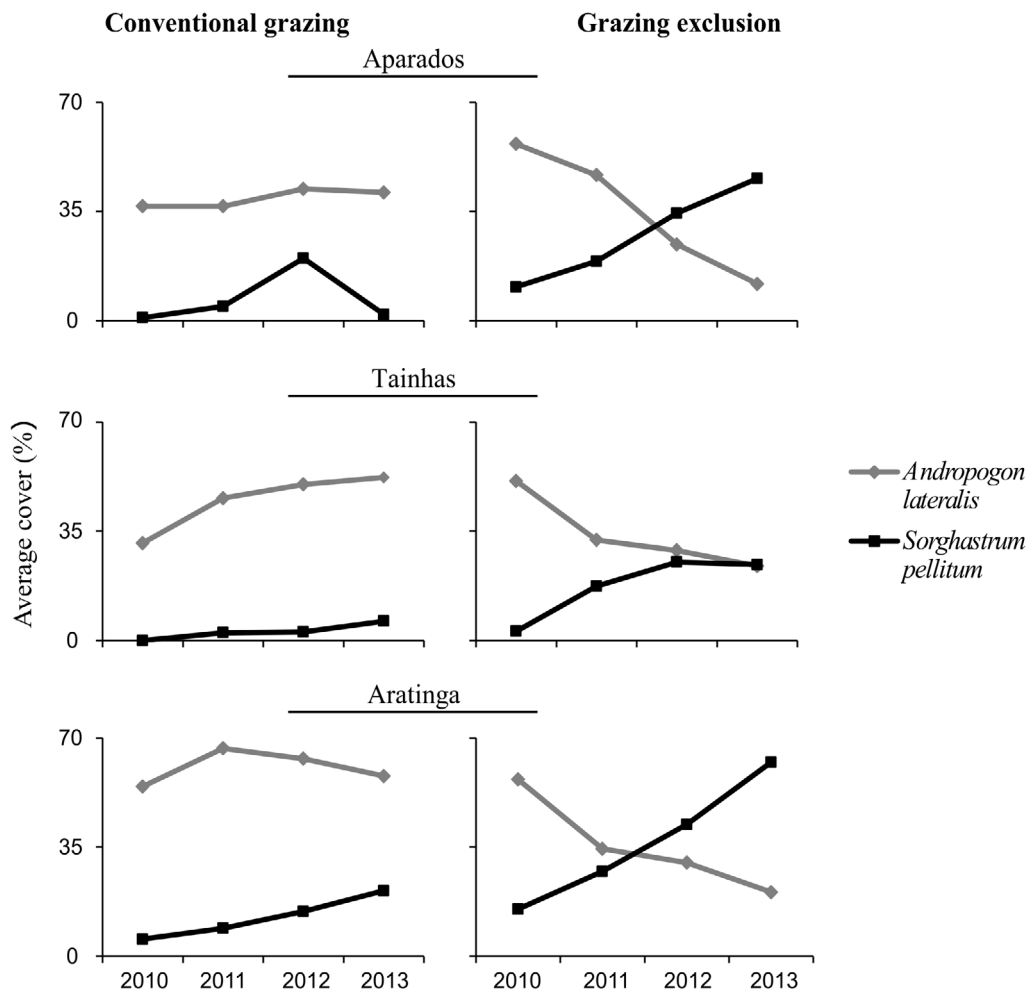


Figure 6. Relative abundance of dominant grassland species along three years period with and without exclusion treatment.

richness on the scale of sampling unit and plot (Figure 7). These results are in accordance with the general finding that disturbances such as grazing have a positive effect on species richness in grassland under highly productive climatic conditions (Lezama *et al.* 2014).

BIOLOGICAL CHARACTERISTICS, CONSERVATION STATE AND CHALLENGES OF THE SOUTH BRAZILIAN HIGHLAND GRASSLANDS

Highland grasslands in Southern Brazil – a brief characterization

In terms of composition, Poaceae, Asteraceae, Fabaceae and Cyperaceae were the families with highest species number in our case study.

According to Boldrini *et al.* (2009), Asteraceae is the most species-rich family in the region, followed by Poaceae. When interpreting the data from our case study, we need to consider that at all four sites the plots were situated in mesic grasslands, sometimes with a minor contribution of rock outcrops, and all at sites under grazing. The sites selected for the LTER/PELD *Campos Sulinos* thus can be considered typical grasslands for the region, but do not include habitats with more specific conditions (such as extended rock outcrops, humid grasslands and peat bogs). The family Poaceae was mostly represented by tussock species (such as *Andropogon lateralis*, *Axonopus siccus*, *Schizachyrium tenerum*). Prostrate rhizomatous species, such as *Paspalum notatum*, one of the most important species in the Pampa biome, were of less importance. *Paspalum pumilum* and

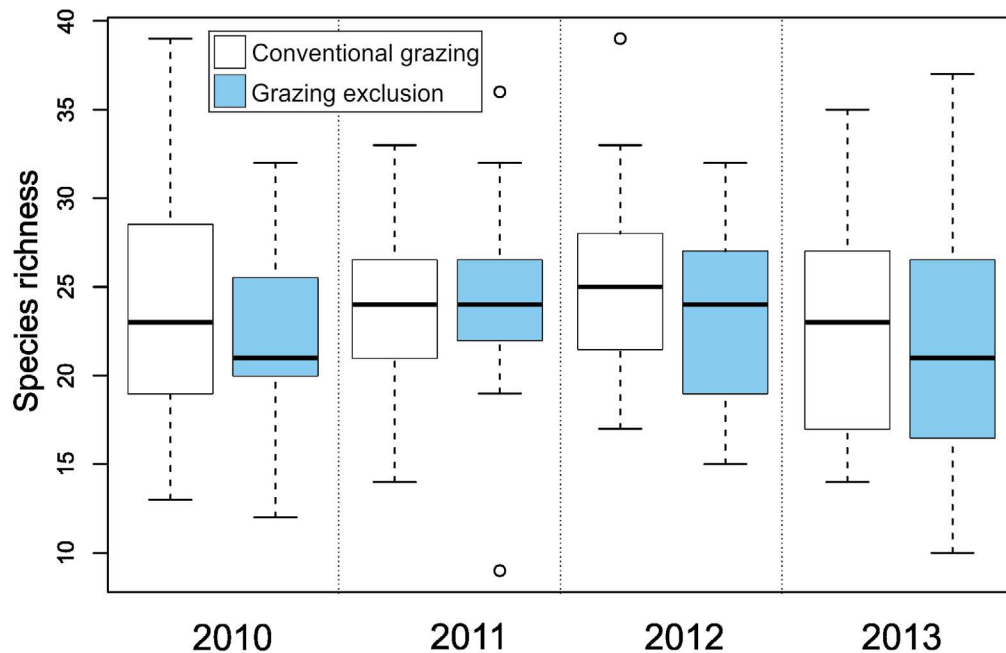


Figure 7. Variation of species richness among sampling dates and treatments ($n = 216$; 27 1m^2 plots per treatment in each year; pooled data from APA, ARA and TAI). Study sites: Aparados da Serra National Park (APA), Aratinga Ecological Station (ARA), Tainhas State Park (TAI), Vacaria municipality (VAC).

Andropogon macrothrix are indicative of more humid conditions (Boldrini *et al.* 2009). A striking feature of the *Campos de Cima da Serra* grasslands and of the Pampa grasslands further to the south is the co-occurrence of both C3 and C4 grasses. In our case study, approximately one third of the grasses were microthermic species, from the genera *Chascolytrum*, *Nasella* and *Piptochaetium*, among others. However, contribution of these species may be reduced by the common practice of winter burns, which may affect these species more than the C4 grasses that have not started to resprout at the moment of burning. Studies on this are missing at current. Our results also point out the importance of long-term studies to assess species richness more accurately, as evidenced by the increasing species number over time.

Floristic relations between highland grasslands in Southern Brazil and in other regions (*Campos de Altitude*, *Campos Rupestres*) have yet to be explored in more detail. Clearly, the *Campos de Cima da Serra* are distinct from other highland grasslands in Brazil in terms of geological substrate, geomorphology, soils and topography, and in consequence of these factors, in terms

of landscape physiognomy. Also in contrast to the other highland grassland types in Brazil, the *Campos de Cima da Serra* grasslands have been used for cattle grazing since introduction of cattle in the region, reflecting the productive conditions in the region. As has been stated before for the *Campos Sulinos* region as a whole, *i.e.* including both the Highland grasslands treated in this paper and the grasslands situated in the Pampa biome, grazing and/or fire can be considered as necessary disturbances – or management types – for maintenance of grassland physiognomy, composition and diversity (*e.g.* Boldrini & Eggers 1996, Nabinger *et al.* 2000, Carvalho *et al.* 2006, Overbeck *et al.* 2007, Pillar & Vélez 2010). Without these disturbances, tall tussock grasses become dominant and lead to exclusion of other species (Boldrini & Eggers 1996, Overbeck *et al.* 2005), leading to losses in plant species diversity. This, in consequence, will influence habitat diversity for different groups of animals living in grasslands. Fire disturbance, for example, may influence functional traits and community assembly patterns in spiders through modifications in habitat structure (Podgaiski *et al.* 2013). Furthermore,

current climatic conditions in theory allow for forest development, and in absence of grazing or fire, processes of shrub encroachment have been demonstrated (Oliveira & Pillar 2004), leading to losses of typical grassland species. The bud bank, *i.e.* the underground ‘reservoir’ for vegetation recovery after disturbances, has been shown to decrease quite rapidly in the absence of these disturbances (Fidelis *et al.* 2014). While discussion on the necessity of disturbances for maintenance of grasslands are debated polemically in southern Brazil (*e.g.* Pillar & Véllez 2010, Overbeck *et al.* 2016), this dependence of grasslands under productive climatic conditions on frequent or regular disturbances is not a unique feature for this region but a general feature of grasslands around the world, as grassland ecosystems evolved under the presence of fire and herbivores (Bond 2005, Veldman *et al.* 2015).

Land use change as principal threat for the Campos de Cima da Serra grasslands

The largest threat of the grasslands presented here comes from land use change – for agriculture, urbanization and forestry – similar to other grasslands in Brazil and in the world (Bond & Parr 2010). Cordeiro & Hasenack (2009) showed that in 2002/2003 (the last period for which data is available) less than 50% of the original extent of grasslands still existed in the region. Since 2002, the region has seen a strong expansion both by silvicultural plantations, specifically Pine, and by agriculture. According to Hermann *et al.* (2016), silvicultural plantations doubled in area between 2002/2003 and 2008/2009 in the region, and this expansion mostly was at the expense of grasslands. Recent transformation of grasslands into agricultural areas has not been quantified so far, but increasing areas used to cultivation of grains and horticultural products are easily visible throughout the region. Past conversion into agricultural fields had occurred mostly in the western part of the region, where soils are deeper and thus more suitable for agriculture, but more recently agricultural activities have affected areas closer to the edge of the plateau, together with tree plantations that can easily be established on shallow soils as well. While forests

are protected from transformation into other land uses, grasslands in the region are not, which reflects the lack of knowledge and understanding about grassland biodiversity, ecosystem services and their importance for conservation and society. CONAMA resolution 423 established the successional stages of the grassland ecosystems in the Atlantic Forest biome (CONAMA 2010), however, has not succeeded in impeding transformation of grassland to other uses as it is not effectively applied. Legal Reserve (*Reserva Legal*) and Permanent Protection Areas (*Áreas de Preservação Permanente*) in the highland grasslands, as well as in *Campos Sulinos* grasslands in general, often include considerable parts of non-grassland vegetation (*e.g.* riparian forests), and thus do not contribute to conservation of grassland.

Conservation Units – sufficient for protection of grasslands?

Around 26,500 ha of the *Campos de Cima da Serra* region (1.9% of original grassland cover in Atlantic Forest biome in the States of RS and SC; Boldrini 2009) are formally protected in conservation units (Brandão *et al.* 2007). Transformation into agriculture and silviculture is no risk for areas included in conservation units. However, this does not mean that grassland biodiversity is sufficiently conserved within their borders. On the one hand, the conservation units in the region and their buffer zones – Aparados da Serra and Serra Geral National Parks, Tainhas State Park and Aratinga Ecological Station – all contain areas with tree plantations, or with history of plantation or agricultural use. While no formal studies exist so far, our observations in the region indicate that after clear-cutting of trees, these areas do not develop into natural grasslands: Active restoration is necessary (see below), but has not been initiated so far, and neither do experiences with restoration of grassland exist for southern Brazil (Overbeck *et al.* 2013). Knowledge on restoration of degraded grasslands clearly is important for grasslands in conservation units.

Furthermore, as discussed above, exclusion of management – the current aim in the most restrictive levels of conservation units – is no adequate strategy for conservation of grasslands

and their biodiversity. The fact that cattle are still present in considerable areas is a consequence of the long time needed for regularization of property questions that arose with the creation of the conservation units. As discussed above, conservation of grassland biodiversity requires management. If it is the aim of the conservation units to preserve the characteristic landscapes in the region, *i.e.* the forest-grassland mosaics, their scenic beauty and their biodiversity, active management is necessary (Overbeck *et al.* 2016). Ample evidence exists from around the world that protection of grasslands under productive conditions is not possible without allowing for the ecological processes that shape these systems (*e.g.* Bond & Parr 2010, Bond *et al.* 2005, Bond & Keeley 2005). This has been recognized for instance in the North American prairies, where fire and grazing are being used as a management tool to conserve prairie remnants, their diversity and stability (*e.g.* Fuhlendorf & Engle 2004, Collins & Calabrese 2012). This is also being increasingly recognized for the Brazilian Cerrado, where at current a shift is on the way regarding the use of fire as a management tool (Fidelis & Pivello 2011, ATBC 2014). Although the main objective of a conservation unit should obviously be conservation and not production, it has been shown that, in general terms, productivity and conservation of plant species richness are not opposing goals in private properties in the *Campos Sulinos* (Nabinger *et al.* 2009). To allow management in conservation units as a basic premise to conserve grasslands does not mean that this management needs to be the same used in rangelands that are not formally protected. Management in a conservation unit should be specifically designed to maximize biodiversity at different spatial scales, focusing on all ecosystems present and not only grasslands. A basis for this would be a zoning plan that would delimit areas not to be actively managed (*e.g.* non-grassland habitats such as forests where grazing and fire are detrimental to biodiversity conservation) as well as different management units that may differ in management type, intensity and frequency. Also, areas without management, *i.e.* where successional processes may be observed, should also be included. At any rate, biodiversity monitoring under different types of management

is important to create a better scientific basis for management. Our case study specifically points out to the importance of long-term monitoring in order to accurately estimate diversity and the dynamics of the system.

Restoration of grasslands – challenges for research and practice

Ongoing high conversion rates of these grasslands make restoration a necessary component of conservation strategies. Even within the conservation units and their buffer zones in the region, extended areas with pine plantations exist, some already cut, some still with trees (sometimes hundreds of hectares in area). After cutting of trees, these areas do not develop into grasslands on their own. Without active restoration, areas often develop into shrubland, with dominance by *Baccharis uncinella*, and usually abundant regeneration of pine trees can be observed, and these may then invade adjacent areas. Additionally, these areas may be prone to invasion of the Fabaceae shrub *Ulex europaeus*, which is widely distributed among un-managed roadsides. The vague knowledge on species composition and ecology of these secondary grasslands only aggravate the restoration challenges for these ecosystems (Overbeck *et al.* 2013).

No experiences with restoration of degraded grassland areas in southern Brazil exist so far, as restoration of grassland had not been a priority in Brazilian environmental policy. Restoration of degraded grasslands in and around conservation units should be a priority, but the necessity to restore exists in other areas as well, including in the different categories of protected areas, such as Legal Reserve (*Reserva Legal*) and Permanent Protection Areas (*Áreas de Preservação Permanente*). A main problem is that at current no seed material of native grassland species is available, which turns large-scale restoration into an immense challenge. Based on knowledge obtained in other countries, we know that for restoration of grasslands, the inclusion of management, *i.e.* grazing and/or fire, are important parts of the restoration strategy (Bullock 2011). However, inclusion of these disturbances in conservation or restoration, as discussed above, is still a taboo in the Brazilian conservation debate.

CONCLUSION

The *Campos de Cima da Serra* are unique and diverse ecosystems that face many conservation challenges, mostly due to land use change. They are clearly distinct from other highland grasslands in Brazil, considering landscape physiognomy, species composition and role of disturbances for their maintenance. Their conservation is not adequately considered in laws and existing regulations are not sufficiently implemented. Furthermore, grazing or fire – necessary for maintenance of grasslands under productive climatic conditions, but with negative consequences for forest systems – are not considered as important tools for grassland conservation. But there are also opportunities. Livestock grazing is an economic activity that can contribute to biodiversity conservation in southern Brazil, and there are promising examples towards implementation of more efficient conservation and a more sustainable management of grasslands, e.g. with the Alianza del Pastizal initiative in the Pampa biome and grasslands in neighboring countries (Bilenca & Miñarro 2004). The great potential arising from this has not been recognized by the general public, nor in conservation politics. Further, conservation of natural ecosystems – grasslands, but other ecosystems as well – is an important basis for the touristic potential in the region.

The *Campos de Cima da Serra* grasslands are located in a marginal situation at the southern tip of the Atlantic Forest biome. Conservation of these grasslands and of those in the *Campos de Altitude* further to the north needs strategies distinct from that of the different forest types included in the Atlantic Forest biome. Increased knowledge on biodiversity and ecological characteristics of these systems in the general public and in the conservation sphere is an important first step towards an effective conservation of these systems.

ACKNOWLEDGEMENTS

Our thanks go to Valério De Patta Pillar for coordination of the LTER/PELD *Campos Sulinos* and all support and advice offered, and to all students and colleagues who helped with field work and species identification. We thank Mariana de Souza Vieira for contributing ideas to this manuscript. Further, we thank staff at

SEMA and ICMBio, the owners of the area in Vacaria and Aparados and the land managers at all study sites for all support. LTER/PELD *Campos Sulinos* received financial support by CNPq (Grants 558282/2009-1 and 403750/2012-1).

REFERENCES

- Almeida, A., Prado, P., & Lewinsohn, T. 2004. Geographical distribution of Eupatorieae (Asteraceae) in South-eastern and South Brazilian Mountain Ranges. *Plant Ecology*, 174(1), 163-181.
- Almeida, J. 2009. Fatores abióticos. In: I. I. Boldrini (Ed.), *Biodiversidade dos campos do planalto das araucárias*. pp. 19-38. Brasília: Ministério do Meio Ambiente.
- Alvares, C. A., Stape, J. L., Sentelhas, P. C., de Moraes Gonçalves, J. L., & Sparovek, G. 2013. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, 22(6), 711-728.
- Alves, R. V., & Kolbek, J. 2010. Can campo rupestre vegetation be floristically delimited based on vascular plant genera? *Plant Ecology*, 207(1), 67-79.
- ATBC 2014. Resolution 19. Promoting Sustainable Fire Management in Cerrado. (Retrieved in Jan 3rd, 2015). <http://tropicalbiology.org/tropicalbiology/wp-content/uploads/2014/04/ATBC-resolution19-Cerrado-burning.pdf>
- Behling, H. 2002. South and southeast Brazilian grasslands during Late Quaternary times: a synthesis. *Palaeogeography Palaeoclimatology Palaeoecology*, 177(1-2), 19-27.
- Behling, H., Pillar, V. D., & Bauermann, S. G. 2005. Late Quaternary grassland (Campos), gallery forest, fire and climate dynamics, studied by pollen, charcoal and multivariate analysis of the São Francisco de Assis core in western Rio Grande do Sul (southern Brazil). *Review of Palaeobotany and Palynology*, 133(3-4), 235-248.
- Bilenca D., & Miñarro, F. 2004. Identificación de áreas valiosas de pastizal en las pampas y campos de Argentina, Uruguay y sur de Brasil. 1st ed. Ciudad Autónoma de Buenos Aires, BUE: Fundación Vida Silvestre Argentina: p. 323.
- Boldrini, I. I., & Eggers, L. 1996. Vegetação campestre do sul do Brasil: dinâmica de espécies à exclusão do gado. *Acta Botanica Brasilica*, 10(1), 37-50.
- Boldrini, I. I., Eggers, L., Mentz, L. A., Miotto, S. T. S., Matzenbacher, N. I., Longhi-Wagner, H. M., Trevisan, R., Schneider, A. A., & Setubal, R. B. 2009. Flora. In: I. I. Boldrini (Ed.), *Biodiversidade dos campos do Planalto das Araucárias*. pp. 39-94. Brasília: MMA.
- Bond, W. J. 2005. Large parts of the world are brown or black: a different view on the 'Green World' hypothesis. *Journal of Vegetation Science*, 16(3), 261-266.
- Bond, W. J., & Keeley, J. E. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. *Trends in Ecology & Evolution*, 20(7), 387-394.
- Bond, W. J., & Parr, C. L. 2010. Beyond the forest edge: Ecology, diversity and conservation of the grassy biomes. *Biological Conservation*, 143(10), 2395-2404.

- Bond, W. J., Woodward, F. I., & Midgley, G. F. 2005. The global distribution of ecosystems in a world without fire. *New Phytologist*, 165(2), 525-538.
- Brandão, T., Trevisan, R., Both, R. 2007. Unidades de Conservação e os Campos do Rio Grande do Sul. *Revista Brasileira de Biociências*, 5(1), 843-845.
- Bullock, J. M. 2011. Semi-natural grasslands. Technical Report. The UK National Ecosystem Assessment, UNEP-WCMC, Cambridge, UK. p. 36.
- Carvalho, P. C. D. F., Fisher, V., Santos, D. T. D., Ribeiro, A. M. L., Quadros, F. L. F. D., Castilhos, Z. M. S., Poli, C. H. E. C., Monteiro, A. L. G., Nabinger, C., & Genro, T. C. M., & Jacques, A. V. A. 2006. Produção Animal no Bioma Campos Sulinos. *Brazilian Journal of Animal Science*, 35(Supl. Esp.), 156-202.
- Collins, S. L., & Calabrese, L. B. 2012. Effects of fire, grazing and topographic variation on vegetation structure in tallgrass prairie. *Journal of Vegetation Science*, 23(3), 563-575.
- CONAMA. 2010. Resolução nº 423, de 12 de abril de 2010. DOU nº 69, de 13/04/2010, páginas 55-57. Brasília, DF.
- Cordeiro, J. L. P., & Hasenack, H. 2009. Cobertura vegetal atual do Rio Grande do Sul. In: V. D. Pillar, D. Müller-Dombois, Z. M. S. Castilhos & A. V. A. Jaques (Eds.), *Campos Sulinos: Conservação e Uso Sustentável da Biodiversidade*. pp. 285-299. Brasília: MMA.
- Dresseno, A. L. P., & Overbeck, G. E. 2013. Structure and composition of a grassland relict within an urban matrix: potential and challenges for conservation. *Iheringia Série Botânica*, 68(1), 59-71.
- Faria, A. P. 2010. Classificação de Montanhas pela Altura. *Revista Brasileira de Geomorfologia*, 6(2), 21-28.
- Ferreira, P. M. A., Müller, S. C., Boldrini, I. I., & Eggers, L. 2010. Floristic and vegetation structure of a granitic grassland in Southern Brazil. *Revista Brasileira de Botânica*, 33(1), 21-36.
- Fidelis, A., Appezzato-da-Glória, B., Pillar, V. D., & Pfadenhauer, J. 2014. Does disturbance affect bud bank size and belowground structures diversity in Brazilian subtropical grasslands? *Flora - Morphology, Distribution, Functional Ecology of Plants*, 209(2), 110-116.
- Fidelis, A., & Pivello, V. R. 2011. Deve-se usar o fogo como instrumento de manejo no Cerrado e Campos Sulinos? *Biodiversidade Brasileira*, 1(2), 12-25.
- Fuhlendorf, S. D., & Engle, D. M. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. *Journal of Applied Ecology*, 41(4), 604-614.
- FZB/RS. 2014. Lista da flora ameaçada do Rio Grande do Sul, Porto Alegre. Retirado de http://www.fzb.rs.gov.br/upload/20141208161010anexo_i_taxons_da_flora_nativa_do_estado_rio_grande_do_sul_ameacadas_de_extincao_1.pdf
- Heringer, I., & Jacques, A. V. A. 2002. Composição florística de uma pastagem natural submetida a queima e manejos alternativos. *Ciencia Rural*, 32(2), 315-321.
- Hermann, J.-M., Lang, M., Gonçalves, J., & Hasenack, H. 2016. Forest-grassland biodiversity hotspot under siege: land conversion counteracts nature conservation. *Ecosystem Health and Sustainability*, 2(6): DOI: 10.1002/ehs2.1224
- Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, 25(15), 1965-1978.
- IBGE. 2004. Mapa da vegetação do Brasil e Mapa de Biomas do Brasil. Retirado de <http://www.ibge.gov.br>
- Iganci, J. R. V., Heiden, G., Miotto, S. T. S., & Pennington, R. T. 2011. Campos de Cima da Serra: the Brazilian Subtropical Highland Grasslands show an unexpected level of plant endemism. *Botanical Journal of the Linnean Society*, 167(4), 378-393.
- Lezama, F., Baeza, S., Altesor, A., Cesa, A., Chaneton, E. J., & Paruelo, J. M. 2014. Variation of grazing-induced vegetation changes across a large-scale productivity gradient. *Journal of Vegetation Science*, 25(1), 8-21.
- Longhi-Wagner, H. M., Welker, C. A. D., & Waechter, J. L. 2012. Floristic affinities in montane grasslands in eastern Brazil. *Systematics and Biodiversity*, 10(4), 537-550.
- Magurran, A. E., & McGill, B. J. (Eds.). 2011. *Biological diversity: frontiers in measurement and assessment*. Oxford and New York: Oxford University Press: p. 368.
- Martinelli, G. 2007. Mountain biodiversity in Brazil. *Brazilian Journal of Botany*, 30(4), 587-597.
- Matzenauer, R., Radin, B., & Almeida, I. R. (Eds.). 2011. *Atlas Climático: Rio Grande do Sul*. Porto Alegre: Fundação Estadual de Pesquisa Agropecuária (FEPAGRO).
- Nabinger, C., Moraes, A., & Marschin, G. E. 2000. Campos in Southern Brazil. In: G. Lemaire, J. G. Hodgson, A. Moraes, C. Nabinger & P. C. F. Carvalho (Eds.), *Grassland Ecophysiology and Grazing Ecology*. pp. 355-376. Wallingford: CABI.
- Nabinger, C., Ferreira, E. T., Freitas, A. K., Carvalho, P. C. F., & Sant'Anna, D. M. (2009). Produção animal com base no campo nativo: aplicações de resultados de pesquisa. In: V. D. Pillar, D. Müller-Dombois, Z. M. S. Castilhos & A. V. A. Jaques (Eds.), *Campos Sulinos: Conservação e Uso Sustentável da Biodiversidade*. pp. 175-198. Brasília: MMA.
- Oliveira, J. M., & Pillar, V. D. 2004. Vegetation dynamics on mosaics of Campos and Araucaria forest between 1974 and 1999 in Southern Brazil. *Community Ecology*, 5(2), 197-202.
- Overbeck, G. E., Hermann, J.-M., Andrade, B. O., Boldrini, I. I., Kiehl, K., Kirner, A., Koch, C., Kollmann, J., Meyer, S. T., Müller, S. C., Nabinger, C., Pilger, G. E., Trindade, J. P. P., Vélez-Martin, E., Walker, E. A., Zimmermann, D. G., & Pillar, V. D. 2013. Restoration Ecology in Brazil – Time to Step Out of the Forest. *Natureza & Conservação*, 11(1), 92-95.
- Overbeck, G. E., Müller, S. C., Fidelis, A., Pfadenhauer, J., Pillar, V. D., Blanco, C. C., Boldrini, I. I., Both, R., & Forneck, E. D. 2007. Brazil's neglected biome: The

- South Brazilian Campos. *Perspectives in Plant Ecology Evolution and Systematics*, 9(2), 101-116.
- Overbeck, G. E., Müller, S. C., Pillar, V. D., & Pfadenhauer, J. 2005. Fine-scale post-fire dynamics in southern Brazilian subtropical grassland. *Journal of Vegetation Science*, 16(6), 655-664.
- Overbeck, G. E., Vélez-Martin, E., Scarano, F. R., Lewinsohn, T. M., Fonseca, C. R., Meyer, S.T., Müller, S.C., Ceotto, P., Dadalt, L., Durigan, G., Ganade, G., Gossner, M. M., Guadagnin, D. L., Lorenzen, K., Jacobi, C. M., Weisser, W. W., & Pillar, V.D. 2015. Conservation in Brazil needs to include non-forest ecosystems. *Diversity and Distributions* 21(12), 1455-1460.
- Overbeck, G.E., Ferreira, P.M.A. & Pillar, V.D. 2016. Conservation of mosaics calls for a perspective that considers all types of mosaic-patches. Reply to: Luza, A.L. et al. 2014. *Natureza & Conservação*. DOI: 10.1016/j.ncon.2016.05.002.
- Parr, C. L., Lehmann, C. E. R., Bond, W. J., Hoffmann, W. A., & Andersen, A. N. 2014. Tropical grassy biomes: misunderstood, neglected, and under threat. *Trends in Ecology & Evolution*, 29(4), 205-213.
- Pillar, V. D. 2011. MULTIV software para análise multivariada, testes de aleatorização e autoreamostragem "bootstrap". Departamento de Ecologia, UFRGS, Porto Alegre.
- Pillar, V. D., & Quadros, F. L. F. 1997. Grassland-forest boundaries in Southern Brazil. *Coenoses*, 12(2-3), 119-126.
- Pillar, V. D. P., & Vélez, E. 2010. Extinção dos Campos Sulinos em unidades de conservação: um fenômeno natural ou um problema ético? *Natureza & Conservação*, 8(1), 84-86.
- Podgaiski, L. R., Joner, F., Lavorel, S., Moretti, M., Ibanez, S., Mendonça, M. S., Pillar, V. D. 2013. Spider Trait Assembly Patterns and Resilience under Fire-Induced Vegetation Change in South Brazilian Grasslands. *PLoS ONE*, 8(3), e60207.
- Rizzini, C. T. 1997. *Tratado de fitogeografia do Brasil: aspectos ecológicos, sociológicos e florísticos*. 2nd ed. Rio de Janeiro, RJ: Âmbito Cultural Edições Ltda: p. 747.
- Safford, H. D. 1999. Brazilian Páramos I. An introduction to the physical environment and vegetation of the Campos de Altitude. *Journal of Biogeography*, 26(4), 693-712.
- Sarmiento, G. 1992. Adaptive strategies of perennial grasses in South American savannas. *Journal of Vegetation Science*, 3(3), 325-336.
- Scarano, F. R. 2007. Rock outcrop vegetation in Brazil: a brief overview. *Brazilian Journal of Botany*, 30(4), 561-568.
- Vasconcelos, M. F. 2011. O que são Campos Rupestres e Campos de Altitude nos topos de montanha do leste do Brasil? *Brazilian Journal of Botany*, 34(2), 241-246.
- Veldman, J. W., Buisson, E., Durigan, G., Fernandes, G. W., Le Stradic, S., Mahy, G., Negreiros, D., Overbeck, G. E., Veldman, R. G., Zaloumis, N. P., Putz, F. E., Bond, W. J. 2015. Towards an old-growth concept for grasslands, savannas, and woodlands. *Frontiers in Ecology and the Environment*, 13(3), 154-162.

Submitted: 23 January 2015

Accepted: 12 August 2015

Appendix 1. Plant species in the studied sites in the highlands of the southernmost state of Brazil, Rio Grande do Sul. In addition to family and species name, we give information on the degree of threat (VU: vulnerable; FZB/RS 2014), classification as endemic species (End) and classification of photosynthetic carbon metabolism (Met) for Poaceae species. Study sites: Aparados da Serra National Park (APA), Aratinga Ecological Station (ARA), Tainhas State Park (TAI), Vacaria municipality (VAC).

Family/ Species	Met	TAI	VAC	APA	ARA
Acanthaceae					
<i>Ruellia morongii</i> Britton				X	X
<i>Stenandrium diphyllum</i> Nees				X	X
Amaranthaceae					
<i>Pfaffia tuberosa</i> (Spreng.) Hicken		X	X	X	X
Apiaceae					
<i>Centella asiatica</i> (L.) Urb.				X	X
<i>Cyclospermum leptophyllum</i> (Pers.) Sprague ex Britton & P. Wilson		X			
<i>Eryngium ebracteatum</i> Lam.				X	X
<i>Eryngium eriophorum</i> Cham. & Schltldl.			X	X	
<i>Eryngium horridum</i> Malme					X
Araliaceae					
<i>Hydrocotyle exigua</i> Malme		X	X		X
<i>Hydrocotyle pusilla</i> A. Rich.				X	
Asteraceae					
<i>Achyrocline alata</i> (Kunth) DC.				X	
<i>Achyrocline satureioides</i> (Lam.) DC.		X		X	X
<i>Acmella bellidioides</i> (Smith) R.K.Jansen			X	X	
<i>Angelphytum</i> sp.				X	
<i>Aspilia montevidensis</i> (Spreng.) Kuntze		X	X		
<i>Baccharis articulata</i> (Lam.) Pers.		X	X		
<i>Baccharis crispa</i> Spreng.		X	X	X	X
<i>Baccharis dracunculifolia</i> DC.				X	
<i>Baccharis pentodonta</i> Malme		X	X	X	X
<i>Baccharis riograndensis</i> L. Teodoro & J. Vidal		X		X	
<i>Baccharis subtropicalis</i> G. Heiden (VU)		X		X	X
<i>Baccharis tridentata</i> Vahl				X	
<i>Barrosoa candolleana</i> (Hook. & Arn.) R.M. King & H. Rob.					X
<i>Berroa gnaphalioides</i> (Less.) Beauverd		X			
<i>Calea cymosa</i> Less.		X		X	
<i>Calea uniflora</i> Baker				X	
<i>Calypocarpus biaristatus</i> (DC.) H. Rob.					X
<i>Chaptalia exscapa</i> (Pers.) Baker			X		X
<i>Chaptalia integerrima</i> (Vell.) Burkart		X	X	X	X
<i>Chaptalia mandonii</i> (Schultz-Bip.) Burkart		X		X	X
<i>Chaptalia piloselloides</i> (Vahl) Baker		X	X	X	

Continue...

...Continued

Family/ Species	Met	TAI	VAC	APA	ARA
<i>Chaptalia runcinata</i> Kunth		X	X	X	X
<i>Chaptalia sinuata</i> (Less.) Baker			X		
<i>Chevreulia acuminata</i> Less.		X	X	X	X
<i>Chevreulia revoluta</i> A.A. Schneid. & Trevis. (End)				X	X
<i>Chevreulia sarmentosa</i> (Pers.) Blake		X	X		X
<i>Chromolaena ascendens</i> (Sch. Bip. ex Baker) R.M. King & H. Rob.			X		
<i>Chrysolaena flexuosa</i> (Sims) H. Rob.		X	X	X	X
<i>Conyza bonariensis</i> (L.) Cronquist			X		X
<i>Conyza primulifolia</i> (Lam.) Cuatrec. & Lourteig		X		X	
<i>Elephantopus mollis</i> Kunth					X
<i>Eupatorium subhastatum</i> Hook. & Arn.		X			X
<i>Gamochaeta americana</i> (Mill.) Weddell		X	X	X	X
<i>Gamochaeta coarctata</i> (Willd.) Kerguelen				X	
<i>Gamochaeta filaginea</i> (DC.) Cabrera		X		X	
<i>Gamochaeta simplicicaulis</i> (Willd.) Cabrera			X		
<i>Holocheilus brasiliensis</i> (L.) Cabrera		X			X
<i>Holocheilus illustris</i> (Vell.) Cabrera					X
<i>Hypochaeris catharinensis</i> Cabrera (End)		X		X	
<i>Hypochaeris chillensis</i> (Kunth) Britton			X		
<i>Hypochaeris megapotamica</i> Cabrera		X			X
<i>Hypochaeris</i> sp. 1			X		
<i>Jaegeria hirta</i> (Lag.) Less.					X
<i>Lessingianthus hypochaeris</i> (DC.) H. Rob.			X		
<i>Lessingianthus rubricaulis</i> (Bonpl.) H. Rob.			X		
<i>Lessingianthus sellowii</i> (Less.) H. Rob.		X	X		
<i>Lucilia acutifolia</i> (Less.) ex. Baker		X	X	X	X
<i>Lucilia nitens</i> Less.		X	X	X	X
<i>Neja filiformis</i> (Spreng.) Nees		X			
<i>Noticastrum decumbens</i> (Baker) Cuatrec. (End)		X	X	X	X
<i>Orthopappus angustifolius</i> (Sw.) Gleason		X			X
<i>Podocoma bellidifolia</i> Baker		X			
<i>Podocoma hirsuta</i> (Hook.& Arn.) Baker			X		
<i>Pterocaulon alopecuroides</i> (Lam.) DC.		X	X		
<i>Senecio brasiliensis</i> (Spreng) Less.			X		
<i>Senecio conyzifolius</i> Baker (End)				X	X
<i>Senecio selloi</i> (Spreng.) DC.		X			X
<i>Stenocephalum megapotamicum</i> (Spreng.) Sch. Bip.			X		
<i>Stevia lundiana</i> DC.		X		X	X
<i>Symphotrichum squamatum</i> (Spreng.) G.L. Nesom				X	
<i>Trichocline catharinensis</i> var. <i>catharinensis</i> Cabrera		X	X	X	X
<i>Vernonanthura nudiflora</i> (Less.) H. Rob.		X			X

Continue...

...Continued

Family/ Species	Met	TAI	VAC	APA	ARA
<i>Vernonia echioides</i> Less.				X	
<i>Viguiera anchusifolia</i> (DC.) Baker		X			
<i>Viguiera immarginata</i> (DC.) Herter			X		
Cactaceae					
<i>Parodia haselbergii</i> (F. Haage) F.H. Brandt (VU)		X			
<i>Parodia ottonis</i> (Lehm.) N.P. Taylor (VU)		X			
<i>Parodia</i> sp.		X			
Calyceraceae					
<i>Acicarpa procumbens</i> Less.				X	
Campanulaceae					
<i>Lobelia camporum</i> Pohl		X	X	X	X
<i>Triodanis</i> sp.				X	
<i>Wahlenbergia linarioides</i> (Lam.) A. DC.		X	X	X	X
Caryophyllaceae					
<i>Cerastium commersonianum</i> DC.		X		X	X
<i>Cerastium humifusum</i> Cambess. ex A. St.-Hil.					X
Cistaceae					
<i>Helianthemum brasiliense</i> (Lam.) Pers.		X	X	X	X
Commelinaceae					
<i>Commelina</i> sp.				X	
Convolvulaceae					
<i>Cuscuta xanthochortos</i> Mart.			X		
<i>Dichondra macrocalyx</i> Meisn.				X	
<i>Dichondra sericea</i> Swartz		X	X	X	X
<i>Evolvulus sericeus</i> Sw.		X	X		
Cyperaceae					
<i>Bulbostylis sphaerocephala</i> (Boeck.) C.B. Clarke			X		
<i>Bulbostylis capillaris</i> (L.) C.B. Clarke		X		X	
<i>Bulbostylis juncooides</i> (Vahl) Kük. ex Osten		X			
<i>Bulbostylis</i> sp. nov		X			
<i>Bulbostylis subtilis</i> M.G. López		X			X
<i>Carex longii</i> subsp. <i>meridionalis</i> (Kük.) Luceño & Alves					X
<i>Carex phalaroides</i> Kunth		X		X	X
<i>Carex sororia</i> Kunth					X
<i>Cyperus aggregatus</i> (Willd) Endl.		X		X	X
<i>Cyperus hermaphroditus</i> (Jacq.) Standl.			X		X
<i>Cyperus reflexus</i> Kunth		X		X	X
<i>Eleocharis montana</i> (Kunth) Roem. & Schult.				X	
<i>Eleocharis nudipes</i> (Kunth) Palla				X	
<i>Eleocharis viridans</i> Kük.				X	

Continue...

...Continued

Family/ Species	Met	TAI	VAC	APA	ARA
<i>Kyllinga brevifolia</i> Rottb.				X	
<i>Kyllinga odorata</i> Vahl		X			X
<i>Kyllinga vaginata</i> Lam.		X	X	X	X
<i>Lipocarpha humboldtiana</i> Nees		X			
<i>Rhynchospora barrosiana</i> Guagl.		X	X	X	X
<i>Rhynchospora brownii</i> subsp. <i>americana</i> Guagl.		X			
<i>Rhynchospora emaciata</i> (Nees) Boeck.		X			
<i>Rhynchospora flexuosa</i> C.B. Clarke				X	X
<i>Rhynchospora holoschoenoides</i> (Rich.) Herter				X	
<i>Rhynchospora junciformis</i> (Kunth) Boeckeler		X			
<i>Rhynchospora rugosa</i> (Vahl) Gale		X		X	
<i>Rhynchospora setigera</i> Griseb.		X			X
<i>Rhynchospora tenuis</i> Willd. ex Link		X			
<i>Scleria distans</i> Poir.				X	
<i>Scleria sellowiana</i> Kunth				X	X
Droseraceae					
<i>Drosera brevifolia</i> Pursh				X	
Ericaceae					
<i>Gaylussacia brasiliensis</i> (Spreng.) Meisn.				X	
Eriocaulaceae					
Eriocaulaceae				X	
Erythroxylaceae					
<i>Erythroxylum microphyllum</i> A. St. -Hil.			X		
Euphorbiaceae					
<i>Euphorbia papillosa</i> A. St.-Hil.		X			
<i>Euphorbia peperomioides</i> Boiss.		X		X	X
<i>Euphorbia spathulata</i> Lam.			X		
<i>Euphorbia stenophylla</i> (Klotzsch & Garcke) Boiss.				X	
<i>Tragia bahiensis</i> Müll. Arg.		X	X		
<i>Tragia uberabana</i> Müll. Arg.		X			
Fabaceae					
<i>Adesmia ciliata</i> Vogel (End)			X		X
<i>Aeschynomene falcata</i> (Poir.) DC.		X			
<i>Crotalaria hilariana</i> Benth.		X	X	X	
<i>Desmanthus virgatus</i> (L.) Willd.		X		X	X
<i>Desmodium adscendens</i> (Sw.) DC.		X	X		
<i>Desmodium craspediferum</i> A.M.G. Azevedo & M.L.A.A. Oliveira		X			
<i>Desmodium incanum</i> DC.		X			
<i>Desmodium triarticulatum</i> Malme		X			
<i>Desmodium uncinatum</i> (Jacq.) DC.		X			

Continue...

...Continued

Family/ Species	Met	TAI	VAC	APA	ARA
<i>Eriosema tacuareboense</i> Arechav.		x			
<i>Galactia gracillima</i> Benth.		x	x	x	
<i>Galactia marginalis</i> Benth.		x	x	x	
<i>Galactia neesii</i> DC.		x			
<i>Macroptilium prostratum</i> (Benth.) Urb.		x	x	x	
<i>Mimosa</i> sp.				x	
<i>Poiretia tetraphylla</i> (Poir.) Burkart				x	
<i>Rhynchosia diversifolia</i> Micheli		x	x	x	
<i>Stylosanthes montevidensis</i> Vogel		x	x		
<i>Tephrosia adunca</i> Benth.		x	x	x	
<i>Trifolium riograndense</i> Burkart		x	x	x	
<i>Vigna peduncularis</i> (Kunth) Fawc. & Rendle		x		x	
<i>Zornia burkartii</i> Vanni		x		x	x
<i>Zornia ramboana</i> Mohlenbr.		x			
Hypericaceae					
<i>Hypericum cordatum</i> (Vell.) N. Robson			x		
<i>Hypoxis decumbens</i> L.		x	x	x	x
Iridaceae					
<i>Herbertia lahue</i> (Molina) Goldblatt			x	x	
<i>Sisyrinchium micranthum</i> Cav.				x	x
<i>Sisyrinchium palmifolium</i> L.			x	x	x
<i>Sisyrinchium sellowianum</i> Klatt		x			
<i>Sisyrinchium</i> sp. 1				x	
<i>Sisyrinchium</i> sp. 2		x			
<i>Sisyrinchium vaginatum</i> Spreng.				x	x
Juncaceae					
<i>Juncus microcephalus</i> Kunth				x	
<i>Luzula ulei</i> Buchenau				x	x
Lamiaceae					
<i>Cunila galioides</i> Benth.			x	x	
<i>Glechon ciliata</i> Benth.		x		x	x
<i>Glechon spathulata</i> Benth.			x		
<i>Rhabdocaulon gracile</i> (Benth.) Epling				x	
<i>Salvia ovalifolia</i> A. St.-Hil.		x			
Liancaeeae					
<i>Cliococca selaginoides</i> (Lam.) C.M. Rogers & Mildnerso			x		
Loganiaceae					
<i>Spigelia</i> sp.			x		
Lythraceae					
<i>Cuphea glutinosa</i> Cham. & Schldl.		x	x		
Malpighiaceae					

Continue...

...Continued

Family/ Species	Met	TAI	VAC	APA	ARA
<i>Stigmaphyllon ciliatum</i> (Lam.) A. Juss.			X		
Malvaceae					
<i>Byttneria scabra</i> L.			X		
<i>Krapovickasia macrodon</i> (DC.) Fryxell		X	X		X
<i>Pavonia reticulata</i> Garcke			X		
Melastomaceae					
<i>Tibouchina gracilis</i> Cogn.		X	X	X	X
Myrtaceae					
<i>Campomanesia aurea</i> O. Berg		X	X	X	
<i>Psidium australe</i> Cambess.			X		
<i>Psidium luridum</i> (Spreng.) Burret			X		
Orchidaceae					
<i>Habenaria parviflora</i> Lindl.				X	X
<i>Rhynchanthera brachyrhyncha</i> Cham.				X	
<i>Skeptrostachys balanophorostachya</i> (Rchb. f. ex Warm.) Garay		X		X	X
Orobanchaceae					
<i>Agalinis communis</i> (Cham. & Schltld.) D'Arcy			X	X	
<i>Buchnera longifolia</i> Kunth				X	X
Oxalidaceae					
<i>Oxalis bipartita</i> A. St.-Hil.				X	X
<i>Oxalis brasiliensis</i> Lodd.				X	
<i>Oxalis eriocarpa</i> DC.				X	
<i>Oxalis lasiopetala</i> Zucc.				X	
Plantaginaceae					
<i>Plantago australis</i> Lam.		X			
<i>Plantago tomentosa</i> Lam.			X	X	X
Poaceae					
<i>Agenium villosum</i> (Nees) Pilg.	C4		X		
<i>Agrostis lenis</i> Roseng., B.R. Arrill. & Izag. (VU)	C3	X			
<i>Agrostis montevidensis</i> Spreng. ex Nees	C3	X	X	X	X
<i>Andropogon lateralis</i> Nees	C4	X	X	X	X
<i>Andropogon macrothrix</i> Trin.	C4	X	X	X	
<i>Andropogon selloanus</i> (Hack.) Hack.	C4		X		
<i>Andropogon ternatus</i> (Spreng.) Nees	C4	X	X		X
<i>Anthaenantia lanata</i> (Kunth) Benth.	C4				X
<i>Aristida filifolia</i> (Arechav.) Herter	C4		X		
<i>Aristida flaccida</i> Trin. & Rupr.	C4	X			
<i>Aristida laevis</i> (Nees) Kunth	C4			X	
<i>Aristida venustula</i> Arechav.	C4	X			
<i>Axonopus affinis</i> Chase	C4	X	X	X	X

Continue...

...Continued

Family/ Species	Met	TAI	VAC	APA	ARA
<i>Axonopus argentinus</i> Parodi	C4	x	x		
<i>Axonopus compressus</i> (Sw.) P. Beauv.	C4				x
<i>Axonopus pellitus</i> (Nees ex Trin.) Hitchc. & Chase	C4	x	x	x	x
<i>Axonopus purpusii</i> var. <i>glabrescens</i> Valls ex Longhi-Wagner	C4		x		
<i>Axonopus ramboi</i> G.A. Black	C4		x	x	x
<i>Axonopus suffultus</i> (Mikan ex Trin.) Parodi	C4	x	x		
<i>Bothriochloa laguroides</i> (DC.) Herter	C4			x	
<i>Bromus auleticus</i> Trin. ex Nees	C3			x	
<i>Calamagrostis viridiflavescens</i> (Poir.) Steud.	C3	x			x
<i>Chascolytrum calothea</i> (Trin.) L. Essi, Longhi-Wagner & Souza-Chies	C3	x		x	
<i>Chascolytrum lamarckianum</i> (Nees) Matthei	C3	x		x	x
<i>Chascolytrum poomorphum</i> (J. Presl) L. Essi, Longhi-Wagner & Souza-Chies	C3	x		x	x
<i>Chascolytrum scabrum</i> (Nees ex Steud.) Matthei	C3			x	
<i>Chascolytrum subaristatum</i> (Lam.) Desv.	C3	x	x		
<i>Chascolytrum uniolae</i> (Nees) Essi, Longhi-Wagner & Souza-Chies	C3	x		x	x
<i>Danthonia cirrata</i> Hack. & Arechav.	C3	x	x		
<i>Danthonia montana</i> Döll	C3			x	
<i>Danthonia secundiflora</i> (Swallen) Roseng., Arril. & Izag.	C3	x			
<i>Deschampsia cespitosa</i> (L.) P. Beauv.	C3	x			
<i>Dichanthelium sabulorum</i> (Lam.) Gould & C.A. Clark	C3	x	x	x	x
<i>Digitaria corynotricha</i> (Hack.) Henrard	C4		x		
<i>Eragrostis airoides</i> Nees	C4	x		x	x
<i>Eragrostis bahiensis</i> Schrad. ex Schult.	C4			x	
<i>Eragrostis lugens</i> Nees	C4	x	x	x	x
<i>Eragrostis neesii</i> Trin.	C4	x	x		
<i>Eragrostis polytricha</i> Nees	C4	x	x	x	x
<i>Eriochrysis</i> sp.	C4	x			
<i>Eustachys uliginosa</i> (Hack.) Herter	C4			x	x
<i>Gymnopogon burchellii</i> (Munro ex Döll) Ekman	C4	x			
<i>Gymnopogon grandiflorus</i> Roseng., B.R. Arrill. & Izag.	C4		x	x	x
<i>Ichnanthus procurrens</i> (Nees ex Trin.) Swallen	C3		x		
<i>Lolium multiflorum</i> Lam.	C3				x
<i>Microchloa indica</i> (L. f.) P. Beauv.	C4	x			
<i>Mnesithea selloana</i> (Hack.) de Koning & Sosef	C4	x	x	x	x
<i>Nassella filiculmis</i> (Delile) Barkworth (End)	C3	x			
<i>Nassella melanosperma</i> (J. Presl) Barkworth	C3	x			
<i>Nassella nutans</i> (Hack.) Barkworth	C3	x		x	
<i>Nassella vallsii</i> (A.Zanin & Longhi-Wagner) Peñail.	C3	x	x		x

Continue...

...Continued

Family/ Species	Met	TAI	VAC	APA	ARA
<i>Panicum bergii</i> Arechav.	C4	x			x
<i>Paspalum barretoii</i> Canto-Dorow, Valls & Longhi-Wagner	C4			x	
<i>Paspalum compressifolium</i> Swallen	C4	x		x	x
<i>Paspalum dilatatum</i> Poir.	C4	x		x	x
<i>Paspalum guenoarum</i> Arechav.	C4		x		x
<i>Paspalum maculosum</i> Trin.	C4	x		x	x
<i>Paspalum notatum</i> Flüggé	C4	x	x		
<i>Paspalum plicatulum</i> Michx.	C4	x	x	x	x
<i>Paspalum polyphyllum</i> Nees ex Trin.	C4	x	x	x	x
<i>Paspalum pumilum</i> Nees	C4	x		x	x
<i>Paspalum umbrosum</i> Trin.	C4				x
<i>Piptochaetium alpinum</i> L. B. Sm. (VU, End)	C3			x	x
<i>Piptochaetium montevidense</i> (Spreng.) Parodi	C3	x	x	x	x
<i>Piptochaetium ruprechtianum</i> E. Desv.	C3	x		x	x
<i>Piptochaetium stipoides</i> (Trin. & Rupr.) Hack. ex Arechav.	C3	x	x	x	x
<i>Poa lanigera</i> Swallen	C3	x			
<i>Saccharum angustifolium</i> (Nees) Trin.	C4			x	
<i>Sacciolepis vilvoides</i> (Trin.) Chase	C4	x		x	
<i>Schizachyrium condensatum</i> (Kunth) Nees	C4	x		x	
<i>Schizachyrium gracilipes</i> (Hack.) A. Camus	C4			x	x
<i>Schizachyrium hatschbachii</i> Peichoto	C4	x		x	x
<i>Schizachyrium imberbe</i> (Hack.) A. Camus	C4	x			
<i>Schizachyrium microstachyum</i> (Desv. ex Ham.) Roseng., B.R. Arrill. & Izag.	C4	x	x		x
<i>Schizachyrium spicatum</i> (Spreng.) Herter	C4	x		x	x
<i>Schizachyrium tenerum</i> Nees	C4	x	x	x	x
<i>Sisyrinchium megapotamicum</i> Malme	C4		x	x	
<i>Setaria parviflora</i> (Poir.) Kerguelen	C4	x	x	x	x
<i>Setaria vaginata</i> var. <i>vaginata</i> Spreng.	C4	x			
<i>Sorghastrum pellitum</i> (Hack.) Parodi	C4	x	x	x	x
<i>Sporobolus camporum</i> Swallen	C4	x		x	
<i>Sporobolus indicus</i> (L.) R. Br.	C4	x	x		x
<i>Steinchisma decipiens</i> (Nees ex Trin.) W.V. Br.	C3	x		x	
<i>Steinchisma hians</i> (Elliott) Nash	C3	x	x	x	x
<i>Trachypogon montufarii</i> (Kunth) Nees	C4	x	x	x	x
<i>Vulpia bromoides</i> (L.) Gray	C3	x			
Polygonaceae					
<i>Polygala brasiliensis</i> L.				x	x
<i>Polygala linoides</i> Poir.		x	x	x	
<i>Polygala molluginifolia</i> A. St.-Hil & Moq.				x	

Continue...

...Continued

Family/ Species	Met	TAI	VAC	APA	ARA
<i>Polygala pulchella</i> A. St.-Hil & Moq.		x			x
Primulaceae					
<i>Lysimachia</i> sp.				x	x
Rubiaceae					
<i>Borreria brachystemonoides</i> Cham. & Schltld.				x	
<i>Borreria dasycephala</i> (Cham. & Schltld.) Bacigalupo & E.L. Cabral		x			
<i>Borreria eryngioides</i> Cham. & Schltld.		x			
<i>Borreria tenella</i> (Kunth) Cham. & Schltld.		x		x	
<i>Borreria verticillata</i> (L.) G. Mey.			x		
<i>Diodia radula</i> (Willd. ex Roem. & Schult.) Delprete		x		x	
<i>Galianthe fastigiata</i> Griseb.		x	x		x
<i>Galium humile</i> Cham. & Schltld.		x		x	x
<i>Galium richardianum</i> (Gillies ex Hook. & Arn.) Endl. ex Walp.		x			x
<i>Galium uruguayense</i> Bacigalupo		x		x	
<i>Galium vile</i> (Cham. & Schltld.) Dempster					x
<i>Oldenlandia salzmännii</i> (DC.) Benth. & Hook. f. ex B.D.Jacks		x			x
<i>Richardia brasiliensis</i> Gomes		x	x		
<i>Richardia humistrata</i> (Cham. & Schltld.) Steud.		x	x	x	x
Scrophulariaceae					
Scrophulariaceae					x
Solanaceae					
<i>Calibrachoa sellowiana</i> (Sendtn.) Wijsman			x		
<i>Petunia integrifolia</i> Schinz & Thell.		x		x	
<i>Solanum aculeatissimum</i> Jacq.					x
Turneraceae					
<i>Turnera sidoides</i> L.			x		
Verbenaceae					
<i>Glandularia catharinae</i> (Moldenke) N. O'Leary & P. Peralta		x			
<i>Glandularia marrubioides</i> (Cham.) Tronc.			x	x	
<i>Verbena hirta</i> Spreng.				x	
<i>Verbena rigida</i> Spreng.		x		x	