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VEGETAÇÃO DOS CAMPOS DO SUL DO BRASIL E FATORES AMBIENTAIS DETERMINANTES

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PREFÁCIO

A presente tese está organizada na forma de dois capítulos, formatados conforme as normas dos periódicos científicos em que serão publicados. Esta tese foi realizada com dados de vegetação campestre e variáveis ambientais coletadas através da rede de pesquisa "Biodiversidade dos campos e dos ecótonos campo-floresta no sul do Brasil: bases ecológicas para sua conservação e uso sustentável", participante do Sistema Nacional de Pesquisa em Biodiversidade – SISBIOTA.

O Capítulo I, apresenta uma síntese regional dos padrões de organização da vegetação campestre no sul do Brasil, através da análise de riqueza, espécies indicadoras delimita diferenças entre as duas unidades fitogeográficas reconhecidas como província Pampeana e província Paranaense. O artigo intitulado "*The South Brazilian Campos Sulinos: one grassland region but distinct composition in Pampa and Highland grasslands*", foi submetido ao periódico Applied Vegetation Science na seção Vegetation Suvery.

O Capítulo II aborda a utilização de variáveis ambientais, para explicação dos padrões de distribuição da vegetação registrados na primeira parte desta tese. Para investigar quais as relações de descritores ambientais (variáveis químicas do solo e variáveis climáticas) com os padrões de organização da vegetação, foram utilizadas análises exploratórias. O artigo II intitulado "*The influence of environmental drivers in the South Brazilian Grasslands*", será submetido ao periódico Austral ecology.

Desta forma, a presente tese contribui com uma síntese regional dos padrões de organização dos *Campos Sulinos* e investigação sobre fatores ambientais associados a esses padrões. Esperamos que o produto gerado através do desenvolvimento deste trabalho possa ser utilizado como subsídio para o desenvolvimento de pesquisas relacionadas conservação e uso sustentável dos Campos Sulinos.

Sumário

RESUMO

Os Campos do Sul do Brasil incluem as formações campestres do bioma Pampa e os campos que formam mosaicos com florestas de Araucária, incluídos no bioma Mata Atlântica. Este estudo visa apresentar uma síntese dos padrões regionais da vegetação campestre no sul do Brasil, através da caracterização de padrões de comunidades campestres e identificação das variáveis ambientais relevantes para os padrões de distribuição dos campos. A área de estudo compreende os campos do Rio Grande do Sul, Santa Catarina e sul do Paraná. Através de um desenho amostral estratificado, unidades campestres regionais foram delimitadas por características de solo e geomorfologia, em unidades regionais, Unidades Amostrais de Paisagem (UAP) foram alocadas de modo a abranger diferentes fisionomias dos campos da região. No âmbito de cada UAP, foram demarcadas três Unidades Amostrais Locais (UAL), estas unidades serviram de base para os registros de variáveis ambientais e levantamento da vegetação. Para obtenção de variáveis climáticas foi utilizado o banco de dados georreferenciados disponibilizado pelo Instituído Nacional de Meteorologia, as variáveis de solo foram coletadas através de três amostras em cada UAL. Para o levantamento da vegetação, houve a demarcação de nove unidades amostrais de 1 m^2 em cada UAL, onde estimou-se a cobertura de todas as espécies vasculares. As diferenças entre a riqueza dos campos foram exploradas através da diversidade de Hill, Análise de Coordenadas Principais (PCoA) e análise de espécies indicadoras (IndVal). Para analisar a influência das variáveis ambientais nas comunidades campestres foram realizadas Análise de Correspondência Canônica (CCA) e para avaliar a proporção de influência das variáveis ambientais foi realizada Análise de Redundância (RDA). Nossos resultados revelaram diferenças na riqueza e diversidade entre os campos do Pampa e do bioma Mata Atlântica, sendo os primeiros caracterizados pela dominância de *Paspalum notatum* e os segundos pela dominância de *Andropogon lateralis, Schizachyrium tenerum* e *Piptochaetium montevidense*. Os campos do Pampa foram relacionados com fertilidade do solo, pH e altas temperaturas, enquanto os campos do bioma Mata Atlântica foram relacionados com maior porcentagem de argila e matéria orgânica, baixa fertilidade, e maiores índices pluviométricos. Porém a RDA evidenciou pequena explicação dos padrões de vegetação explicados pelo solo, seguido pelo clima, a maior porcentagem de explicação foi atribuída a variáveis espaciais. Embora as análises exploratórias tenham mostrado a separação das comunidades campestres do sul do Brasil, conforme os padrões florísticos já registrados, nossos resultados indicam a necessidade de incluir outras variáveis ambientais para estabelecer padrões mais claros da distribuição das comunidades campestres no sul do Brasil.

Palavras chave: campos sulinos, variáveis ambientais, espécies indicadoras, bioma Pampa, diversidade vegetal, campos do bioma Mata Atlântica.

ABSTRACT

South Brazilian Grasslands include grasslands from Pampa biome and mosaics of grassland and Araucaria forest grasslands from Atlantic forest biome. This study aims to synthesize the regional patterns of the Southern Brazilian Grasslands, through the characterization of patterns grasslands communities and identification of the environmental variables that have relevance in distribution of grasslands patterns. The study area comprises the grasslands regions of Rio Grande do Sul, Santa Catarina and southern Paraná state. Through the adoption of a stratified sampling design, regional grasslands units were delimited by soil and geomorphology characteristics, in the regional grasslands units, Sample Units (SUs) were allocated to cover different parts of the region. Within each SU, three Sample Plots (SPs) were demarcated, these units served as the basis for the records of environmental variables and vegetation survey. To obtain climatic variables, the geo-referenced database provided by the National Institute of Meteorology was utilized; soil variables were collected through three samples in each SP. For the vegetation survey, nine quadrants of $1m^2$ were demarcated in each SP, where it was estimated the coverage of all vascular species. The differences between the richness of the grasslands were explored through Hill diversity, Principal Coordinates Analysis (PCoA) and indicator species analysis (IndVal). In order to analyze the influence of the environmental variables in the grasslands communities, we performed Canonical Correspondence Analysis (CCA) and to evaluate the proportion of influence of the environmental variables we performed Redundancy Analysis (RDA). Our results revealed differences in richness and diversity between the grasslands of the Pampa and the Atlantic Forest biome, the former being characterized by the dominance of *Paspalum notatum* and the latter by the dominance of *Andropogon lateralis*, *Schizachyrium tenerum* and

Piptochaetium montevidense. The grasslands of the Pampa were related to soil fertility, pH and high temperatures, while the grasslands of the Atlantic Forest biome were related to higher percentage of clay, organic matter, low fertility, and higher precipitation rates. However, the RDA evidenced a small explanation of the vegetation patterns explained by the soil, followed by the climate, the highest percentage of explanation was attributed to spatial variables. Although the exploratory analyzes have shown the separation of the southern Brazilian grasslands communities corresponding to the floristic recorded, our results indicate the need to include variables to establish clearer patterns of the distribution of the grasslands communities in the south of Brazil.

Key words: Atlantic Forest biome grasslands, environmental variables, indicator species, Southern Brazilian Grasslands fields, Pampa biome, plant diversity.

CAPÍTULO I

Classification of South Brazilian grasslands: implications for conservation

Abstract

Aims

We offer a first classification of South Brazilian grasslands (*Campos Sulinos*) based on quantitative vegetation data and describing grassland types in terms of dominant and indicator species.

Location

South Brazilian grasslands (Paraná, Santa Catarina, Rio Grande do Sul states).

Methods

We described vegetation plots in 170 sampling units throughout the region using a stratified nested design, totalizing 1529 1 m² quadrats. We classified vegetation using cluster analysis based on Bray-Curtis dissimilarities, establishing three vegetation types and ten subtypes. We conducted indicator species analysis within the resulting subtypes, and for all possible combinations of subtypes.

Results

In Cluster analyses, a clear separation of poorly drained grasslands from the drier sites appeared. Further, a clear distinction of grasslands in the South Brazilian highland region, situated in the Atlantic Forest biome, and the grasslands of the Pampa biome, to the south, emerged, reflecting climatic and management differences. Highland grasslands showed lower species cover dominance, while in the Pampa, *Paspalum notatum* clearly was the most important species and the abundance of exotic species was higher.

Conclusions

Our study provides the first classification of South Brazilian grasslands based on quantitative vegetation data recorded in a standardized sampling design. The data supports the division of grasslands into the main phytogeographic units of the region (Brazilian biome classification). Grasslands in these two regions also differ in terms of species dominance pattern (higher dominance in Pampa grasslands, likely also due to higher grazing level) and in terms of conservation state (low presence of exotic species in highland grasslands). Our

results are important for conservation policies, which can now consider the presence of different grassland types in different region, but more data will be necessary for a more detailed classification that considers different abiotic features in more detail.

Keywords: floristic pattern; grassland; indicator species; Brazilian Highland grasslands; Pampa biome; Atlantic Forest biome; species diversity; southern Brazil.

Nomenclature: Andrade et al. (2018); APG IV (2016); PPG I (2016).

Running title: South Brazilian grassland classification.

Introduction

Brazil is not only a country with extremely species-rich forests, but also contains a diversity of non-forest ecosystems that cover about 30% of the country's area (Overbeck et al. 2015). Open and grass-dominated ecosystems are found in all Brazilian biomes, but are dominant in the subtropical Pampa, at the southern tip of the country, in the tropical Cerrado (Brazilian savanna), and in the Pantanal, a hyper-seasonal savanna. Grasslands, in contrast to savannas without a conspicuous tree component, may occur in the other biomes as well, but are the main vegetation type in the southernmost part of Brazil. Here, they are found in two of the six Brazilian biomes in the IBGE (2004) classification, the Pampa and Atlantic Forest biomes. Regionally, these grasslands are known as *Campos Sulinos* (i.e. Southern Grasslands in Portuguese; Overbeck et al. 2007). In the Pampa biome, located in the southern half of the state of Rio Grande do Sul, grasslands are the dominant natural vegetation type, giving way to forest vegetation only along rivers or in regions or sites with a more accentuated topography. These grasslands are part of the large grassland region that extends to Uruguay and central-eastern Argentina, collectively known as Río de la Plata grasslands (Soriano et al. 1992). To the north of the Pampa, grasslands on the South Brazilian highland plateau (hereinafter referred to as 'highland grasslands') in northern Rio Grande do Sul and in Santa Catarina and Paraná states form mosaics with forests of the Atlantic Forest, primarily *Araucaria* forest (Overbeck et al. 2007 for a review).

Pampa and highland grasslands share many ecological similarities: they are species-rich ecosystems, with Poaceae, Asteraceae, Fabaceae and Cyperaceae as the most dominant families (Boldrini 2009) and both contain C_3 and C_4 grass species. In both regions, free range cattle grazing is an important economic activity, and shrub and forest encroachment processes take place in the absence of disturbances (Oliveira & Pillar 2005; Blanco et al. 2007). However, contrary to Pampa grasslands, due to increased temperature seasonality highland grasslands are traditionally managed with fire at the end of winter. Highland grasslands present lower carrying capacity during winter and thus are in general subject to lower livestock stocking rates throughout the year, which leads to higher amounts of ungrazed biomass during the growing season and increased standing dead biomass in winter. In consequence, farmers use fire at the end of winter in order to burn accumulated biomass and stimulate resprouting (Boldrini 1997; Overbeck & Pfadenhauer 2007). This fire management, while not reducing plant diversity (Overbeck et al. 2005), selects for species that have organs protected from fire and against species with an early-season development, such as C_3 grasses (Overbeck et al. 2007; Fidelis et al. 2010). In Pampa grasslands, grazing pressure in general is higher, which may have negative consequences for productivity (Carvalho & Batello 2009) and biodiversity (Mysterud 2006; Overbeck et al. 2007). It has been shown that the different management practices influence species distribution and especially their dominance patterns (see e.g. Andrade et al. 2016; Koch et al. 2016), but no synthesis over different regions exist.

In recent years, there have been advances in the floristic knowledge of grassland ecosystems in the region, but studies usually considered single sites or, at best, smaller regions, and have been conducted using different sampling designs and methods (e.g. for Pampa: Caporal & Boldrini 2007; Ferreira & Setubal 2009; Freitas et al. 2009; Setubal & Boldrini 2010; Pinto et al. 2013; Menezes et al. 2015; Silva Filho et al. 2017; e.g. for highland grasslands: Zanin et al. 2009; Moro & Carmo 2010; Kozera et al. 2012; Andrade et al. 2016; Moraes et al. 2016; Silva et al. 2016). These studies are important to describe local floristic patterns and grassland vegetation structure, and can be used to describe regional vegetation patterns. Overall, they point to the dominance of highland grassland by tall-growing tussock grasses, and dominance of prostrate species in the Pampa.

However, a comprehensive analysis of the grassland vegetation in the entire region, highlighting similarities and differences in terms of characteristic species, is still lacking, even to evaluate if grasslands in the two phytogeographic domains – i.e. Pampa and highland grasslands – do in fact differ in terms of species composition. This is problematic, since a more detailed knowledge of vegetation patterns is a fundamental basis for conservation decisions, for instance, for the systematic planning of protected area networks that should consider the diversity of habitat or vegetation types (Margules & Pressey 2000) and the singularities in distribution of biodiversity (e.g. Saraiva et al. 2018). At present, grasslands in the Atlantic Forest biome have a higher protection level, as specific legislation exists to protect all remnants of natural vegetation types in this region, a global biodiversity hotspot, including grassland vegetation (CONAMA 2010).

From a broader perspective, a general description of the *Campos Sulinos* region is important to enable comparisons between these grasslands and adjacent regions, such as the grasslands found in Uruguay (e.g. Lezama et al. in press), the Cerrado, or even with other grasslands in the world, like those under similar climatic conditions. Indeed, even within Brazil, the lack of knowledge on composition and ecology of South Brazilian grasslands has led – and continues to lead – to the use of inadequate terms for them, even in the 'official' IBGE (2004) vegetation classification that uses the terms 'Steppe' or 'Steppe-Savanna' for systems found under very distinct climatic conditions than those of a typical steppe region (Wesche et al. 2016).

Here, we provide the first general description of South Brazilian grasslands in terms of plant composition, based on data collected by a uniform sampling protocol with sites representing the entire region. Our data also allows to provide a first floristic classification of these grasslands and thus the recognition of different grassland community types and their characteristic species. We expected to find a rather clear distinction between Pampa and highland grasslands, which also show climatic differences. Also, within the Pampa grasslands, we expected to find additional floristic differences due to soil features, e.g. humid vs. drier conditions, and to geological substrates, as shown for Uruguayan grasslands (Lezama et al. *in press*).

Methods

Study area

Our study region, the *Campos Sulinos* (Overbeck et al. 2007), encompasses two major phytogeographic systems in South America: the Pampean province, part of the Chacoan domain, and the Paraná province, part of the Amazonian domain (Cabrera & Willink 1980). This corresponds to the division between Atlantic Forest biome and Pampa biome in the Brazilian biome classification (IBGE 2004; Fig. 1). In the highland grasslands, the grasslands situated at elevations above 400 m a.s.l. are found in mosaics mainly with *Araucaria* forest, one of the forest types of the Atlantic forest *sensu lato*. Forests have been expanding over grasslands in the past millennia, driven by climatic changes. Grasslands are the older vegetation type, and forest expansion is currently in process. Palaeoecological studies have demonstrated that the dominance of grasslands through Pleistocene to mid-Holocene can be attributed to a climate that was drier and cooler than today during the glacial period, and became warmer in the Holocene (Behling 2002; Behling et al. 2004; Behling & Pillar 2007). Modern humid climatic conditions in the late Holocene led to the expansion of *Araucaria* forest and Atlantic forest from refugia (Behling & Pillar 2007), partially replacing grassland vegetation (Klein 1960) where site conditions and disturbance regime allowed this (e.g. Müller et al. 2012). Current climate is subtropical without a dry season and hot (Cfa) or temperate summers (Cfb) according to the Köppen system (Alvares et al. 2013). The mean annual precipitation ranges from 1000 in the south to 2200 mm in the northeast, while mean annual temperature, mostly depending on altitude, ranges from 11 ºC to 20 ºC (Alvares et al. 2013).

Sampling design and data collection

Sampling was carried out during spring and summer between the years 2011 and 2013. We adopted a stratified, nested sampling design, with ten regional strata delimited primarily in terms of soil and geomorphology (Hasenack et al. 2010 unpubl., which was extended to the northern part of the highland grasslands). Landsat 5 satellite images (from

2009) were georeferenced to identify and evaluate the spatial distribution of land use/cover types. CartaLinx was used to digitize visually interpreted polygons and ArcView GIS 3.2 for mapping of land use/cover types. The study area was divided into grid cells of approximately 87 km^2 and in each stratum we randomly selected grid cells according to the level of grassland vegetation conservation (below 30% and above 60% of grassland cover). In each selected cell, we delimited one 2 km × 2 km landscape sampling unit presenting natural grassland dominance. Overall, 33 landscape units were surveyed in the Pampa grasslands in Rio Grande do Sul state, and 24 landscape units in the highland grassland enclaves within the Atlantic Forest biome in the states of Rio Grande do Sul, Santa Catarina and Paraná.

In the grassland portions of each landscape unit, we preferentially delimited three 70 m × 70 m plots in a way that they represented the topographic variation within the landscape unit. We took care that these plots were covered by grassland, while excluding extremes in terms of habitat conditions, such as large rock outcrops, very steep sites, or permanent wetlands. Our focus was on mesic to poorly drained (but never permanently waterlogged) grasslands. The 70 m × 70 m plots were our sampling units for all data analyses. The vegetation survey was carried out in nine quadrats of 1 m^2 systematically set in each 70 m × 70 m plot (Fig. 1). In total, we sampled 57 landscape units, 170 plots, and 1529 quadrats (in one landscape unit one 70 x 70 m plot was not described, and in one 70 x 70 m plot only 8 instead of 9 quadrats were described). In each quadrat, we recorded all plant species with shoots present in the quadrat (rooted within the quadrat or not) and identified them to the lower taxonomic hierarchy as possible. Species cover was estimated with a modification of Londo's (1976) decimal scale, with categories representing intervals of 10% cover, and the addition of a finer subdivision for the first 10% (<1%, 1-5%, 5-10%, 10-20%, 20-30%, etc.), but for the analyses we used species presence-absence data in each quadrat. Plant family classification followed APG IV (2016) for angiosperms, and PPG I (2016) for ferns and lycophytes. Bryophytes were not identified to the species level and were considered as a single group in analyses.

Data analysis

We subjected the matrix of relative frequency of all plant species in the 170 plots of 70 m x 70 m to complete linkage cluster analysis based on Bray Curtis dissimilarity. We limited the analysis to a maximum number of ten clustering groups and tested the stability of groups in 10 000 iterations by bootstrap resampling (Pillar 1999). We described the groups by calculating mean species richness at the quadrat and 70 x 70 m plot level, total vegetation cover and the Simpson diversity index (D) on the quadrat level, and number and cover of exotic species as an indicator of conservation state of each group. We compared groups regarding to these parameters by permutation analysis of variance, using Euclidean distance (Pillar & Orlóci 1996). We identified indicator species significantly associated to each grassland group or set of groups by Indicator species analysis (Dufrêne & Legendre 1997), an appropriate complementary method to vegetation classification (Salovaara et al. 2004).

Aiming to assess the influence of general environmental characteristics such as geological substrate, soil fertility and drainage conditions, we plotted all 70 x 70 m plots (categorized according to cluster groups) over simplified soil and geological maps. We constructed a simplified soil map based on the Brazilian soil survey mapped at a scale of 1:5 000 000 (Santos et al. 2011). For this, we created five general soil classes by joining soil types according to their chemical and structural characteristics. The geological map was based on mapping of the Brazilian Geologic Service (CPRM) at a scale of 1:6 000 000 (available at http://geosgb.cprm.gov.br/downloads/). Climate variables were extracted from the WorldClim database (Fick & Hijmans 2017).

Cluster analysis, bootstrap resampling and permutation analysis of variance were conducted using software MULTIV (available at http://ecoqua.ecologia.ufrgs.br; Pillar 1997). For indicator species analysis, we used the package indicspecies (De Caceres & Legendre 2009) on the R platform (R Core Team 2013).

Results

In total, 905 plant taxa were recorded in our sampling across the South Brazilian region (only 33 taxa [3.6%] could not be identified to the species level); this number included 43 exotic species. Cluster analysis identified grassland vegetation groups at different partition levels (Fig. 2), but only the classification into three groups was stable by bootstrap resampling (P > 0.05, Pillar 1999, see S3). However, a finer classification within these three stable groups reveals, in total, ten groups that we describe as grassland vegetation subtypes with clear indicator species (Table 1), which are in line with our knowledge and field experience about grassland vegetation patterns in the study region. Therefore, our classification (Fig. 2) identified a group A of mesic grasslands in the highland sites (grassland subtypes 1-4), a group B of mesic grassland in the Pampa biome (grassland subtypes 5-8) and a group C of humid grasslands integrating sites both along the coastline and in the hinterland (subtypes 9-10).

Highland grasslands (Type A)

Grassland subtype 1

This group was composed of only three sampling plots in one landscape unit situated in the highland grasslands within an *Araucaria* forest matrix in northern Rio Grande do Sul, on shallow soils of the basaltic plateau (Fig. 2). This sampling plot presented the highest mean annual precipitation (1922 mm) among all sampled sites. Vegetation is dominated by *Andropogon lateralis* (with mean cover of 48.5%; see Appendix S1) and *Axonopus ramboi*, both species have with a wider distribution pattern. Indicator species include *A. ramboi*, *Solanum mauritianum*, *Tibouchina urbanii*, *Calea phyllolepis* and *Mikania paranensis* (for complete results see Appendix S2). This group clearly separates from others due to specific site factors: situated in a private reserve, this is the only grassland site in our data set without influence of cattle grazing and fire (see Fig. 3), for today more than 20 years. Exclusion has resulted in reduced species richness in comparison to other sites (only 7.7 species per m^2; Table 2) and high dominance of a few tall-growing species (see also Overbeck et al. 2005) as well as forest encroachment (Oliveira & Pillar 2005).

Grassland subtype 2

Sampling Plots of group 2 are also located in the highland grasslands in Rio Grande do Sul, likewise in the basaltic region and mostly close to the steep escarpments in the northeast, also with high precipitation levels and relatively low temperature (Table 3), i.e. in terms of abiotic conditions very similar to grasslands subtype 1, but – as all subtypes except for subtype 1 – under grazing. Grassland subtype 2 is also found in mosaics with *Araucaria* forest. The vegetation is dominated by grasses like *Andropogon lateralis* (with mean cover of 33%), *Schizachyrium tenerum* and *Axonopus pellitus.* Indicator species include *Rhynchospora flexuosa*, *Paspalum maculosum*, *Scleria distans* and *Baccharis subtropicalis*, all characteristic for high soil humidity levels (due to high precipitation around the year), as well as some species that are restricted to this region, such as *Calydorea crocoides*, *Moritzia dasyantha* and *Piptochaetium alpinum*.

Grassland subtype 3

This subtype was formed by grasslands found in a wide region in the northeastern part of Rio Grande do Sul and southeastern part of Santa Catarina states. Just as the two former groups, these grasslands are located on the basaltic plateau on shallow soils (Fig. 2), a bit further inland and less humid (mean annual precipitation of about 1694 mm). Grasslands are dominated mostly by *Paspalum notatum, Piptochaetium montevidense, Andropogon lateralis* and *Schizachyrium tenerum*; other dominant species vary among specific site. Vegetation cover is more balanced among the more dominant species and *A. lateralis* is not as dominant as in the former groups. Indicator species include *Trifolium riograndense, Paspalum compressifolium* and *Plantago guilleminiana.*

Grassland subtype 4

This group is the last, and northernmost subtype, of the basaltic plateau. Plots are found at sites with deeper soils, with sampling plots located in the border region between Santa Catarina and Paraná state. These grasslands have the highest altitude and the lowest temperature in the coldest months of all plots in our data set (maximum altitude: 1270 m) and, just as those from subtypes 1-3, are under Cfb climate. Grasslands are dominated by species like *Schizachyrium tenerum*, *Piptochaetium montevidense, Paspalum plicatulum, Chaetogastra gracilis* and *Axonopus pellitus*, species that also occur in sampling plots from subtypes 1-3. Similar to the last subtype, no single species has outstanding dominance. Indicator species include *Paspalum glaucescens*, *Chromolaena latisquamulosa*, *Rhynchospora pungens*, *Pteridium arachnoideum*, *Chaptalia mandonii* and *Verbena hirta*.

Mesic Pampa grassland (Type B)

Grassland subtype 5

Sites of this subtype, the largest group in terms of number of sampling plots, are widely spread in the southern part of the state of Rio Grande do Sul, in the Pampa biome, mostly on sedimentary substrate and soils with a B textural horizon. Mean annual precipitation is about 1486 mm, much lower than in the former groups, but in the middle of the range verified for the Pampa sampled sites. These sites comprise 458 (50.6 %) of the total 905 sampled species. Only one indicator species was selected specifically for this group, *Gamochaeta simplicicaulis*, which indicates considerable variation in terms of local species composition within this group. High dominance of *Paspalum notatum*, with mean cover of 30%, is characteristic for this group, other dominant – albeit with much lower cover – species are *Andropogon laterais* and *Axonopus affinis*. Notably, the invasive alien grass *Eragrostis plana* is the fifth-most abundant species.

Grassland subtype 6

The sampling plots from this subtype were found in three distinct regions within the *Campos Sulinos* region: in the northern part of the Pampa biome, on deep soils, where large parts of natural grasslands have been transformed into agricultural areas, and in the western and southern part, on shallow soils and soils with B textural horizon. Sampling plots share the dominance of *Paspalum notatum* (with mean cover of 35.7%), followed by *Axonopus affinis*, *Eryngium horridum*, *Aristida jubata* and *Andropogon laterais*. Indicator species included tussock species such as *Aristida laevis*, *Aristida filifolia* and *Melica brasiliana*, as well as *Chaptalia nutans*. Dominant species showed some similarity to those of subtype 5, but with lower dominance of *A. lateralis* and *E. plana*.

Grassland subtype 7

Sampling plots from this group, located on shallow soils, were restricted to a small region in the west of Rio Grande do Sul. These sites have the highest annual precipitation level among all Pampa sampled sites, with values similar to the lowest mean precipitation among the highland grassland groups. While *Paspalum notatum* was the most dominant species in this group, its cover values were only half of those of subtypes 5 and 6. *Microchloa indica* and *Tripogon spicatus* were other species with high cover values. Indicator species included species characteristic of shallow soils like *T. spicatus*, *Nierembergia scoparia*, *Ayenia mansfeldiana, M. indica*, and *Plantago penantha* which has a restricted distribution. One characteristic species of the southeastern part of the *Campos Sulinos* in general found in this group (even though only with low cover) is the Fabaceae *Vachellia caven*, a small treelet occurring in the grasslands and giving the vegetation a savanna-like aspect (Figure 3).

Grassland subtype 8

This group was composed of only three sampling plots in one landscape units situated in the inner coastal plain in the southern part of Rio Grande do Sul state, on late holocene sedimentary deposits and flat relief (Figure 3). These SP have the lowest mean annual precipitation of all sampled groups (about 1287 mm). Soil drainage can be prevented by the B textural soil horizon, characteristic in the region (Figure 2). *Symphyotrichum squamatum, Paspalum dilatatum, Campomanesia aurea, Lippia ramboi* and *Paspalum modestum* are the most dominant species. Dominance in this group is similar to the last group, but much lower than that in subtypes 5 and 6. The indicator species include species characteristic for poorly drained soils like *Eleocharis flavescens*, *Eleocharis maculos*a, *Eclipta prostrata* and *Ludwigia peploides*, indicating that soil humidity of plots of this subtype tends to be higher.

Humid Pampa grassland (Type C)

Grassland subtype 9

This group was composed of nine sampling plots in seven landscape units, situated both in the southwest, continental, part of RS state, and in lowlands in the coastal region, always in sedimentary lowland areas. Dominant species include the widely distributed grasses *Axonopus affinis* and *Andropogon lateralis* as well as *Paspalum pumilum*, *Eleocharis viridans* and *Luziola peruviana,* all characteristic for humid conditions. Indicator species include species characteristic of poorly drained soils like *Eleocharis viridans*, *Eleocharis sellowiana*, *Eleocharis montana* and *Leersia hexandra*, as well as *Rhynchospora emaciata* and *Cyperus haspan*.

Grassland subtype 10

This group was composed of sampling plots in the coastal region both in the northern and in the southern part of Rio Grande do Sul. Mean annual precipitation also is rather low when compared to the other groups (1326 mm), and mean and maximum temperature are also slightly lower when compared to the other groups in the Pampa region, probably as a result of its proximity of the sea. *Paspalum notatum, Paspalum pumilum, Axonopus affinis* and *Axonopus* aff. *affinis* dominate the vegetation. Indicator species are *Hydrocotyle bonariensis*, *Axonopus* aff. *affinis*, *Pterocaulon cordobense*, *Rhynchospora brittonii*, *Eleocharis bonariensis*, *Andropogon leucostachyus*. This last species is highly characteristic of coastal grasslands.

Discussion

A first general description of the South Brazilian grasslands

Our data allowed the first general description and classification of the South Brazilian grasslands (*Campos Sulinos*) grasslands based on a quantitative assessment of species composition across the entire region, obtained under a standardized sampling design. Estimates for the region indicate the occurrence of more than 3000 plant species in these grassland ecosystems (Boldrini 1997). Our sampling of 57 landscape units with a total of 170 sampling plots revealed 905 vascular plant species, nearly one third of the estimated species pool for the *Campos Sulinos* region. We should, however, interpret this total number of species considering the focus of our sampling on mesic to humid grasslands, which excluded extreme, azonal sites occurring within the grassland matrix. It is well known that some habitats such as rock outcrops, can be very rich in species from families specially adapted to these environments, e.g. Cactaceae, with many species restricted to the region (Saraiva et al. 2014). Small wetlands inserted into the grassland matrix also have a rich species composition, e.g. we find several species of *Hippeastrum* (Amaryllidaceae; Büneker and Bastian 2017). Additionally, many species, including endemics, have limited distribution patterns, such as those belonging to genera *Lathyrus* and *Lupinus* (Boldrini et al. 2009) and/or very small population sizes, e.g. in the genera *Petunia* (Lorenz-Lemke et al. 2006; Fregonezi et al.

2013), and thus cannot be easily sampled with a design such as ours. Overall, our sample was adequate to characterize species composition of zonal vegetation of South Brazilian grassland ecosystems.

The *Campos Sulinos* emerge as a species-rich grassland region dominated, in terms of species cover, by C4 grasses. Among the ten species with the highest relative cover for the entire region, we found representants from different life forms, i.e. the tussock grasses *Andropogon lateralis* (C4; mean cover: 6.3%), *Piptochaetium montevidense* (C3; 3.9%), *Schizachyrium tenerum* (C4; 2.7%) and *Paspalum plicatulum* (C4; 2.2%); the rhizomatous grasses *Paspalum notatum* (C4; 16.3%; the most abundant species over the entire region) and *Paspalum pumilum* (C4; 2.0%); the stoloniferous *Axonopus affinis* (C4; 3.4%); the prostrate forb *Dichondra sericea* (1.1%), the prostrate forb *Richardia humistrata* (1.3%) and the subshrub *Baccharis crispa* (1.6%). Often, tussock grasses are found together with prostrate grasses, but when grazing pressure is low – or no grazing occurs, as in the plots of grassland subtype 1 – tall-growing tussock grasses outcompete the rhizomatous grasses and other low-growing species. In contrast, under high grazing pressure, prostrate species with their rapid resource-acquisition strategy (Cruz et al. 2010) and fast biomass regeneration after defoliation by grazing animals dominate, as in subtypes 5 and 6, where *P. notatum* makes up to one third of total vegetation cover. Shrubs and subshrubs can contribute substantially to vegetation cover, *B. crispa* and other similar species of the same genus are the most common examples. Taller shrubs may also occur, such as other species from *Baccharis* (e.g., *B. pentodonta, B. dracunculifolia* and *B. uncinella*) or other shrubs from the Asteraceae or a few other families. Abundance of these species is often mediated by grazing management, and in some areas farmers control shrubs mechanically. A conspicuous species found throughout the region *Eryngium horridum* (Apiaceae), a large-growing spiny rosette species, which together with some co-generic species with similar habit can become very abundant, also in response to the disturbance regime (Fidelis et al. 2008), and likewise is often subject to specific management by farmers.

An important characteristic of the *Campos Sulinos* region is the co-existence of C3 and C4 grasses. Overall, 37% of grasses are C3, and 63% are C4. C3 grasses – *Nassella*, *Piptochaetium* and *Chascolytrum* (Biganzoli & Zuloaga 2015) among the most species-rich genera – never reach abundance levels as high as those of the dominating C4 grasses, but they can be particularly abundant during early spring, before most C4 species starts their regrowth. This also explains their importance for cattle grazing management, since these species provide high-quality biomass at a period where the C4 species are still not very productive due to low temperatures.

Pampa and highland grasslands as two distinct grasslands regions within the Campos Sulinos

Our results support the division of South Brazilian grasslands into two phytogeographical units: the Pampa and the Parana province, according to Cabrera & Willink (1980), which is the basis for the Brazilian biome classification (IBGE 2004). Grasslands of the two regions are distinct in terms of floristic composition, even though they share a large number of species, and we can thus consider them as discrete ecological units within Brazil's *Campos Sulinos* region. These differences reflect major phytogeographic patterns (Waechter 2002) and may also be influenced by differences in ecogeographical speciation process (e.g. Fregonezi et al. 2013; Barros et al. 2015). Besides, the presence of distinct environmental features and differences in management between the two regions – mainly the rather frequent use of fire in the highland grasslands, and absence of such practices in the Pampa (Boldrini 1997, Overbeck & Pfadenhauer 2007) – likely contributed to shaping the extant plant communities (see e.g. Overbeck et al. 2005; Müller et al. 2007 on the effects of fire). Overall, this broad classification into two distinct grassland types finds its correspondence for forests (Oliveira-Filho et al. 2013), where subtropical Atlantic and Pampean forests differ clearly in terms of composition. However, in contrast to our grasslands, Pampean forests are much reduced in species richness compared to the forests further to the north (Oliveira-Filho et al. 2013).

Indicator species analysis (for complete results see Appendix S2) was helpful for the description and distinction of the different grassland groups (Fig. 2). *Schizachyrium tenerum* was the only indicator species for all four highland grassland subtypes. However, *Scleria sellowiana*, *Chromolaena latisquamulosa* and *Baccharis pentodonta* were selected as indicators for three, and *Andropogon lateralis, Sorghastrum pellitum, Axonopus pellitus* and *Andropogon macrothrix* – all C4 tussock grasses – for two of these subtypes of the highland grasslands. Some shrub species are considered typical for forest-grassland ecotone sites of highland grasslands, e.g. *Mikania decumbens* (Moro & Carmo 2010), others are widely spread shrubs that can form an upper layer in the grasslands, e.g. *Baccharis uncinella* and *B. pentodonta* (Boldrini 2009), especially after abandonment situation, i.e. exclusion of fire and grazing (Overbeck et al. 2005, 2007). Importantly, these species are grassland species, even though they characterize early stages of forest encroachment in grassland, especially in the absence of management (Oliveira & Pillar 2006).

The four mesic grassland subtypes of the Pampa were characterized by two indicator species, namely *Oxalis eriocarpa* and *Bothriochloa laguroides*. All species occurred with high frequency and were not common in sampling units of the other subtypes. Interestingly, the two largest grassland subtypes, 5 and 6, shared only one indicator species, *Nassella neesiana*. Subtypes 5 and 7 were indicated by *Eryngium echinatum*, *Ruellia morongii* and *Richardia stellaris*, low-growing species characteristic of heavily grazed sites. The three more humid grassland subtypes (subtypes 8-10) were indicated by *Luziola peruviana*, *Lobelia hederacea* and *Centella asiatica.* The latter is actually widely distributed, but much more common where humidity is higher. The grass *Paspalum pumilum* is another typical species of the humid sites of the Pampa, but was shared, as an indicator species, with grassland subtype 2 in the highlands, the region with highest precipitation (Table 3). *Paspalum pumilum* was not found in the plots of subtype 1, which are under similar climate, but due to grazing exclusion for two decades in the studied landscape unit, they were dominated by tall grasses (see Boldrini & Eggers 1996; Overbeck et al 2005) that outcompete low-growing species such as *P. pumilum* (see above).

Similarity between the Campos Sulinos and other grassland regions

Few studies have, so far tried to establish parallels between species composition and ecology of the *Campos Sulinos* to other grassland regions of the world. As expected, the *Campos Sulinos*, and especially the Pampa grasslands, share many features and dominant species with Uruguayan grasslands located just south and adjacent to our study region (Altesor et al. 2005). Indeed, the Río de la Plata grasslands can be considered as an ecological unit (Andrade et al. 2018), despite clear compositional changes along the latitudinal gradient.

Further, few species, but many genera, are shared with the neotropical savanna ecosystems e.g. Brazilian Cerrado, which are under tropical seasonal climate and thus ruled by distinct ecological processes. One of the distinct features of the *Campos Sulinos*, just as of the Río de la Plata grasslands as a whole is the co-existence of C3 and C4 grasses. This is a feature that we can also find in North American prairies (Paruelo et al. 1998). The *Campos Sulinos* share not only ecological characteristics, but also main plant genera with the Tallgrass prairie in North America, which stimulated Overbeck et al. (2018) to discuss implications for conservation strategies in South Brazilian grasslands, especially concerning the use of fire. This calls for more comparative studies – such as they exist e.g. between North American and South African grasslands (examples include Knapp et al. 2014 and Smith et al. 2016; see also Overbeck et al. 2018) – between *Campos Sulinos* and other grassland regions, not only regarding floristics, but also ecological characteristics. At the moment, few studies exist that attempt to conduct comparative studies among the world's grassland regions.

Conservation state of the Campos Sulinos

A recent study, using part of our dataset (Staude et al. 2018), showed that land-use change in the region, i.e. mostly the conversion of grassland into cropland or tree plantations, has led to losses in species richness and to biotic homogenization of grassland remnants. Overall, approximately 60% of the original grassland areas have been lost in the past decade and, depending on the region, 5-17% of remnant grasslands showed signs of degradation (Andrade et al. 2015).

On the other hand, number and cover of exotic species in the region as a whole is rather low when compared to neighboring grassland regions (see also Rolim et al. 2015). Interestingly, in our study, with focus on natural grasslands, exotic species were much less frequent in highland compared to Pampa grasslands, indicating in the former a better conservation state of the remaining natural grasslands. However, a recent study including primary and secondary grasslands in the highlands revealed a considerable importance of exotic species (Koch et al. 2016). This, together with the fast and severe current land-use changes (Hermann et al. 2016) likely indicates ongoing degradation processes of natural ecosystems in the region as a whole, even though the impact of these processes has not yet been detected on species composition in primary grasslands. Exotic species, mostly *Eragrostis plana*, reached ca. 5% of species abundance in the Pampa, especially in grassland subtype 5, the largest group in terms of sampling plots, and in grassland subtype 9. *Eragrostis plana*, was indicator species for grassland subtypes 5, 8 and 9. This species was introduced from Africa and is considered the most problematic invader in the region (Guido et al. 2016, Dresseno et al. 2018). Another highly invasive species, *Cynodon dactylon* (Guido et al. 2016), was indicator for grassland subtypes 8 and 10. In highland grasslands as well as in the coastal region, invasion of *Pinus elliottii* strongly transforming natural environments, has been identified as cause of biodiversity loss. Presence of these invasive species are related to changes in land management in the region (Vila & Ibañéz 2011, Guido et al. 2016). In fact, all three of them have been and – with the exception of *Eragrostis plana* – continue to be used intentionally throughout the region. Overgrazing certainly is another problem in the region – as Carvalho & Batello (2009) point out this is a consequence of management policy that has mistakenly promoted the use of stocking rate as a measure of productivity instead of measuring actual productivity. Our data, e.g. consistently high cover of *P. notatum* and other prostrate species, alongside with invasion e.g. of *E. plana*, are indicators of the high grazing pressure, which is a problem not only for biodiversity, but for productivity as well (Mysterud et al. 2006). Inappropriate management practices, the low protection levels of grasslands, and a forest-biased conservation policy (Brandão et al. 2007; Overbeck et al. 2015), together with rapid land-use changes (Oliveira et al. 2017), certainly put South Brazilian grasslands under threat, with some regional differences (see Andrade et al. 2015). Further, our classification of South Brazilian grassland types should be useful for evaluating efficiency protected area networks and for devising conservation strategies and policies.

Perspectives and conclusions

Our classification of South Brazilian grasslands may be based on a small dataset relatively to other studies that describe vegetation patterns. Nonetheless, the data permits a first general description of South Brazilian grasslands as a whole based on quantitative data, and a first description of principal vegetation units within these grasslands. Certainly, more detailed classifications, e.g. considering soil features or small-scale topographic variation

(Setubal & Boldrini 2010) will be possible if a larger database were available. Our results should thus be considered as a first step towards a better knowledge of the *Campos Sulinos* and their floristic variation, but more research efforts are clearly necessary. In the past two decades there has been considerable progress in taxonomic and ecological studies of South Brazilian grassland plants, which facilitated field work and large sampling campaigns, also due to close collaboration between ecologists and plant taxonomists (see Halme et al. 2015; Sheldon 2016).

On the basis of our existing database and other available studies, we should be able to identify regions with gaps in field data and conduct more directed sampling in order to improve the database for further studies. Apart from revealing more details about floristic patterns and community assembly processes (e.g. Menezes et al. 2016), future studies that increase the available data should also be directed in a way to contribute to conservation and management strategies on a larger scale, e.g. by evaluating beta diversity patterns and protection gaps. This would also show the importance of field-based studies for conservation efforts and increase public awareness for grassland vegetation.

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Table 1. Mean frequency values (from 0 to 100%) of Indicator Species per grassland subtype (cluster group) or sets of subtypes). When more than ten species were selected in IndVal analysis, only the ten species with the highest IndVal value are shown. Mean frequency values are given for all groups; grey shadowing indicates for which groups (grassland subtypes) species were selected as indicators. Order of species follow decreasing mean frequency values by subtype grasslands.

				Highland grassland				Mesic Pampa grassland				Humid Pampa grassland	
Family	**Species**	**Indval**	**P**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Poaceae	Andropogon lateralis	0.746	0.001	96.30	93.65	27.78	0.00	37.04	22.59	0.00	0.00	37.04	26.98
Asteraceae	Calea phyllolepis	0.961	0.001	92.59	0.00	0.00	7.58	0.00	0.00	0.00	0.00	0.00	0.00
Melastomataceae	Chaetogastra gracilis	0.804	0.001	51.85	15.87	23.33	49.49	1.85	1.85	0.00	11.11	19.75	4.76
Poaceae	Dichanthelium sabulorum	0.932	0.001	48.15	33.33	54.72	43.94	40.21	43.33	2.78	0.00	44.44	35.91
Poaceae	Sorghastrum pellitum	0.665	0.01	48.15	22.22	8.33	3.03	1.32	0.00	0.00	0.00	12.35	0.00
Asteraceae	Baccharis crispa	0.907	0.001	44.44	34.92	78.33	53.03	19.31	36.67	0.00	44.44	16.05	40.67
	Bryophyta spp.	0.894	0.001	44.44	17.46	1.39	0.00	3.17	1.11	38.89	0.00	0.00	1.59
Poaceae	Axonopus ramboi	1	0.001	44.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melastomataceae	Tibouchina urbanii	1	0.001	44.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Danthonia montana	0.775	0.001	37.04	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asteraceae	Barrosoa candolleana	0.805	0.002	18.52	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sellaginellaceae	Selaginella sp.	0.785	0.001	14.81	36.51	0.00	0.00	5.56	1.48	0.00	0.00	0.00	0.00
Poaceae	Panicum sp.	0.816	0.001	14.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Schizachyrium tenerum	0.947	0.001	11.11	57.14	73.61	97.98	7.41	8.89	0.00	0.00	0.00	0.00
Alstroemeriaceae	Bomarea edulis	0.577	0.044	11.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asteraceae	Mikania paranensis	0.816	0.001	11.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solanaceae	Solanum mauritianum	1	0.001	11.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Axonopus pellitus	0.906	0.001	7.41	84.13	26.94	72.73	0.00	0.00	0.00	0.00	0.00	0.00
Iridaceae	Gelasine coerulea	0.73	0.002	7.41	1.59	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyperaceae	Scleria sellowiana	0.615	0.024	3.70	15.87	5.28	15.66	1.06	0.00	0.00	0.00	4.94	0.00

Polygalaceae	Polygala brasiliensis	0.655	0.004	3.70	9.52	3.61	3.03	0.00	5.19	0.00	29.63	0.00	0.00
Iridaceae	Sisyrinchium vaginatum	0.682	0.005	3.70	4.76	6.11	21.21	1.59	0.00	0.00	0.00	1.23	0.00
Alstroemeriaceae	Alstroemeria isabelleana	0.577	0.044	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Paspalum pumilum	0.883	0.001	0.00	68.25	18.33	0.00	2.65	7.04	0.00	22.22	45.68	72.62
Poaceae	Paspalum maculosum	0.823	0.001	0.00	68.25	21.11	7.58	0.26	1.11	0.00	0.00	2.47	0.00
Cyperaceae	Rhynchospora flexuosa	0.882	0.001	0.00	65.08	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Paspalum polyphyllum	0.815	0.001	0.00	57.14	11.11	17.68	0.00	0.00	0.00	0.00	0.00	0.00
Rubiaceae	Galium humile	0.781	0.001	0.00	52.38	32.22	6.06	3.44	0.00	0.00	0.00	7.41	7.94
Cyperaceae	Scleria distans	0.766	0.001	0.00	46.03	0.28	0.00	0.53	0.37	0.00	0.00	7.41	12.70
Iridaceae	Sisyrinchium micranthum	0.874	0.001	0.00	39.68	5.56	3.54	51.85	28.15	61.11	7.41	32.10	12.70
Poaceae	Andropogon macrothrix	0.753	0.004	0.00	38.10	3.89	30.30	0.26	0.74	0.00	0.00	0.00	1.59
Asteraceae	Hypochaeris lutea	0.89	0.001	0.00	36.51	1.11	0.00	0.00	1.85	0.00	0.00	0.00	0.00
Cyperaceae	Rhynchospora barrosiana	0.668	0.011	0.00	33.33	2.78	0.00	0.53	0.37	0.00	0.00	3.70	28.57
Cyperaceae	Carex phalaroides	0.826	0.001	0.00	31.75	6.39	0.51	37.04	7.41	0.00	0.00	1.23	0.00
Poaceae	Agrostis montevidensis	0.703	0.007	0.00	26.98	14.72	3.54	1.85	13.70	0.00	11.11	3.70	0.00
Asteraceae	Chevreulia revoluta	0.884	0.001	0.00	26.98	6.67	37.88	0.00	0.00	0.00	0.00	0.00	0.00
Asteraceae	Baccharis subtropicalis	0.728	0.002	0.00	22.22	4.44	0.00	6.08	0.00	0.00	0.00	0.00	3.17
Orchidaceae	Habenaria parviflora	0.716	0.002	0.00	22.22	2.50	0.51	0.26	0.74	0.00	0.00	0.00	4.76
Euphorbiaceae	Euphorbia peperomioides	0.91	0.001	0.00	20.63	2.78	48.99	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Axonopus affinis	0.897	0.017	0.00	17.46	36.39	33.33	52.65	50.37	11.11	29.63	76.54	34.92
Asteraceae	Gamochaeta americana	0.87	0.025	0.00	14.29	36.11	43.94	21.43	21.48	30.56	18.52	13.58	7.94
Asteraceae	Chaptalia exscapa	0.731	0.003	0.00	14.29	30.83	14.65	3.97	8.52	0.00	0.00	1.23	0.00
Araliaceae	Hydrocotyle exigua	0.721	0.01	0.00	14.29	11.39	9.60	33.60	9.63	0.00	0.00	17.28	0.00
Asteraceae	Disynaphia ligulaefolia	0.655	0.007	0.00	14.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plantaginaceae	Plantago tomentosa	0.691	0.004	0.00	12.70	3.89	0.00	11.64	11.85	13.89	0.00	4.94	0.00
Asteraceae	Baccharis pentodonta	0.789	0.001	0.00	12.70	40.00	14.65	0.00	0.00	0.00	0.00	0.00	0.00
Asteraceae	Chaptalia runcinata	0.734	0.003	0.00	12.70	23.89	1.52	17.20	7.04	16.67	0.00	3.70	1.59
Cyperaceae	Bulbostylis sphaerocephala	0.576	0.039	0.00	12.70	6.11	20.71	0.53	0.37	0.00	0.00	1.23	0.00
Apiaceae	Eryngium elegans	0.551	0.026	0.00	11.11	2.50	0.00	0.79	0.00	5.56	0.00	0.00	0.00

Iridaceae	Herbertia lahue	0.659	0.006	0.00	11.11	0.56	0.00	14.02	14.44	25.00	0.00	1.23	0.00
Asteraceae	Trichocline catharinensis	0.698	0.004	0.00	9.52	23.06	5.56	0.26	0.00	0.00	0.00	0.00	0.00
Cyperaceae	Rhynchospora rugosa	0.7	0.006	0.00	9.52	15.83	0.00	2.38	0.00	0.00	0.00	17.28	0.00
Asteraceae	Lucilia linearifolia	0.646	0.011	0.00	9.52	1.94	16.67	0.00	0.00	0.00	0.00	0.00	0.00
Melastomataceae	Acisanthera alsinaefolia	0.508	0.046	0.00	9.52	1.67	0.00	0.00	0.00	0.00	0.00	0.00	6.35
Asteraceae	Chromolaena ascendens	0.878	0.001	0.00	9.52	35.83	39.39	0.53	2.22	0.00	0.00	0.00	1.79
Poaceae	Axonopus compressus	0.619	0.019	0.00	9.52	18.61	7.07	2.65	0.74	0.00	0.00	0.00	0.00
Asteraceae	Noticastrum decumbens	0.691	0.004	0.00	9.52	11.11	29.80	0.79	0.00	2.78	0.00	0.00	0.00
Cyperaceae	Kyllinga vaginata	0.767	0.001	0.00	9.52	3.89	0.00	26.19	11.11	33.33	33.33	16.05	19.05
Asteraceae	Chevreulia sarmentosa	0.862	0.001	0.00	7.94	36.39	13.64	48.41	48.52	5.56	0.00	3.70	13.29
Hypoxidaceae	Hypoxis decumbens	0.799	0.001	0.00	7.94	21.67	4.04	39.95	28.15	16.67	11.11	14.81	9.72
Poaceae	Chascolytrum subaristatum	0.789	0.001	0.00	7.94	16.39	1.01	29.10	37.04	0.00	0.00	2.47	0.00
Poaceae	Chascolytrum poomorphum	0.587	0.044	0.00	7.94	5.56	0.00	5.56	1.48	0.00	0.00	14.81	1.79
Iridaceae	Calydorea crocoides	0.655	0.007	0.00	7.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oxalidaceae	Oxalis perdicaria	0.566	0.036	0.00	6.35	0.83	14.14	0.00	0.74	0.00	0.00	0.00	0.00
Cyperaceae	Eleocharis viridans	0.798	0.001	0.00	6.35	0.00	0.00	8.73	10.00	0.00	11.11	72.84	5.36
Cyperaceae	Eleocharis maculosa	0.875	0.001	0.00	6.35	0.00	0.00	0.53	0.00	0.00	33.33	0.00	3.37
Poaceae	Eragrostis polytricha	0.85	0.001	0.00	4.76	42.50	62.63	1.85	11.11	0.00	0.00	0.00	6.35
Asteraceae	Chevreulia acuminata	0.79	0.002	0.00	4.76	37.78	17.17	28.04	18.15	2.78	0.00	4.94	0.00
Campanulaceae	Wahlenbergia linarioides	0.738	0.002	0.00	4.76	19.44	13.13	17.72	8.15	2.78	0.00	0.00	0.00
Poaceae	Steinchisma hians	0.869	0.001	0.00	4.76	18.33	2.53	60.05	34.44	38.89	29.63	53.09	12.90
Asteraceae	Gamochaeta filaginea	0.676	0.006	0.00	4.76	0.00	0.00	6.35	21.85	0.00	3.70	9.88	27.98
Boraginaceae	Moritzia dasyantha	0.655	0.007	0.00	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Piptochaetium montevidense	0.955	0.001	0.00	3.17	79.72	57.07	69.05	85.19	33.33	0.00	7.41	5.36
Convolvulaceae	Dichondra sericea	0.909	0.001	0.00	3.17	46.94	30.81	60.85	67.78	0.00	11.11	17.28	25.20
Apiaceae	Centella asiatica	0.869	0.001	0.00	3.17	5.83	13.13	13.76	10.00	0.00	29.63	66.67	83.93
Asteraceae	Hypochaeris catharinensis	0.639	0.012	0.00	3.17	5.00	24.24	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Paspalum plicatulum	0.926	0.001	0.00	1.59	60.28	63.64	32.01	45.56	0.00	29.63	16.05	16.87
Asteraceae	Aspilia montevidensis	0.751	0.009	0.00	1.59	37.22	6.57	15.61	25.93	0.00	44.44	3.70	5.36

Amaranthaceae	Pfaffia tuberosa	0.756	0.001	0.00	1.59	22.78	4.55	23.02	15.56	0.00	0.00	0.00	1.59
Poaceae	Aristida flaccida	0.827	0.001	0.00	1.59	10.83	50.00	0.00	0.74	0.00	0.00	0.00	0.00
Lythraceae	Cuphea glutinosa	0.677	0.011	0.00	1.59	6.94	0.00	16.93	18.52	0.00	22.22	3.70	4.76
Verbenaceae	Glandularia marrubioides	0.53	0.041	0.00	1.59	1.11	9.09	0.00	0.00	0.00	0.00	0.00	0.00
Campanulaceae	Lobelia hederacea	0.8	0.002	0.00	1.59	0.83	0.51	2.91	2.22	0.00	33.33	28.40	54.96
Acanthaceae	Ruellia morongii	0.601	0.021	0.00	1.59	0.28	0.00	20.11	2.59	11.11	0.00	0.00	0.00
Cyperaceae	Rhynchospora brittonii	0.622	0.013	0.00	1.59	0.28	0.00	0.00	0.37	0.00	0.00	0.00	20.63
Cyperaceae	Cyperus haspan	0.628	0.009	0.00	1.59	0.00	0.00	0.00	0.00	0.00	0.00	12.35	0.00
Poaceae	Paspalum notatum	0.956	0.001	0.00	0.00	66.94	9.09	92.86	92.22	47.22	29.63	27.16	53.97
Rubiaceae	Richardia humistrata	0.905	0.001	0.00	0.00	38.89	0.51	50.53	68.15	0.00	0.00	6.17	23.02
Poaceae	Mnesithea selloana	0.863	0.001	0.00	0.00	34.44	4.55	56.08	44.81	0.00	0.00	4.94	19.84
Poaceae	Schizachyrium microstachyum	0.639	0.039	0.00	0.00	29.72	21.72	5.29	9.26	0.00	0.00	0.00	1.79
Fabaceae	Desmodium incanum	0.821	0.001	0.00	0.00	20.83	0.00	67.72	42.22	5.56	3.70	9.88	4.76
Asteraceae	Lucilia nitens	0.802	0.001	0.00	0.00	19.17	18.18	0.79	14.44	0.00	11.11	0.00	3.17
Fabaceae	Trifolium riograndense	0.613	0.019	0.00	0.00	18.61	0.00	1.06	6.30	0.00	0.00	0.00	0.00
Asteraceae	Baccharis articulata	0.71	0.003	0.00	0.00	15.83	16.67	1.32	0.00	0.00	0.00	0.00	4.76
Cyperaceae	Kyllinga odorata	0.754	0.004	0.00	0.00	13.89	9.60	13.76	17.78	13.89	40.74	3.70	28.77
Fabaceae	Crotalaria hilariana	0.762	0.001	0.00	0.00	13.61	18.69	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Setaria parviflora	0.927	0.001	0.00	0.00	13.33	2.02	62.70	68.52	22.22	51.85	14.81	16.47
Cyperaceae	Bulbostylis juncoides	0.649	0.016	0.00	0.00	11.94	10.61	2.12	1.48	22.22	0.00	0.00	0.00
Asteraceae	Pterocaulon alopecuroides	0.602	0.037	0.00	0.00	11.11	12.12	4.76	0.74	0.00	0.00	1.23	0.00
Asteraceae	Chrysolaena flexuosa	0.608	0.04	0.00	0.00	10.83	11.11	2.91	7.41	0.00	0.00	0.00	1.59
Asteraceae	Hypochaeris radicata	0.605	0.02	0.00	0.00	9.44	1.52	0.00	0.00	0.00	0.00	0.00	0.00
Asteraceae	Lucilia acutifolia	0.676	0.009	0.00	0.00	9.44	15.15	1.59	0.74	0.00	0.00	0.00	0.00
Fabaceae	Stylosanthes montevidensis	0.686	0.01	0.00	0.00	8.89	20.20	5.56	13.33	0.00	0.00	0.00	0.00
Rubiaceae	Galium richardianum	0.752	0.002	0.00	0.00	8.61	4.04	35.98	19.26	5.56	3.70	1.23	16.87
Poaceae	Paspalum compressifolium	0.574	0.043	0.00	0.00	8.33	0.51	0.00	0.00	0.00	0.00	0.00	0.00
Dennstaedtiaceae	Pteridium arachnoideum	0.809	0.001	0.00	0.00	8.06	25.25	0.00	0.00	0.00	0.00	0.00	0.00
Poaceae	Andropogon selloanus	0.792	0.001	0.00	0.00	7.78	1.01	4.76	29.26	0.00	0.00	2.47	48.61

Plantaginaceae	Plantago guilleminiana	0.535	0.042	0.00	0.00	7.50	1.01	0.00	0.00	0.00	0.00	0.00	0.00
Apiaceae	Eryngium horridum	0.687	0.007	0.00	0.00	6.94	2.53	15.61	40.74	0.00	3.70	0.00	1.79
Asteraceae	Hypochaeris chillensis	0.664	0.019	0.00	0.00	6.67	19.19	8.99	12.59	0.00	0.00	2.47	0.00
Poaceae	Eragrostis neesii	0.854	0.001	0.00	0.00	6.67	0.00	25.40	50.37	77.78	0.00	0.00	8.53
Asteraceae	Lessingianthus hypochaeris	0.805	0.001	0.00	0.00	5.28	23.74	0.79	1.85	0.00	0.00	0.00	0.00
Myrtaceae	Campomanesia aurea	0.872	0.001	0.00	0.00	5.00	1.01	1.06	8.15	0.00	48.15	0.00	0.00
Cyperaceae	Rhynchospora pungens	0.845	0.001	0.00	0.00	4.17	32.83	2.38	0.37	0.00	0.00	0.00	0.00
Apiaceae	Cyclospermum leptophyllum	0.853	0.001	0.00	0.00	3.61	0.00	43.65	23.33	27.78	3.70	6.17	15.48
Poaceae	Piptochaetium stipoides	0.742	0.001	0.00	0.00	3.33	0.00	24.34	14.07	5.56	0.00	0.00	0.00
Poaceae	Bothriochloa laguroides	0.734	0.001	0.00	0.00	3.33	0.00	23.54	19.26	13.89	3.70	0.00	1.59
Convolvulaceae	Evolvulus sericeus	0.852	0.001	0.00	0.00	3.06	1.52	31.48	45.93	77.78	0.00	3.70	5.36
Poaceae	Aristida laevis	0.579	0.036	0.00	0.00	3.06	0.00	5.82	18.15	0.00	0.00	0.00	0.00
Polygalaceae	Polygala pumila	0.625	0.01	0.00	0.00	2.78	8.59	0.79	0.37	5.56	0.00	0.00	0.00
Poaceae	Sporobolus indicus	0.835	0.001	0.00	0.00	2.78	0.00	40.74	27.78	19.44	7.41	1.23	23.81
Fabaceae	Trifolium polymorphum	0.648	0.006	0.00	0.00	2.78	0.00	23.81	10.37	8.33	0.00	0.00	0.00
Plantaginaceae	Plantago myosuros	0.715	0.001	0.00	0.00	2.50	0.00	21.69	20.74	0.00	3.70	0.00	3.37
Asteraceae	Gyptis pinnatifita	0.821	0.001	0.00	0.00	2.22	22.73	0.00	1.11	0.00	0.00	0.00	0.00
Asteraceae	Stenocephalum megapotamicum	0.901	0.001	0.00	0.00	1.94	30.81	0.00	0.00	0.00	0.00	0.00	0.00
Asteraceae	Facelis retusa	0.709	0.004	0.00	0.00	1.94	0.00	17.99	22.96	0.00	7.41	12.35	3.57
Rubiaceae	Borreria verticillata	0.645	0.01	0.00	0.00	1.94	0.00	17.46	5.56	5.56	0.00	4.94	0.00
Asteraceae	Symphyotrichum squamatum	0.935	0.001	0.00	0.00	1.67	0.51	3.17	4.07	0.00	88.89	0.00	3.37
Poaceae	Aristida venustula	0.722	0.002	0.00	0.00	1.67	0.00	28.31	9.26	11.11	0.00	0.00	0.00
Poaceae	Axonopus aff. affinis	0.726	0.002	0.00	0.00	1.67	0.00	0.00	0.00	0.00	0.00	2.47	49.21
Asteraceae	Soliva sessilis	0.801	0.001	0.00	0.00	1.39	0.00	38.62	11.85	61.11	0.00	3.70	1.59
Fabaceae	Stylosanthes leiocarpa	0.607	0.014	0.00	0.00	1.11	0.00	3.97	10.37	0.00	0.00	4.94	21.03
Poaceae	Aristida filifolia	0.562	0.04	0.00	0.00	1.11	0.00	0.26	8.52	0.00	0.00	0.00	0.00
Poaceae	Eragrostis bahiensis	0.612	0.012	0.00	0.00	0.83	0.00	2.12	0.74	0.00	0.00	17.28	4.76
Cyperaceae	Pycreus polystachyos	0.769	0.002	0.00	0.00	0.83	0.00	0.79	5.56	5.56	25.93	14.81	52.38
Araliaceae	Hydrocotyle bonariensis	0.805	0.001	0.00	0.00	0.83	0.00	0.53	0.00	0.00	3.70	12.35	53.97

Poaceae	Melica brasiliana	0.531	0.044	0.00	0.00	0.83	0.00	0.00	12.96	0.00	0.00	0.00	0.00
Euphorbiaceae	Croton glechomifolius	0.854	0.001	0.00	0.00	0.56	28.28	0.00	1.11	0.00	0.00	0.00	0.00
Asteraceae	Gamochaeta simplicicaulis	0.554	0.045	0.00	0.00	0.56	0.51	12.43	0.00	0.00	0.00	0.00	0.00
Orobanchaceae	Agalinis communis	0.644	0.008	0.00	0.00	0.56	0.00	8.47	17.04	16.67	18.52	0.00	41.87
Rubiaceae	Oldenlandia salzmannii	0.783	0.001	0.00	0.00	0.56	0.00	1.06	1.85	0.00	3.70	39.51	19.05
Fabaceae	Desmodium adscendens	0.642	0.011	0.00	0.00	0.56	0.00	0.53	1.85	0.00	0.00	17.28	30.16
Cyperaceae	Fimbristylis complanata	0.692	0.004	0.00	0.00	0.56	0.00	0.26	9.26	0.00	14.81	0.00	25.20
Oxalidaceae	Oxalis eriocarpa	0.735	0.002	0.00	0.00	0.28	0.00	20.11	14.44	5.56	3.70	0.00	0.00
Plantaginaceae	Mecardonia procumbens	0.704	0.006	0.00	0.00	0.28	0.00	10.85	10.00	2.78	0.00	32.10	1.59
Asteraceae	Conyza bonariensis	0.605	0.031	0.00	0.00	0.28	0.00	9.52	7.78	2.78	0.00	2.47	3.37
Verbenaceae	Lippia ramboi	0.993	0.001	0.00	0.00	0.28	0.00	0.26	0.37	0.00	62.96	0.00	0.00
Poaceae	Andropogon leucostachyus	0.616	0.008	0.00	0.00	0.28	0.00	0.00	0.37	0.00	0.00	0.00	4.96
Poaceae	Paspalum glaucescens	0.853	0.001	0.00	0.00	0.00	30.30	0.00	0.00	0.00	0.00	0.00	0.00
Asteraceae	Mikania decumbens	0.905	0.001	0.00	0.00	0.00	28.79	0.00	0.00	0.00	0.00	0.00	0.00
Fabaceae	Vigna luteola	0.809	0.001	0.00	0.00	0.00	0.51	0.00	0.00	0.00	25.93	0.00	0.00
Asteraceae	Baccharis coridifolia	0.614	0.016	0.00	0.00	0.00	0.00	28.84	22.59	2.78	0.00	2.47	0.00
Juncaceae	Juncus capillaceus	0.755	0.001	0.00	0.00	0.00	0.00	23.02	18.15	0.00	40.74	2.47	14.48
Poaceae	Vulpia bromoides	0.839	0.002	0.00	0.00	0.00	0.00	20.11	6.67	63.89	0.00	0.00	0.00
Poaceae	Eragrostis plana	0.654	0.008	0.00	0.00	0.00	0.00	20.11	4.07	0.00	29.63	20.99	1.79
Poaceae	Paspalum lepton	0.671	0.009	0.00	0.00	0.00	0.00	19.84	9.63	0.00	48.15	17.28	19.64
Lamiaceae	Scutellaria racemosa	0.684	0.009	0.00	0.00	0.00	0.00	19.58	6.30	0.00	0.00	2.47	1.59
Plantaginaceae	Plantago penantha	0.848	0.001	0.00	0.00	0.00	0.00	19.31	0.00	55.56	0.00	2.47	0.00
Rubiaceae	Richardia stellaris	0.827	0.001	0.00	0.00	0.00	0.00	18.25	26.30	86.11	0.00	0.00	0.00
Poaceae	Nassella neesiana	0.612	0.029	0.00	0.00	0.00	0.00	16.40	6.30	0.00	0.00	0.00	0.00
Apiaceae	Eryngium echinatum	0.626	0.028	0.00	0.00	0.00	0.00	14.81	0.00	36.11	0.00	0.00	0.00
Apiaceae	Eryngium nudicaule	0.621	0.018	0.00	0.00	0.00	0.00	11.90	27.04	2.78	0.00	0.00	14.48
Poaceae	Eleusine tristachya	0.772	0.002	0.00	0.00	0.00	0.00	10.58	5.93	47.22	44.44	0.00	1.79
Malvaceae	Krapovickasia flavescens	0.676	0.007	0.00	0.00	0.00	0.00	9.52	18.15	0.00	18.52	0.00	0.00
Juncaceae	Juncus microcephalus	0.712	0.004	0.00	0.00	0.00	0.00	8.73	3.33	0.00	11.11	28.40	9.52

Plantaginaceae	Berroa gnaphalioides	0.923	0.001	0.00	0.00	0.00	0.00	8.20	0.00	47.22	0.00	0.00	0.00
Plantaginaceae	Scoparia montevidensis	0.88	0.001	0.00	0.00	0.00	0.00	4.50	10.74	58.33	0.00	0.00	1.79
Cyperaceae	Bulbostylis scabra	0.822	0.001	0.00	0.00	0.00	0.00	3.97	22.96	61.11	3.70	0.00	27.38
Cyperaceae	Kyllinga brevifolia	0.782	0.001	0.00	0.00	0.00	0.00	3.44	3.33	8.33	33.33	29.63	30.56
Poaceae	Steinchisma decipiens	0.816	0.001	0.00	0.00	0.00	0.00	3.17	27.04	0.00	40.74	4.94	23.61
Cyperaceae	Eleocharis bonariensis	0.564	0.033	0.00	0.00	0.00	0.00	2.91	0.00	0.00	0.00	3.70	19.05
Cyperaceae	Rhynchospora emaciata	0.629	0.009	0.00	0.00	0.00	0.00	2.12	0.00	0.00	0.00	17.28	0.00
Verbenaceae	Glandularia selloi	0.651	0.007	0.00	0.00	0.00	0.00	1.85	21.11	0.00	0.00	3.70	16.87
Poaceae	Cynodon dactylon	0.64	0.008	0.00	0.00	0.00	0.00	1.85	3.33	2.78	18.52	0.00	17.86
Poaceae	Luziola peruviana	0.678	0.006	0.00	0.00	0.00	0.00	1.85	0.00	0.00	11.11	23.46	28.57
Plantaginaceae	Gratiola peruviana	0.673	0.011	0.00	0.00	0.00	0.00	1.32	1.85	0.00	0.00	9.88	20.83
Asteraceae	Eclipta prostrata	0.837	0.001	0.00	0.00	0.00	0.00	1.32	0.74	0.00	25.93	3.70	5.36
Poaceae	Tripogon spicatus	0.992	0.001	0.00	0.00	0.00	0.00	1.06	0.00	66.67	0.00	0.00	0.00
Poaceae	Panicum aquaticum	0.781	0.002	0.00	0.00	0.00	0.00	1.06	0.00	0.00	0.00	23.46	20.63
Poaceae	Paspalum indecorum	0.857	0.001	0.00	0.00	0.00	0.00	0.79	0.00	36.11	0.00	0.00	0.00
Malvaceae	Melochia chamaedrys	0.849	0.001	0.00	0.00	0.00	0.00	0.79	0.00	19.44	0.00	0.00	0.00
Cyperaceae	Eleocharis sellowiana	0.635	0.01	0.00	0.00	0.00	0.00	0.53	1.11	0.00	0.00	33.33	1.79
Poaceae	Leersia hexandra	0.568	0.013	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	16.05	0.00
Asteraceae	Pterocaulon angustifolium	0.932	0.001	0.00	0.00	0.00	0.00	0.26	4.81	0.00	33.33	0.00	0.00
Poaceae	Microchloa indica	0.864	0.001	0.00	0.00	0.00	0.00	0.26	0.00	61.11	0.00	0.00	0.00
Asteraceae	Pterocaulon cordobense	0.651	0.007	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	25.40
Poaceae	Eragrostis cataclasta	0.891	0.001	0.00	0.00	0.00	0.00	0.00	14.07	0.00	29.63	0.00	75.79
Asteraceae	Chaptalia nutans	0.548	0.032	0.00	0.00	0.00	0.00	0.00	4.81	0.00	0.00	0.00	0.00
Cyperaceae	Eleocharis minima	0.654	0.014	0.00	0.00	0.00	0.00	0.00	2.96	0.00	18.52	13.58	22.42
Euphorbiaceae	Croton parvifolius	0.968	0.001	0.00	0.00	0.00	0.00	0.00	2.22	0.00	33.33	0.00	0.00
Poaceae	Panicum gouinii	0.673	0.005	0.00	0.00	0.00	0.00	0.00	2.22	0.00	3.70	0.00	17.66
Poaceae	Phalaris angusta	0.982	0.001	0.00	0.00	0.00	0.00	0.00	1.11	0.00	29.63	0.00	0.00
Asteraceae	Pluchea sagittalis	0.52	0.04	0.00	0.00	0.00	0.00	0.00	0.74	0.00	3.70	0.00	3.17
Cyperaceae	Cyperus uncinulatus	0.866	0.001	0.00	0.00	0.00	0.00	0.00	0.00	52.78	0.00	0.00	0.00

Solanaceae	Nierembergia scoparia	0.866	0.001	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00
Fabaceae	Sesbania punicea	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	62.96	0.00	0.00
Plantaginaceae	Bacopa monnieri	0.707	0.002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.22	0.00	20.63
Asteraceae	Jaegeria hirta	0.707	0.002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.52	0.00	9.72
Menyanthaceae	Nymphoides indica	0.658	0.004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.11	4.94	20.63
Cyperaceae	Eleocharis montana	0.577	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.28	0.00

Table 2. Species diversity and indicator of conservation state of grassland groups.

Cluster group	Number of quadrats	Species richness per group (total)	Species richness per $1m^2$ (mean)	Simpson diversity index, per $1m^2$ (mean)	Exotic species richness (total)	Exotic specie (% relative cover; mean
1	27	40	7.74^{h}	0.72^{e}	0	0
2	63	161	19.40^{e}	0.87^{c}	3	0.11
3	360	443	23.60^{bc}	0.97^{b}	10	0.23
4	198	243	23.85^{b}	0.98^{a}	3	0.26
5	378	459	27.91^{a}	0.90^{c}	25	4.58
6	270	415	27.08^{a}	0.86^{c}	25	1.37
7	36	108	21.96^{cd}	0.93^{c}	3	1.89
8	27	94	20.11^{de}	0.94^{ab}	4	2.37
9	81	182	16.59^{g}	0.95^{d}	9	4.67
10	62	172	19.62^{f}	0.93^{cd}	7	1.64

Table 3. Summary of environmental conditions for Cluster groups based on monthly climate normals from WorldClim database (1970-2000). Precmean: mean annual precipitation, Precmax: month with maximum accumulated precipitation, Precmin: month with minimum accumulated precipitation, Tmax: hottest month temperature, Tmin: coldest month temperature. Groups 1 to 4 correspond to Cfb climate, groups 5 to 10 to Cfa climate.

Cluster group	Tmean (ºC)	Tmax (ºC)	Tmin (ºC)	Precmean (mm)	Precmax (mm)	Precmin (mm)
1	15.7	24.8	7.2	1922	183	134
2	15.6	24.7	7.2	1734	174	122
3	15.8	25.5	6.7	1694	171	112
4	15.0	25.1	4.2	1876	195	116
5	18.7	30.4	8.7	1486	146	99
6	18.1	29.9	8.1	1413	139	92
7	20.5	32.5	9.4	1729	185	111
8	18.0	28.6	8.2	1287	131	71
9	19.1	30.3	9.0	1552	156	102
10	18.0	28.1	9.0	1326	130	84

Figure 1. Distribution of 57 landscape sampling units in grassland remnants of the Brazilian Pampa and Atlantic Forest biomes (IBGE 2004) in southern Brazil (PR: Paraná, SC: Santa Catarina and RS: Rio Grande do Sul states). In each landscape unit of 2 x 2 km we placed three plots of 70 x 70 m, where vegetation was sampled in nine systematically distributed quadrats of 1 m^2.

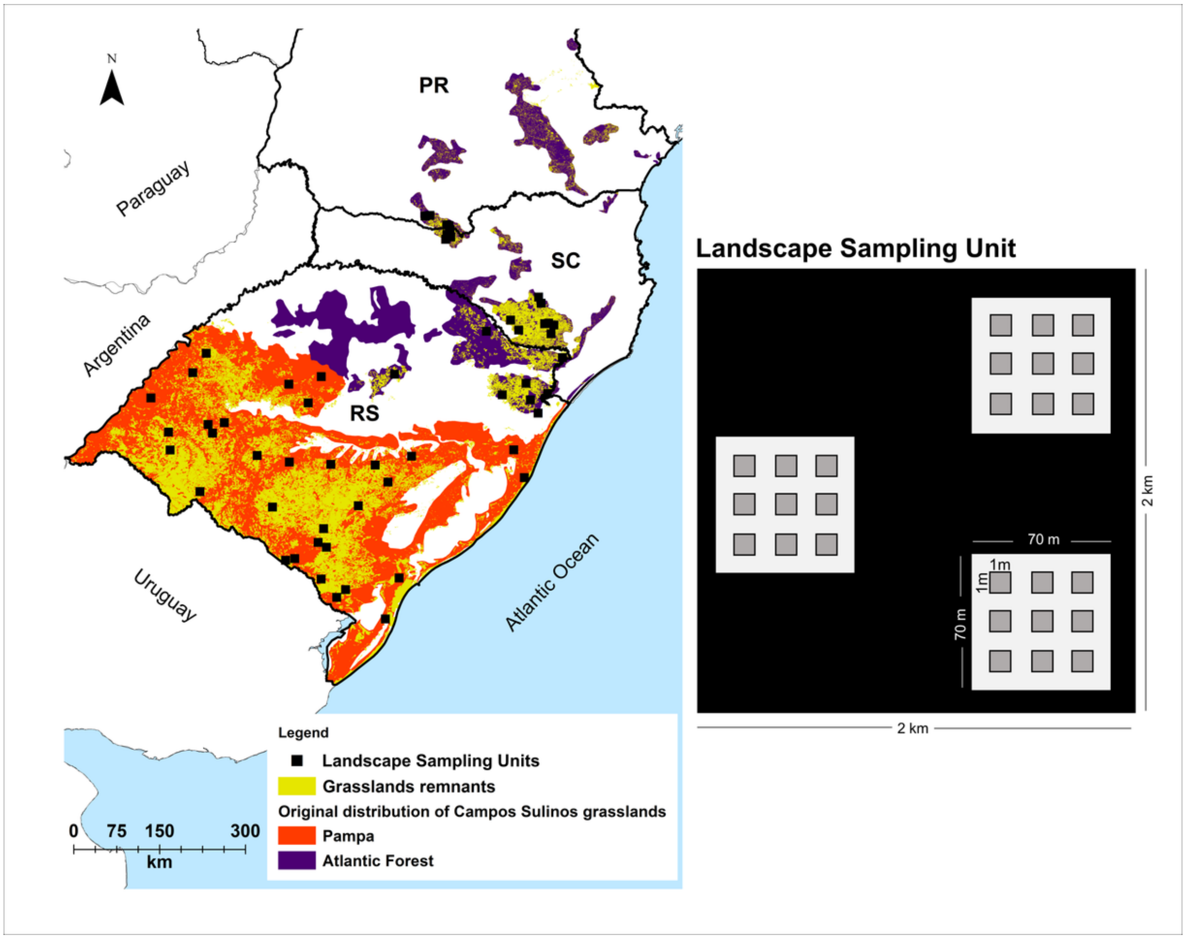


Figure 2. Sampled grasslands of the South Brazilian region plotted on a simplified geological (A) and soil map (B), and identified by the corresponding grassland types (same colors) found using complete linkage cluster analysis (C). The soil classes were defined by joining soil types according to the following Brazilian Soil Classification System [Embrapa 2006] (in parentheses, the corresponding term according to USDA soil taxonomy [USDA 2010]): (i) expansive clay: *Vertissolos* (Vertisols) and *Chernossolos* (Molisols); (ii) deep soils: *Latossolos* (Oxisols), *Nitossolo* (Ultisols/ Oxisols/ Kandic) and *Neossolos Quartzarênicos* (Quartzipsamments); (iii) shallow soils: Neossolos (Entisols) and Cambissolos (Inceptisols); (iv) lowland soils: *Gleissolos* (Entisols) and *Organossolos* (Histosols); (v) soils with B textural horizon: *Argissolos* (Ultisols/ Oxisols), *Luvissolos* (Alfisols/ Aridisols), *Espodossolos* (Spodosols), *Plintossolos* (Plinthic subgroup) and *Planossolos* (Alfisols).

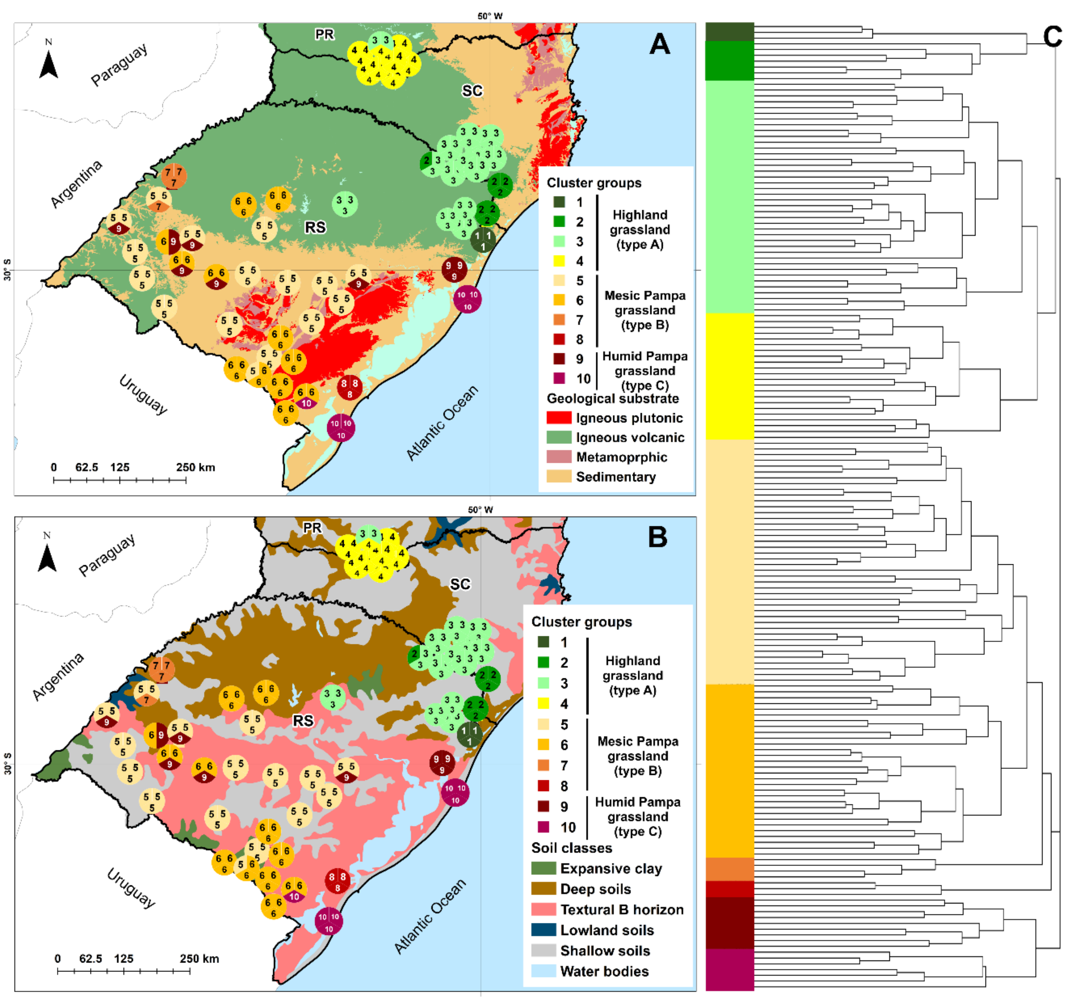
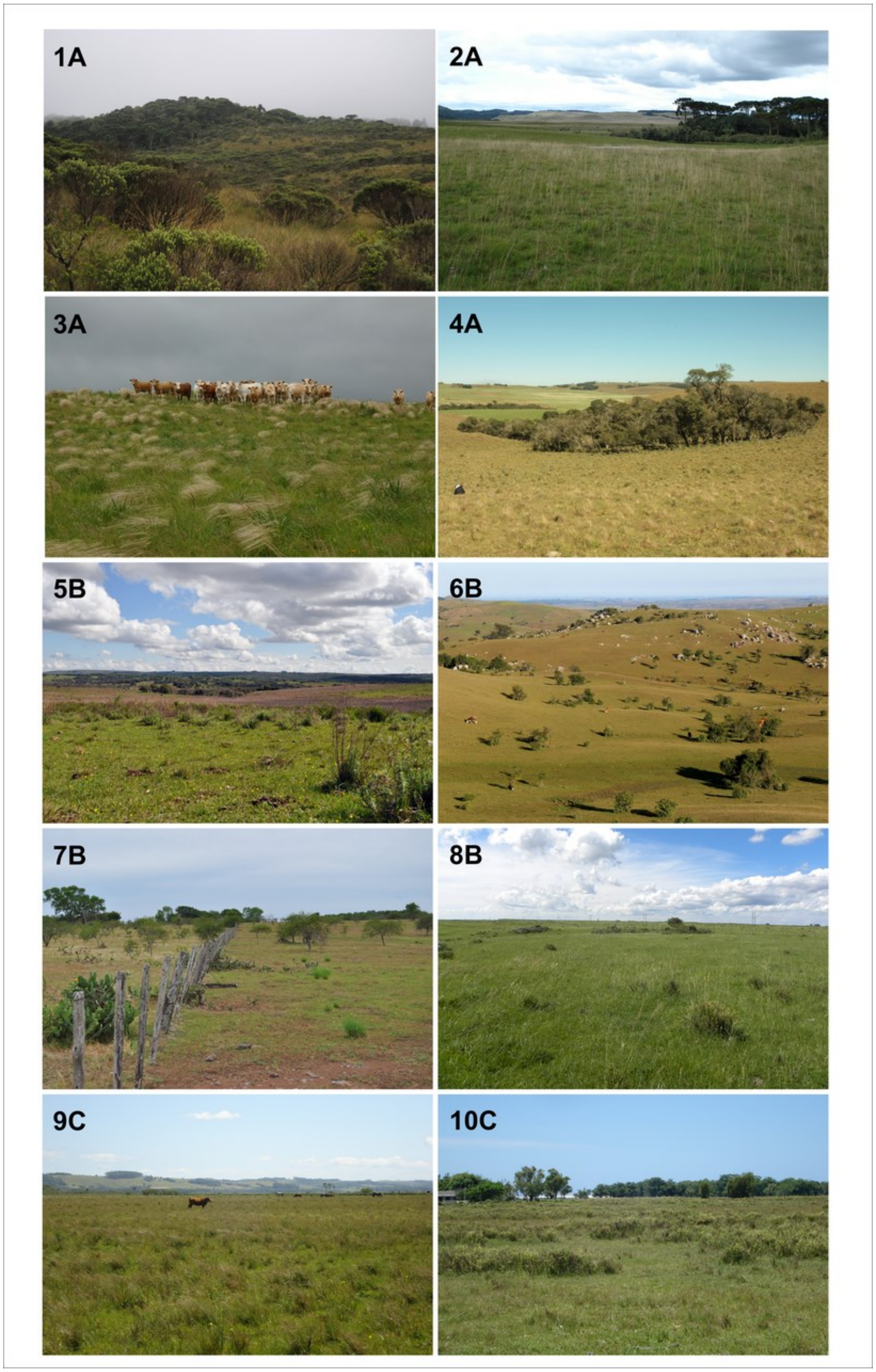


Figure 3. Grassland physiognomy and structure in the South Brazilian grasslands, representing three grassland types (A-C) and ten subtypes (1-10) identified by Cluster analysis. Cluster groups 1 to 4 correspond to Brazilian Highland grasslands and 5 to 10 to Pampa grassland landscapes. Municipalities: 1A: São Francisco de Paula, RS, 2A: Cambará do Sul, RS, 3A: Soledade, RS, 4A: Palmas, SC, 5B: Dom Pedrito, RS, 6B: Herval, RS, 7B: Santo Antônio das Missões, RS, 8B: Rio Grande, RS, 9C: Capivari do Sul, RS, 10C: Palmares do Sul, RS.


1A
2A
3A
4A
5B
6B
7B
8B
9C
10C

Supporting Information

Appendix S1. Complete species list with mean cover value per Cluster Group and information about plant metabolism (only for Poaceae)

Families	Species	C_3/C_4	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Grupo 8	Grupo 9	Grupo 10
Acanthaceae	*Stenandrium dulce*						0.03	0.02				
Acanthaceae	*Justicia axillaris*				0.024		0.06	0.02				
Acanthaceae	*Ruellia hypericoides*						0.01	0.12				
Acanthaceae	*Ruellia multifolia*					0.15						
Acanthaceae	*Ruellia bulbifera*							0.01			0.22	
Acanthaceae	*Ruellia brevicaulis*				0.007	0.32	>.001	>.001				
Acanthaceae	*Ruellia morongii*			0.01	0.001		0.24	0.01	0.07			
Acanthaceae	*Stenandrium diphyllum*				0.001		0.11	0.03	0.26			0.01
Alstroemeriaceae	*Alstroemeria isabelleana*		0.02									
Alstroemeriaceae	*Bomarea edulis*		0.15									
Amaranthaceae	*Gomphrena elegans*						>.001					
Amaranthaceae	*Chenopodium haumanii*						>.001					
Amaranthaceae	*Gomphrena graminea*				0.001		0.01					
Amaranthaceae	*Pfaffia gnaphaloides*				0.009			0.01	0.02			
Amaranthaceae	*Gomphrena perennis*						>.001	0.09				
Amaranthaceae	*Gomphrena celosioides*				0.003		0.01		0.15			
Amaranthaceae	*Alternanthera reineckii*										0.41	
Amaranthaceae	*Pfaffia tuberosa*			0.01	0.538	0.15	0.26	0.10				0.01
Amaranthaceae	*Alternanthera philoxeroides*									1.32		0.06
Amaryllidaceae	*Zephyranthes sp.*						0.001					
Amaryllidaceae	*Habranthus sp.*						>.001	>.001				
Amaryllidaceae	*Nothoscordum bonariense*			0.01			0.01					
Amaryllidaceae	*Habranthus tubispathus*							0.01				0.02

Amaryllidaceae	*Nothoscordum montevidense*				0.001		0.05					
Amaryllidaceae	*Nothoscordum bivalve*				0.003	0.12						
Amaryllidaceae	*Nothoscordum gracile*				0.006		0.01	>.001	0.78			
Anacardiaceae	*Schinus weinmannifolius*				0.096	0.17						
Apiaceae	*Eryngium floribundum*				0.001							
Apiaceae	*Eryngium luzulifolium*				0.001							
Apiaceae	*Daucus pusillus*							>.001				
Apiaceae	*Eryngium juncifolium*					0.01						
Apiaceae	*Eryngium pristis*							0.01				0.01
Apiaceae	*Eryngium scirpinum*					0.04						
Apiaceae	*Eryngium ebracteatum*			0.06	0.001							
Apiaceae	*Eryngium ciliatum*				0.003		0.01	0.07				0.01
Apiaceae	*Lilaeopsis carolinensis*										0.07	0.03
Apiaceae	*Eryngium zozterifolium*			0.18								
Apiaceae	*Eryngium sanguisorba*						0.02					0.20
Apiaceae	*Eryngium elegans*			0.57	0.040		0.01		0.04			
Apiaceae	*Eryngium nudicaule*						0.17	0.46	0.02			0.24
Apiaceae	*Cyclospermum leptophyllum*				0.019		0.30	0.13	0.18	0.10	0.04	0.12
Apiaceae	*Eryngium echinatum*						0.30		2.50			
Apiaceae	*Eryngium horridum*				0.298	0.05	0.91	3.89		0.02		0.01
Apiaceae	*Centella asiatica*			0.02	0.442	0.09	0.86	0.73		1.58	5.80	2.88
Apocynaceae	*Oxypetalum solanoides*							>.001				
Apocynaceae	*Asclepias mellodora*				0.006	>.001	>.001					
Apocynaceae	*Orthosia scoparia*		0.04									
Araliaceae	*Hydrocotyle verticillata*							>.001				0.03
Araliaceae	*Hydrocotyle ranunculoides*						0.02	0.01			0.06	
Araliaceae	*Hydrocotyle exigua*			0.08	0.109	0.05	0.44	0.05			0.18	
Araliaceae	*Hydrocotyle bonariensis*				0.158		>.001			0.02	0.11	0.81

Aristolochiaceae	*Aristolochia sessilifolia*				0.006		>.001	0.04				
Asparagaceae	*Clara ophiopogonoides*							>.001				
Asteraceae	*Baccharis brevifolia*				0.001							
Asteraceae	*Baccharis ramboi*				0.001							
Asteraceae	*Baccharis vulneraria*				0.001							
Asteraceae	*Criscia stricta*				0.001							
Asteraceae	*Gyptis lanigera*				0.001							
Asteraceae	*Stevia myriadenia*				0.001							
Asteraceae	*Vernonia echioides*				0.001							
Asteraceae	*Centratherum camporum*						>.001					
Asteraceae	*Crepis setosa*						>.001					
Asteraceae	*Centratherum punctatum*							>.001				
Asteraceae	*Stenachaenium macrocephalum*							>.001				
Asteraceae	*Baccharis erigeroides*					>.001						
Asteraceae	*Disynaphia spathulata*					>.001						
Asteraceae	*Symphyopappus compressus*				0.003							
Asteraceae	*Stevia collina*					>.001						
Asteraceae	*Baccharis tridentata*						>.001	>.001				
Asteraceae	*Campuloclinium macrocephalum*						>.001	>.001				
Asteraceae	*Pseudognaphalium cheiranthifolium*				0.001	>.001						
Asteraceae	*Soliva macrocephala*						0.01					
Asteraceae	*Lessingianthus rubricaulis*				0.001	>.001		>.001				
Asteraceae	*Erechtites hieracifolius*				0.003		>.001					
Asteraceae	*Badilloa steetzii*				0.009							
Asteraceae	*Baccharis cognata*			0.01								
Asteraceae	*Holocheilus illustris*			0.01								
Asteraceae	*Porophyllum linifolium*						>.001	0.01				
Asteraceae	*Lessingianthus brevifolius*				0.009			>.001				

Asteraceae	*Neja filiformis*						0.01					
Asteraceae	*Picrosia cabreriana*					0.01						
Asteraceae	*Trixis nobilis*					0.01						
Asteraceae	*Stomatanthes oblongifolius*				0.013							
Asteraceae	*Micropsis spathulata*						0.01					
Asteraceae	*Enydra anagallis*										0.01	
Asteraceae	*Pterocaulon lorentzii*				0.001		0.01	0.01				
Asteraceae	*Stevia lundiana*				0.010	0.01	>.001					
Asteraceae	*Senecio conyzifolius*			0.01	0.010							
Asteraceae	*Trixis lessingii*		0.02									
Asteraceae	*Gamochaeta argentina*						>.001		0.02			
Asteraceae	*Holocheilus brasiliensis*			0.02	0.004							
Asteraceae	*Lucilia lycopodioides*					0.02						
Asteraceae	*Cirsium vulgare*						0.01	0.01				
Asteraceae	*Chaptalia nutans*							0.03				
Asteraceae	*Hypochaeris glabra*						0.01	>.001			0.01	0.01
Asteraceae	*Vernonanthura oligactoides*				0.017	0.01						
Asteraceae	*Hypochaeris tropicalis*						0.01		0.02			
Asteraceae	*Conyza canadensis*							0.01				0.03
Asteraceae	*Mikania pinnatiloba*					0.03						
Asteraceae	*Vernonanthura tweedieana*				0.020	0.01						
Asteraceae	*Calea uniflora*							0.03			0.01	
Asteraceae	*Conyza blakei*											0.03
Asteraceae	*Hypochaeris megapotamica*				0.010		0.02	0.01				
Asteraceae	*Gamochaeta falcata*				0.027			0.01				
Asteraceae	*Pterocaulon polypterum*						0.01	0.02			0.01	
Asteraceae	*Stenachaenium riedelii*				0.012	>.001	>.001					0.02
Asteraceae	*Pluchea sagittalis*							>.001		0.02		0.02

Asteraceae	*Symphyotrichum graminifolium*					>.001			0.04			
Asteraceae	*Podocoma spegazzini*				0.039							
Asteraceae	*Pterocaulon balansae*				0.013			0.03				
Asteraceae	*Hypochaeris variegata*							0.04				
Asteraceae	*Achyrocline alata*				0.045							
Asteraceae	*Hysterionica nidorelloides*						0.01		0.04			
Asteraceae	*Baccharis spicata*					0.05						
Asteraceae	*Grazielia serrata*					0.05						
Asteraceae	*Noticastrum gnaphalioides*				0.049							
Asteraceae	*Baccharis caprariifolia*				0.029	0.02						
Asteraceae	*Baccharis gnaphalioides*											0.05
Asteraceae	*Baccharis apicifoliosa*			0.05								
Asteraceae	*Baccharis pseudovillosa*			0.05								
Asteraceae	*Chaptalia graminifolia*			0.04	0.010							
Asteraceae	*Pentacalia desiderabilis*			0.05	0.001							
Asteraceae	*Chromolaena hirsuta*				0.043			>.001				0.01
Asteraceae	*Mikania paranensis*		0.06									
Asteraceae	*Solidago chilensis*				0.049	>.001	>.001	0.01				
Asteraceae	*Sommerfeltia spinulosa*							0.06				
Asteraceae	*Baccharis erioclada*				0.001	0.06						
Asteraceae	*Micropsis dasycarpa*							0.06				
Asteraceae	*Chromolaena squarrulosa*				0.045		>.001	0.02				0.01
Asteraceae	*Calea cymosa*					0.07						
Asteraceae	*Podocoma bellidifolia*				0.078							
Asteraceae	*Conyza sumatrensis*				0.076	0.01						
Asteraceae	*Mikania oblongifolia*					0.09						
Asteraceae	*Gamochaeta coarctata*				0.024		0.03					0.04
Asteraceae	*Baccharis junciformis*			0.11								

Asteraceae	*Gamochaeta simplicicaulis*				0.003	0.03	0.07					
Asteraceae	*Podocoma hieraciifolia*					0.11						
Asteraceae	*Senecio heterotrichius*				0.017		0.01	0.01			0.07	
Asteraceae	*Grazielia nummularia*		0.11									
Asteraceae	*Trichocline macrocephala*				0.115							
Asteraceae	*Senecio madagascariensis*						>.001	0.02			0.09	
Asteraceae	*Baccharis leucopappa*			0.05		0.06						
Asteraceae	*Mikania fulva*					0.12						
Asteraceae	*Senecio oxyphyllus*						0.02				0.10	
Asteraceae	*Pterocaulon rugosum*				0.022	0.09	0.01	>.001				
Asteraceae	*Senecio leptolobus*				0.003		0.03	0.13				
Asteraceae	*Conyza bonariensis*				0.001		0.07	0.04	0.02		0.01	0.02
Asteraceae	*Baccharis pentaptera*				0.052	0.11						
Asteraceae	*Chaptalia piloselloides*			0.06			0.03	>.001	0.04		0.03	
Asteraceae	*Orthopappus angustifolius*				0.003	0.03	0.06	0.09			0.01	
Asteraceae	*Barrosoa betoniciiformis*		0.13	0.05								
Asteraceae	*Baccharis riograndensis*			0.05			0.14					
Asteraceae	*Chaptalia integerrima*				0.151	0.04	0.01	0.01				
Asteraceae	*Pterocaulon cordobense*						>.001					0.22
Asteraceae	*Hieracium commersonii*			0.13	0.010	0.08		0.01				
Asteraceae	*Baccharis linearifolia*					0.24						
Asteraceae	*Baccharis dracunculifolia*			0.01	0.202		0.01	0.01			0.01	
Asteraceae	*Noticastrum diffusum*							>.001		0.24		
Asteraceae	*Disynaphia ligulaefolia*			0.25								
Asteraceae	*Elephantopus mollis*				0.147		0.08	0.03				
Asteraceae	*Dimerostemma arnottii*				0.176	0.09						
Asteraceae	*Lessingianthus sellowii*				0.007		0.01	0.03		0.23		
Asteraceae	*Hypochaeris albiflora*				0.004		0.05	0.01	0.26			

Asteraceae	*Achyrocline flaccida*			0.31	0.007			0.01				
Asteraceae	*Pamphalea heterophylla*						0.02	0.02		0.29		
Asteraceae	*Chrysolaena flexuosa*				0.099	0.07	0.04	0.12				0.01
Asteraceae	*Jaegeria hirta*									0.17		0.17
Asteraceae	*Stevia ophryophylla*				0.006	0.34						
Asteraceae	*Hypochaeris lutea*			0.34	0.006			0.01				
Asteraceae	*Pterocaulon alopecuroides*				0.072	0.28	0.04	>.001			0.01	
Asteraceae	*Hypochaeris radicata*				0.189	0.21						
Asteraceae	*Acmella bellidioides*			0.01	0.233		0.06	0.01			0.11	
Asteraceae	*Baccharis ochracea*				0.140	>.001		0.30				
Asteraceae	*Stenocephalum megapotamicum*				0.017	0.43						
Asteraceae	*Pterocaulon angustifolium*						0.01	0.03		0.42		
Asteraceae	*Lucilia linearifolia*			0.05	0.030	0.38						
Asteraceae	*Senecio brasiliensis*				0.035		0.43	0.01				
Asteraceae	*Noticastrum calvatum*				0.036	0.07	>.001	>.001				0.35
Asteraceae	*Lessingianthus hypochaeris*				0.042	0.42	0.01	0.01				
Asteraceae	*Facelis retusa*				0.010		0.13	0.14		0.12	0.07	0.02
Asteraceae	*Vittetia orbiculata*				0.504							
Asteraceae	*Vernonanthura chamaedrys*				0.367	0.14		>.001				
Asteraceae	*Chevreulia revoluta*			0.15	0.042	0.32						
Asteraceae	*Senecio selloi*						0.03	0.11		0.42		
Asteraceae	*Gamochaeta filaginea*			0.03			0.04	0.16		0.02	0.06	0.30
Asteraceae	*Baccharis subtropicalis*			0.26	0.023		0.40					0.02
Asteraceae	*Gyptis pinnatifita*				0.371	0.40		0.01				
Asteraceae	*Acmella leptophylla*						0.15		0.36	0.26	0.01	0.01
Asteraceae	*Lucilia acutifolia*				0.104	0.73	0.01	>.001				
Asteraceae	*Acanthostyles buniifolius*						0.02	0.81				0.01
Asteraceae	*Grazielia gaudichaudeana*			0.86								

Asteraceae	*Chaptalia mandonii*			0.20	0.141	0.56	0.02					
Asteraceae	*Chaptalia runcinata*			0.16	0.312	0.01	0.18	0.04	0.20		0.02	0.01
Asteraceae	*Mikania decumbens*					0.92						
Asteraceae	*Vernonanthura nudiflora*				0.138			0.02			0.74	0.05
Asteraceae	*Hypochaeris catharinensis*			0.02	0.631	0.35						
Asteraceae	*Barrosoa candolleana*		1.01		0.010							
Asteraceae	*Conyza primulifolia*			0.01	0.608	0.31	0.03	0.01			0.01	0.06
Asteraceae	*Baccharis uncinella*		0.95	0.11	0.026	0.04						
Asteraceae	*Chromolaena congesta*				0.062	1.13						
Asteraceae	*Stenachaenium campestre*				0.020	0.97	0.07	0.19				
Asteraceae	*Trichocline catharinensis*			0.14	0.981	0.14	>.001					
Asteraceae	*Grazielia multifida*					1.34						
Asteraceae	*Baccharis articulata*				0.580	0.45	0.01					0.48
Asteraceae	*Lucilia nitens*				1.034	0.22	>.001	0.12		0.14		0.02
Asteraceae	*Noticastrum decumbens*			0.10	0.612	0.94	>.001		0.02			
Asteraceae	*Stevia alternifolia*				1.076	0.63						
Asteraceae	*Chaptalia exscapa*			0.12	1.420	0.08	0.02	0.06			0.01	
Asteraceae	*Chevreulia acuminata*			0.03	0.927	0.38	0.48	0.16	0.02		0.03	
Asteraceae	*Chromolaena ascendens*			0.05	0.461	1.51	>.001	0.02				0.01
Asteraceae	*Achyrocline satureioides*				0.406	1.94						
Asteraceae	*Hypochaeris chillensis*				0.903	1.45	0.05	0.09			0.05	
Asteraceae	*Soliva sessilis*				0.734		1.24	0.10	0.58		0.02	0.01
Asteraceae	*Baccharis coridifolia*						1.77	1.41	0.02		0.01	
Asteraceae	*Eclipta prostrata*						0.08	>.001		3.03	0.02	0.11
Asteraceae	*Aspilia montevidensis*			0.01	0.815	0.48	0.25	0.42		1.32	0.06	0.03
Asteraceae	*Chevreulia sarmentosa*			0.09	0.786	0.88	1.01	0.58	0.04		0.02	0.11
Asteraceae	*Baccharis pentodonta*			0.07	1.938	1.64						
Asteraceae	*Gamochaeta americana*			0.12	1.604	1.93	0.16	0.15	0.38	0.09	0.08	0.04

Asteraceae	*Calea phyllolepis*		10.28			0.04						
Asteraceae	*Baccharis crispa*		1.24	1.30	1.721	2.87	0.79	1.44		1.21	1.41	2.03
Asteraceae	*Symphyotrichum squamatum*				0.029	0.01	0.03	0.03		16.32		0.02
Berberidaceae	*Berberis laurina*				0.001							
Boraginaceae	*Moritzia ciliata*				0.012							
Boraginaceae	*Moritzia dusenii*			0.01	0.007							
Boraginaceae	*Varronia curassavica*							0.06				
Boraginaceae	*Moritzia dasyantha*			0.07								
Boraginaceae	*Cordia americana*								0.55			
Brassicaceae	*Lepidium serratum*							>.001				
Brassicaceae	*Cardamine chenopodiifolia*						>.001					
Brassicaceae	*Lepidium aletes*						0.01					
Brassicaceae	*Lepidium bonariense*						0.02	0.08				
Bryophyta	*Bryophyta*		1.54	1.22	0.014		0.05	0.05	4.32			0.01
Cactaceae	*Parodia sp.*				0.001							
Cactaceae	*Cactaceae*							>.001				
Cactaceae	*Parodia ottonis*							0.01				
Cactaceae	*Opuntia monacantha*								0.66			
Calyceraceae	*Acicarpha tribuloides*						0.03	>.001				
Calyceraceae	*Acicarpha procumbens*							0.05				
Campanulaceae	*Triodanis perfoliata*						0.001					
Campanulaceae	*Lobelia camporum*				0.001							
Campanulaceae	*Lobelia nummularioides*				0.003							
Campanulaceae	*Wahlenbergia linarioides*			0.03	0.940	0.45		0.04	0.02			
Campanulaceae	*Lobelia hederacea*			0.01	0.024	>.001	0.07	0.06		1.98	0.63	3.06
Caprifoliaceae	*Valeriana reitziana*					0.04						
Caryophyllaceae	*Spergularia platensis*				0.001							
Caryophyllaceae	*Paronychia setigera*							>.001				

Caryophyllaceae	*Spergula arvensis*						>.001	0.01				
Caryophyllaceae	*Cerastium rivulare*						0.01					
Caryophyllaceae	*Silene gallica*							0.01				
Caryophyllaceae	*Sagina procumbens*						0.02	>.001				
Caryophyllaceae	*Paronychia brasiliana*						0.01	>.001			0.03	
Caryophyllaceae	*Polycarpon tetraphyllum*							0.04			0.01	
Caryophyllaceae	*Cerastium humifusum*				0.003						0.06	
Caryophyllaceae	*Spergularia grandis*				0.001		>.001	0.01				0.05
Caryophyllaceae	*Cerastium commersonianum*						0.05	0.01			0.01	
Caryophyllaceae	*Cardionema ramosissima*						0.09	>.001				
Caryophyllaceae	*Cerastium glomeratum*			0.02			0.09	0.01	0.07			
Caryophyllaceae	*Paronychia camphorosmoides*				0.114	0.32	>.001	0.01				
Celastraceae	*Maytenus ilicifolia*				0.003							
Cistaceae	*Crocanthemum brasiliensis*				0.084		0.08	0.06			0.01	0.01
Commelinaceae	*Commelina platyphylla*						>.001					
Commelinaceae	*Commelina benghalensis*							0.01				
Commelinaceae	*Commelina rufipes*										0.01	
Commelinaceae	*Commelina diffusa*						0.01	0.01		0.02		
Commelinaceae	*Tradescantia umbraculifera*						0.04	>.001				
Commelinaceae	*Commelina erecta*				0.230	>.001	0.01	0.02	0.11		0.04	
Convolvulaceae	*Convolvulus blakei*				0.001							
Convolvulaceae	*Convolvulus bonariensis*				0.001							
Convolvulaceae	*Convolvulus laciniatus*						>.001					
Convolvulaceae	*Convolvulus sp.1*					>.001						
Convolvulaceae	*Ipomoea kunthiana*							>.001				
Convolvulaceae	*Convolvulus sp.*						0.02					
Convolvulaceae	*Convolvulus crenatifolius*		0.02		0.003							
Convolvulaceae	*Ipomoea acutisepala*				0.009	0.06						

Convolvulaceae	*Dichondra macrocalyx*			0.08	0.036		0.44	0.02	2.57		0.07	
Convolvulaceae	*Evolvulus sericeus*				0.016	0.01	0.34	0.46	5.10		0.06	0.03
Convolvulaceae	*Dichondra sericea*			0.02	0.963	0.96	1.93	1.43		0.23	0.21	0.51
Cyperaceae	*Bulbostylis major*				0.001							
Cyperaceae	*Rhynchospora praecincta*						>.001					
Cyperaceae	*Cyperus luzulae*						>.001					
Cyperaceae	*Scirpus giganteus*										0.01	
Cyperaceae	*Eleocharis densicaespitosa*											0.01
Cyperaceae	*Rhynchospora globosa*			0.01								
Cyperaceae	*Bulbostylis consanguinea*				0.003	0.01						
Cyperaceae	*Cyperus rigens*				0.013		>.001					
Cyperaceae	*Carex bonariensis*						0.02					
Cyperaceae	*Lipocarpha micrantha*						0.02					
Cyperaceae	*Bulbostylis subtilis*				0.027		>.001					
Cyperaceae	*Eleocharis contracta*				0.022						0.01	
Cyperaceae	*Rhynchospora megapotamica*						0.04					
Cyperaceae	*Bulbostylis capillaris*				0.001	0.04						
Cyperaceae	*Carex longii*						0.01				0.05	
Cyperaceae	*Lipocarpha humboldtiana*			0.06								
Cyperaceae	*Carex sororia*						0.03	0.09				
Cyperaceae	*Cyperus haspan*			0.05							0.07	
Cyperaceae	*Bulbostylis hirtella*			0.12		0.02						
Cyperaceae	*Cyperus hermaphroditus*			0.01	0.117	0.03	>.001					
Cyperaceae	*Abildgaardia ovata*						0.02	0.08			0.01	0.06
Cyperaceae	*Eleocharis bonariensis*						0.05				0.06	0.10
Cyperaceae	*Rhynchospora holoschoenoides*										0.25	
Cyperaceae	*Fimbristylis dichotoma*						0.02	0.17				0.07
Cyperaceae	*Bulbostylis communis*				0.003		0.20	0.02			0.04	0.03

Cyperaceae	*Scleria georgiana*			0.31								
Cyperaceae	*Fimbristylis sp.nov*						0.07		0.11		0.14	
Cyperaceae	*Cyperus reflexus*				0.156	0.06	0.01	0.02	0.02		0.03	0.03
Cyperaceae	*Rhynchospora junciformis*			0.32	0.009		0.01					
Cyperaceae	*Fimbristylis autumnalis*						>.001	0.05		0.28	0.01	0.03
Cyperaceae	*Eleocharis geniculata*						0.01			0.45		0.01
Cyperaceae	*Rhynchospora setigera*				0.055	0.47	0.02	0.04			0.04	
Cyperaceae	*Rhynchospora emaciata*						0.16				0.50	
Cyperaceae	*Eleocharis nudipes*			0.56			0.11					
Cyperaceae	*Rhynchospora brittonii*			0.05	0.001			>.001				0.71
Cyperaceae	*Eleocharis flavescens*						0.01			0.76	0.02	0.13
Cyperaceae	*Fimbristylis complanata*				0.045		>.001	0.37		0.16		0.37
Cyperaceae	*Eleocharis montana*										0.96	
Cyperaceae	*Cyperus uncinulatus*								0.98			
Cyperaceae	*Carex phalaroides*			0.44	0.082	0.01	0.44	0.05			0.01	
Cyperaceae	*Rhynchospora marisculus*			1.25			>.001					
Cyperaceae	*Kyllinga brevifolia*						0.03	0.02	0.05	0.57	0.32	0.37
Cyperaceae	*Rhynchospora edwalliana*				0.086	1.39						
Cyperaceae	*Cyperus aggregatus*			0.04	0.223	0.93	0.03	0.04	0.20		0.02	
Cyperaceae	*Eleocharis maculosa*			0.64			0.02			0.83		0.06
Cyperaceae	*Bulbostylis scabra*						0.04	0.34	0.95	0.02		0.23
Cyperaceae	*Pycreus polystachyos*				0.012		0.01	0.03	0.04	0.69	0.41	0.85
Cyperaceae	*Kyllinga odorata*				0.259	0.08	0.12	0.16	0.09	1.13	0.02	0.19
Cyperaceae	*Rhynchospora tenuis*			1.30	0.350		0.38	0.01			0.15	
Cyperaceae	*Scleria distans*			1.86	0.009		0.05	>.001			0.18	0.15
Cyperaceae	*Scleria sellowiana*		0.02	0.22	0.161	2.15	0.03				0.03	
Cyperaceae	*Rhynchospora rugosa*			0.36	1.054		0.12				1.13	
Cyperaceae	*Bulbostylis juncoides*				0.281	1.33	0.02	0.05	1.02			

Cyperaceae	*Bulbostylis sphaerocephala*			0.98	0.081	1.78	>.001	>.001			0.01	
Cyperaceae	*Rhynchospora pungens*				0.251	2.85	0.06	>.001				
Cyperaceae	*Rhynchospora barrosiana*			2.13	0.156		>.001	>.001			0.06	0.83
Cyperaceae	*Eleocharis sellowiana*						>.001	0.01			3.36	0.01
Cyperaceae	*Kyllinga vaginata*			0.10	0.027		0.41	0.19	1.02	2.48	0.24	0.23
Cyperaceae	*Eleocharis minima*							0.11		0.26	0.43	4.96
Cyperaceae	*Rhynchospora flexuosa*			5.97	0.161							
Cyperaceae	*Eleocharis viridans*			0.56			0.35	0.24		0.31	6.80	0.11
Dennstaedtiaceae	*Pteridium arachnoideum*				0.317	0.22						
Droseraceae	*Drosera brevifolia*						0.01					
Ericaceae	*Agarista nummularia*			0.13								
Ericaceae	*Gaylussacia pseudogaultheria*					0.19						
Eriocaulaceae	*Eriocaulon leptophyllum*			0.11	0.009							
Erythroxylaceae	*Erythroxylum microphyllum*				0.013							
Escalloniaceae	*Escallonia megapotamica*				0.003							
Euphorbiaceae	*Tragia geraniifolia*						>.001					
Euphorbiaceae	*Ditaxis acaulis*							>.001				
Euphorbiaceae	*Manihot hunzikeriana*							>.001				
Euphorbiaceae	*Croton subpannosus*						>.001	>.001				
Euphorbiaceae	*Microstachys hispida*							0.01				
Euphorbiaceae	*Croton aberrans*						>.001	0.01				
Euphorbiaceae	*Croton echinulatus*							0.02				
Euphorbiaceae	*Acalypha communis*							0.03				
Euphorbiaceae	*Acalypha poiretii*				0.030							
Euphorbiaceae	*Euphorbia potentilloides*						>.001	0.02			0.01	
Euphorbiaceae	*Euphorbia stenophylla*				0.003	0.03	0.01					
Euphorbiaceae	*Jatropha isabelliae*						0.01	0.03				
Euphorbiaceae	*Euphorbia papillosa*			0.03	0.012			>.001				

Euphorbiaceae	*Tragia uberabana*				0.043							
Euphorbiaceae	*Euphorbia selloi*						0.01	0.02				0.02
Euphorbiaceae	*Euphorbia serpens*								0.05			
Euphorbiaceae	*Euphorbia hirtella*				0.085							
Euphorbiaceae	*Tragia bahiensis*				0.049		0.02	0.03				
Euphorbiaceae	*Croton hirtus*				0.003	0.09						
Euphorbiaceae	*Croton lanatus*							0.23				
Euphorbiaceae	*Croton parvifolius*							0.17		0.24		
Euphorbiaceae	*Croton glechomifolius*				0.010	1.40		0.01				
Euphorbiaceae	*Croton calycireduplicatus*		2.59									
Euphorbiaceae	*Euphorbia peperomioides*			0.12	0.014	2.71						
Fabaceae	*Crotalaria hilariana*				0.128	0.54						
Fabaceae	*Zornia multinervosa*						0.001					
Fabaceae	*Adesmia latifolia*				0.001							
Fabaceae	*Aeschynomene elegans*				0.001							
Fabaceae	*Collaea stenophylla*				0.001							
Fabaceae	*Mimosa brevipetiolata*						>.001					
Fabaceae	*Rhynchosia lineata*							>.001				
Fabaceae	*Zornia orbiculata*							>.001				
Fabaceae	*Lupinus reitzii*					>.001						
Fabaceae	*Trifolium repens*						>.001					
Fabaceae	*Lathyrus subulatus*						>.001	>.001				
Fabaceae	*Desmodium pachyrhizum*				0.004	>.001						
Fabaceae	*Adesmia ciliata*				0.007							
Fabaceae	*Centrosema virginianum*										0.01	
Fabaceae	*Desmodium uncinatum*											0.01
Fabaceae	*Vicia graminea*				0.009							
Fabaceae	*Zornia sp.1*				0.009							

Fabaceae	*Vigna longifolia*				0.001						0.01	
Fabaceae	*Indigofera sabulicola*						0.01					
Fabaceae	*Mimosa dutrae*				0.010							
Fabaceae	*Galactia australis*				0.012							
Fabaceae	*Zornia sp.*				0.006			0.01				
Fabaceae	*Poiretia latifolia*					0.01						
Fabaceae	*Galactia pretiosa*				0.006	>.001	>.001					
Fabaceae	*Mimosa macrocalyx*				0.007	0.01						
Fabaceae	*Desmodium barbatum*										0.01	
Fabaceae	*Mimosa dolens*				0.001	0.01						
Fabaceae	*Indigofera asperifolia*						0.02					
Fabaceae	*Chamaecrista repens*							0.02				
Fabaceae	*Desmodium craspediferum*			0.02								
Fabaceae	*Lotus uliginosus*										0.02	
Fabaceae	*Adesmia araujoi*				0.010		0.02					
Fabaceae	*Galactia neesii*				0.020	0.01						
Fabaceae	*Adesmia incana*						0.03					
Fabaceae	*Ancistrotropis peduncularis*			0.01	0.007	0.03						
Fabaceae	*Desmanthus virgatus*				0.012	0.03	>.001	>.001				
Fabaceae	*Desmanthus tatuhyensis*				0.023			0.02				
Fabaceae	*Rhynchosia senna*					0.01	0.01	0.03				
Fabaceae	*Zornia pardina*								0.05			
Fabaceae	*Clitoria nana*							0.07				
Fabaceae	*Galactia marginalis*				0.006	>.001	0.04	0.03				
Fabaceae	*Lotus corniculatus*										0.09	
Fabaceae	*Galactia gracillima*				0.045	0.05	>.001	0.02				
Fabaceae	*Eriosema longifolium*				0.017	0.11						
Fabaceae	*Adesmia tristis*			0.05	0.069	>.001						

Fabaceae	*Vachellia caven*								0.13			
Fabaceae	*Crotalaria tweediana*						>.001	0.14				
Fabaceae	*Rhynchosia diversifolia*				0.001		0.04	0.11				
Fabaceae	*Adesmia bicolor*						0.16					
Fabaceae	*Adesmia sulina*					0.19						
Fabaceae	*Mimosa paupera*						0.03		0.18			
Fabaceae	*Zornia ramboiana*				0.003	0.24						
Fabaceae	*Desmodium affine*				0.353							
Fabaceae	*Arachis burkartii*						0.33	0.02	0.07			
Fabaceae	*Macroptilium psammodes*						>.001					0.62
Fabaceae	*Tephrosia adunca*			0.05	0.631	0.03	0.01					
Fabaceae	*Rhynchosia corylifolia*				0.498	0.23		0.01				
Fabaceae	*Stylosanthes leiocarpa*				0.006		0.03	0.09			0.07	0.56
Fabaceae	*Vigna luteola*					0.03				0.78		
Fabaceae	*Trifolium polymorphum*				0.043		0.46	0.11	0.24			
Fabaceae	*Aeschynomene falcata*				0.200	0.96	>.001	0.01				
Fabaceae	*Macroptilium prostratum*			0.02	1.081	>.001	>.001	0.05			0.09	
Fabaceae	*Stylosanthes montevidensis*				0.081	1.16	0.03	0.09				
Fabaceae	*Eriosema tacuaremboense*				0.084	1.29		>.001				
Fabaceae	*Sesbania punicea*									1.63		
Fabaceae	*Trifolium riograndense*				2.125			0.03				
Fabaceae	*Desmodium adscendens*				0.003		>.001	0.01			0.71	2.13
Fabaceae	*Desmodium incanum*				0.206		2.20	1.02	0.22	0.02	0.17	0.23
Gentianaceae	*Centaurium pulchellum*						0.02					
Gentianaceae	*Zygostigma australe*					0.03						
Geraniaceae	*Geranium arachnoideum*				0.010							
Geraniaceae	*Geranium albicans*				0.003		0.01					
Gesneriaceae	*Sinningia allagophylla*					0.01						

Haloragaceae	*Laurembergia tetrandra*										0.01	
Haloragaceae	*Myriophyllum aquaticum*											0.01
Hypericaceae	*Hypericum denudatum*				0.003							
Hypericaceae	*Hypericum cordatum*					>.001						
Hypericaceae	*Hypericum connatum*				0.007							
Hypericaceae	*Hypericum gentianoides*											0.01
Hypericaceae	*Hypericum brasiliense*						0.01	0.01				
Hypoxidaceae	*Hypoxis decumbens*			0.04	0.212	0.02	0.28	0.16	0.11	0.14	0.16	0.05
Iridaceae	*Herbertia quareimana*						>.001					
Iridaceae	*Sisyrinchium commutatum*							>.001				
Iridaceae	*Sisyrinchium pachyrhizum*							>.001				
Iridaceae	*Sisyrinchium uliginosum*				0.009		>.001					
Iridaceae	*Sisyrinchium restioides*			0.01	0.001							
Iridaceae	*Sisyrinchium decumbens*				0.014							
Iridaceae	*Sisyrinchium setaceum*					0.01						
Iridaceae	*Sisyrinchium avenaceum*							0.01				0.01
Iridaceae	*Cypella herbertii*							0.02				
Iridaceae	*Kelissa brasiliensis*						0.01	0.01				
Iridaceae	*Herbertia pulchella*						0.02	>.001				
Iridaceae	*Calydorea crocoides*			0.04								
Iridaceae	*Gelasine coerulea*		0.04	0.01	0.009							
Iridaceae	*Sisyrinchium sellowianum*				0.027		0.01	0.02				
Iridaceae	*Sisyrinchium palmifolium*			0.01		0.06	>.001					
Iridaceae	*Sisyrinchium scariosum*				0.001	0.26						
Iridaceae	*Sisyrinchium minutiflorum*						0.02	0.01		0.10	0.03	0.11
Iridaceae	*Herbertia lahue*			0.06	0.003		0.10	0.08	0.16		0.01	
Iridaceae	*Sisyrinchium platense*						0.53	0.01			0.01	0.01
Iridaceae	*Sisyrinchium micranthum*			0.27	0.156	0.04	0.32	0.15	0.40	0.03	0.26	0.07

Iridaceae	*Sisyrinchium vaginatum*		0.02	0.07	1.286	0.65	0.02				0.01	
Isoetaceae	*Isoetes fuscomarginata*										0.01	
Juncaceae	*Luzula ulei*			0.01								
Juncaceae	*Juncus marginatus*						0.06					0.01
Juncaceae	*Juncus ramboi*			0.07								
Juncaceae	*Juncus imbricatus*						0.04	>.001	0.02		0.06	
Juncaceae	*Juncus densiflorus*						0.08				0.26	
Juncaceae	*Juncus tenuis*				0.003		0.07	0.11	0.07		0.59	0.01
Juncaceae	*Juncus microcephalus*						0.37	0.04		0.23	1.00	0.09
Juncaceae	*Juncus capillaceus*						0.43	0.39		1.02	0.01	0.24
Lamiaceae	*Condea elegans*				0.001							
Lamiaceae	*Hyptis stricta*				0.001							
Lamiaceae	*Stachys micheliana*				0.001							
Lamiaceae	*Glechon spathulata*				0.004							
Lamiaceae	*Ocimum nudicaule*				0.001			0.01				
Lamiaceae	*Glechon thymoides*							0.01				
Lamiaceae	*Salvia procurrens*				0.016							
Lamiaceae	*Teucrium cubense*				0.003		>.001	0.01				
Lamiaceae	*Cantinoa mutabilis*							0.02				
Lamiaceae	*Marsypianthes hassleri*							0.03				
Lamiaceae	*Glechon ciliata*				0.033							
Lamiaceae	*Cantinoa stricta*				0.049	>.001						
Lamiaceae	*Rhabdocaulon gracile*					0.06						
Lamiaceae	*Hyptis brevipes*										0.06	0.03
Lamiaceae	*Salvia lachnostachys*					0.13						
Lamiaceae	*Salvia ovalifolia*				0.004		>.001	0.02			0.11	
Lamiaceae	*Scutellaria racemosa*						0.12	0.03			0.01	0.01
Lamiaceae	*Rhabdocaulon stenodontum*				0.065	0.15						

Lamiaceae	*Cunila galioides*			0.20	0.063	0.01						
Lamiaceae	*Hyptis comaroides*				0.001	0.24	>.001	0.19				
Lentibulariaceae	*Utricularia praelonga*			0.03								
Linaceae	*Linum brevifolium*			0.04	0.003							
Linaceae	*Cliococca selaginoides*				0.082		0.02	0.06				
Loganiaceae	*Spigelia stenophylla*				0.010	0.11						
Lycopodiaceae	*Lycopodiaceae*			0.03								
Lythraceae	*Cuphea sp.*				0.001							
Lythraceae	*Cuphea calophylla*				0.006		0.02	0.01				
Lythraceae	*Cuphea campylocentra*		0.02				0.02					
Lythraceae	*Cuphea acinifolia*				0.050							
Lythraceae	*Heimia apetala*						0.01	0.04		0.14		
Lythraceae	*Heimia salicifolia*						0.01		0.55			
Lythraceae	*Cuphea carthagenensis*				0.001		>.001			0.97	0.01	
Lythraceae	*Cuphea glutinosa*			0.01	0.050		0.11	0.12		1.46	0.02	0.03
Malpighiaceae	*Janusia guaranitica*				0.001							
Malpighiaceae	*Aspicarpa pulchella*				0.071	>.001	0.02	0.11				0.01
Malvaceae	*Byttneria scabra*						>.001					
Malvaceae	*Rhynchosida physocalyx*							>.001				
Malvaceae	*Sida sp.*						>.001					
Malvaceae	*Waltheria communis*				0.004			>.001				
Malvaceae	*Pavonia glechomoides*						0.01	>.001				
Malvaceae	*Sida sp.1*				0.009							
Malvaceae	*Sida spinosa*					0.01						
Malvaceae	*Modiola caroliniana*						0.01	>.001				
Malvaceae	*Pavonia sp.*				0.017							
Malvaceae	*Pavonia reticulata*				0.009	0.01						
Malvaceae	*Krapovickasia urticifolia*		0.02		0.001		>.001					

Malvaceae	*Sida dubia*							0.01		0.02		
Malvaceae	*Sida pseudorubifolia*						0.02	0.02				
Malvaceae	*Sida viarum*						0.01	0.02			0.01	
Malvaceae	*Turnera sidoides*				0.078			>.001				
Malvaceae	*Peltaea edouardii*				0.009	0.08						
Malvaceae	*Byttneria hatschbachii*					0.16						
Malvaceae	*Krapovickasia macrodon*				0.121	0.01		0.04				
Malvaceae	*Pavonia friesii*				0.202							
Malvaceae	*Sida rhombifolia*				0.043		0.02	0.05	0.16		0.01	
Malvaceae	*Melochia chamaedrys*						0.01		0.31			
Malvaceae	*Krapovickasia flavescens*						0.09	0.19		0.26		
Malvaceae	*Ayenia mansfeldiana*				0.010		0.14	0.16	1.00		0.01	
Melastomataceae	*Tibouchina cerastifolia*				0.007							
Melastomataceae	*Leandra riograndensis*				0.009							
Melastomataceae	*Acisanthera variabilis*					0.01						
Melastomataceae	*Tibouchina debilis*				0.043							
Melastomataceae	*Leandra erostrata*					0.06						
Melastomataceae	*Acisanthera alsinaefolia*			0.10	0.009							0.03
Melastomataceae	*Leandra humilis*			0.14								
Melastomataceae	*Rhynchanthera brachyrhyncha*			0.51								
Melastomataceae	*Leandra australis*										0.60	
Melastomataceae	*Miconia hyemalis*		0.69									
Melastomataceae	*Tibouchina urbanii*		1.16									
Melastomataceae	*Chaetogastra gracilis*		0.74	0.13	1.241	3.94	0.02	0.02		0.38	0.64	0.03
Menyanthaceae	*Nymphoides indica*									0.05	0.10	0.76
Monilophyta	*Monilophyta sp.*		0.80		0.143		0.01	>.001	0.13		0.02	
Moraceae	*Dorstenia brasiliensis*				0.014		0.02	0.03	0.04			0.01
Myrtaceae	*Psidium australe*				0.001			>.001				

Myrtaceae	*Eugenia anomala*							0.01				
Myrtaceae	*Eugenia arenosa*							0.01				
Myrtaceae	*Myrsine orentziana*		0.02									
Myrtaceae	*Myrcianthes pungens*		0.04									
Myrtaceae	*Psidium salutare*				0.029		0.04	0.03				
Myrtaceae	*Psidium cattleyanum*		0.13		0.001							
Myrtaceae	*Campomanesia aurea*				0.048	>.001	0.10	0.37		6.67		
Onagraceae	*Ludwigia decurrens*										0.01	
Onagraceae	*Ludwigia octovalvis*										0.01	
Onagraceae	*Ludwigia grandiflora*			0.01								0.02
Onagraceae	*Oenothera indecora*						0.01	>.001		0.10		0.01
Onagraceae	*Ludwigia multinervia*										0.49	
Onagraceae	*Ludwigia peploides*									2.44		0.12
Ophioglossaceae	*Ophioglossaceae sp.*										0.01	
Orchidaceae	*Skeptrostachys balanophorostachya*				0.001		>.001					
Orchidaceae	*Habenaria sp.*				0.006	0.01						
Orchidaceae	*Habenaria parviflora*			0.26	0.020	>.001	>.001	>.001				0.03
Orobanchaceae	*Buchnera longifolia*				0.003	0.01	>.001	0.01				
Orobanchaceae	*Agalinis communis*				0.003		0.06	0.11	0.11	1.98		0.91
Oxalidaceae	*Oxalis hispidula*				0.004							
Oxalidaceae	*Oxalis brasiliensis*				0.016		0.02					
Oxalidaceae	*Oxalis subvillosa*								0.04			
Oxalidaceae	*Oxalis articulata*				0.063			>.001		0.02		
Oxalidaceae	*Oxalis conorrhiza*				0.006		0.06	0.05	0.02			
Oxalidaceae	*Oxalis myriophylla*				0.043	0.21						
Oxalidaceae	*Oxalis lasiopetala*			0.02	0.006	0.03	0.07	>.001			0.14	
Oxalidaceae	*Oxalis eriocarpa*				0.001		0.16	0.09	0.04	0.02		
Oxalidaceae	*Oxalis floribunda*				0.471		0.02	0.01				0.01

Oxalidaceae	*Oxalis tenerrima*					0.67						
Oxalidaceae	*Oxalis perdicaria*			0.04	0.173	0.69		>.001				
Oxalidaceae	*Oxalis bipartita*			0.02	0.484	0.53	0.01				0.02	
Passifloraceae	*Passiflora tenuifila*						>.001					
Pinaceae	*Pinus elliottii*				0.017	0.04						
Plantaginaceae	*Stemodia palustris*						>.001					
Plantaginaceae	*Scoparia ericacea*						0.01					
Plantaginaceae	*Nuttalanthus canadensis*							0.01				
Plantaginaceae	*Plantago sp.*				0.009							
Plantaginaceae	*Veronica arvensis*				0.012							
Plantaginaceae	*Scoparia dulcis*						0.01					0.01
Plantaginaceae	*Stemodia verticillata*						0.01	0.01				
Plantaginaceae	*Mecardonia serpylloides*									0.23		
Plantaginaceae	*Gratiola peruviana*						0.01	0.02			0.06	0.15
Plantaginaceae	*Plantago australis*				0.242		0.01					
Plantaginaceae	*Mecardonia procumbens*				0.001		0.09	0.09	0.02		0.23	0.01
Plantaginaceae	*Plantago tomentosa*			0.07	0.104		0.08	0.07	0.18		0.03	
Plantaginaceae	*Plantago myosuros*				0.242		0.13	0.11		0.10		0.02
Plantaginaceae	*Berroa gnaphalioides*						0.15		0.49			
Plantaginaceae	*Plantago penantha*						0.22		0.55		0.01	
Plantaginaceae	*Scoparia montevidensis*						0.04	0.11	0.66			0.01
Plantaginaceae	*Plantago guilleminiana*				1.280	0.09						
Plantaginaceae	*Bacopa monnieri*									0.69		5.16
Poaceae	*Bromus catharticus*	C_3							0.1111111			
Poaceae	*Urochloa decumbens*	C_4					0.001					
Poaceae	*Aristida echinulata*	C_4			0.001							
Poaceae	*Chascolytrum sp.*	C_3			0.001							
Poaceae	*Nassella sp.2*	C_3			0.001							

Poaceae	*Schizachyrium glaziovii*	C_4			0.001							
Poaceae	*Chascolytrum bulbosum*	C_3					>.001					
Poaceae	*Eragrostis retinens*	C_4					>.001					
Poaceae	*Andropogon bicornis*	C_4						>.001				
Poaceae	*Briza maxima*	C_3						>.001				
Poaceae	*Melica tenuis*	C_3			0.003							
Poaceae	*Schizachyrium gracilipes*	C_4			0.003							
Poaceae	*Chloris berroi*	C_4					>.001					
Poaceae	*Melinis repens*	C_4						>.001				
Poaceae	*Nassella rhizomata*	C_3				>.001						
Poaceae	*Sorghastrum sp.*	C_4			0.004							
Poaceae	*Holcus lanatus*	C_3			0.003		>.001					
Poaceae	*Melica hyalina*	C_3						0.01				
Poaceae	*Nassella planaltina*	C_3				0.01						
Poaceae	*Chascolytrum parodianum*	C_3									0.01	
Poaceae	*Digitaria aequiglumis*	C_4									0.01	
Poaceae	*Polypogon chilensis*	C_3									0.01	
Poaceae	*Nassella torquata*	C_3					0.01	>.001				
Poaceae	*Elionurus sp.*	C_4			0.009							
Poaceae	*Poa lanigera*	C_3			0.009							
Poaceae	*Nassella philippii*	C_3					0.01					
Poaceae	*Paspalum ionanthum*	C_4					0.01					
Poaceae	*Setaria fiebrigii*	C_4					0.01					
Poaceae	*Nassella nutans*	C_3					>.001	0.01				
Poaceae	*Axonopus aff. compressus*	C_4			0.010							
Poaceae	*Nassella sp.1*	C_3			0.010							
Poaceae	*Sporobolus pseudairoides*	C_4						0.01				
Poaceae	*Digitaria purpurea*	C_4				0.01						

Poaceae	*Aristida circinalis*	C_4					0.01	>.001				
Poaceae	*Nassella vallsii*	C_3			0.014							
Poaceae	*Axonopus jesuiticus*	C_4			0.003			0.01				
Poaceae	*Digitaria insularis*	C_4					>.001	>.001				0.01
Poaceae	*Jarava plumosa*	C_3					0.02					
Poaceae	*Eustachys petraea*	C_4			0.006		0.01	>.001				
Poaceae	*Melica eremophila*	C_3					0.02					
Poaceae	*Nassella charruana*	C_3						0.02				
Poaceae	*Nassella sellowiana*	C_3	0.02									
Poaceae	*Phalaris platensis*	C_3					0.01				0.01	
Poaceae	*Bromus auleticus*	C_3						>.001	0.02			
Poaceae	*Festuca ulochaeta*	C_3									0.02	
Poaceae	*Eleusine indica*	C_4					0.01	>.001				0.01
Poaceae	*Digitaria ciliaris*	C_4				0.01	0.01					
Poaceae	*Nassella filiculmis*	C_3						0.02				
Poaceae	*Vulpia australis*	C_3			0.017							0.01
Poaceae	*Piptochaetium uruguense*	C_3					0.02	0.01				
Poaceae	*Eustachys retusa*	C_4					0.03					
Poaceae	*Chascolytrum scabrum*	C_3					0.03					
Poaceae	*Andropogon glaucophyllus*	C_4						0.01				0.02
Poaceae	*Poa annua*	C_3			0.001		0.03					
Poaceae	*Setaria rosengurttii*	C_4					0.03					
Poaceae	*Chascolytrum monandrum*	C_3				0.03						
Poaceae	*Calamagrostis alba*	C_3					0.02	0.02				
Poaceae	*Chascolytrum rufum*	C_3			0.013		0.02	>.001				
Poaceae	*Eustachys distichophylla*	C_4						0.03				0.01
Poaceae	*Piptochaetium ruprechtianum*	C_3					0.03	0.01				
Poaceae	*Anthaenantia lanata*	C_4				0.02	>.001	0.03				

Poaceae	*Sorghastrum stipoides*	C_4				0.04						
Poaceae	*Schizachyrium condensatum*	C_4			0.045							
Poaceae	*Axonopus purpusii*	C_4			0.043		>.001					
Poaceae	*Panicum bergii*	C_4			0.043		>.001	>.001				
Poaceae	*Sporobolus aeneus*	C_4			0.032	0.02						
Poaceae	*Nassella melanosperma*	C_3			0.049	>.001		0.01				
Poaceae	*Bouteloua megapotamica*	C_4					0.07					
Poaceae	*Gymnopogon burchellii*	C_4		0.05	0.014							
Poaceae	*Nassella juergensii*	C_3			0.024		0.04	>.001				
Poaceae	*Andropogon leucostachyus*	C_4			0.001			>.001				0.07
Poaceae	*Aristida megapotamica*	C_4			0.001	0.07						
Poaceae	*Bromidium tandilense*	C_3					>.001		0.07			
Poaceae	*Aristida murina*	C_4					0.03	0.06				
Poaceae	*Paspalum dilatatum x urvillei*	C_4		0.05			0.03					
Poaceae	*Piptochaetium bicolor*	C_3					0.07	0.02				
Poaceae	*Aristida uruguayensis*	C_4					0.03	0.07				
Poaceae	*Paspalum umbrosum*	C_4			0.030		>.001	0.06				
Poaceae	*Echinochloa crusgalli*	C_4						0.09				0.01
Poaceae	*Gymnopogon grandiflorus*	C_4			0.045	0.06						
Poaceae	*Chascolytrum calotheca*	C_3	0.11				>.001					
Poaceae	*Jarava megapotamica*	C_3					>.001	0.12				
Poaceae	*Piptochaetium panicoides*	C_3		0.06	0.065							
Poaceae	*Paspalum almum*	C_4							0.13			
Poaceae	*Melica rigida*	C_3					0.14					
Poaceae	*Cynodon maritimus*	C_4									0.01	0.14
Poaceae	*Calamagrostis viridiflavescens*	C_3			0.023	0.13	>.001	0.01				
Poaceae	*Sporobolus monandrus*	C_4					>.001		0.16			
Poaceae	*Paspalum paucifolium*	C_4					0.17	>.001				

Poaceae	*Eustachys brevipila*	C_4					0.08		0.09			
Poaceae	*Briza minor*	C_3					0.07	0.11			0.01	
Poaceae	*Eragrostis airoides*	C_4		0.04	0.082		>.001	0.06			0.01	
Poaceae	*Melica macra*	C_3						0.20				
Poaceae	*Panicum glutinosum*	C_4			0.197							
Poaceae	*Eragrostis bahiensis*	C_4			0.004		0.04	>.001			0.14	0.03
Poaceae	*Danthonia montevidensis*	C_3					0.01	0.15				0.06
Poaceae	*Melica brasiliana*	C_3			0.004			0.21				
Poaceae	*Paspalum barretoi*	C_4		0.20	0.030							
Poaceae	*Agenium villosum*	C_4			0.227		>.001	>.001				
Poaceae	*Chloris grandiflora*	C_4					0.11		0.13			
Poaceae	*Ichnanthus procurrens*	C_3			0.245	>.001						
Poaceae	*Dichanthelium superatum*	C_3				0.25						
Poaceae	*Chascolytrum uniolae*	C_3		0.03	0.037	>.001	>.001	0.03			0.11	0.04
Poaceae	*Paspalum urvillei*	C_4			0.003		0.03	>.001			0.23	
Poaceae	*Setaria vaginata*	C_4			0.086		0.07	0.01				0.12
Poaceae	*Eriochrysis cayennensis*	C_4		0.31								
Poaceae	*Danthonia cirrata*	C_3			0.124	>.001	0.08	0.10				
Poaceae	*Chascolytrum poomorphum*	C_3		0.04	0.029		0.06	0.02			0.12	0.05
Poaceae	*Sacciolepis vilvoides*	C_3		0.32								0.01
Poaceae	*Danthonia secundiflora*	C_3		0.08	0.219			0.04				
Poaceae	*Nassella tenuiculmis*	C_3			0.019		0.39					
Poaceae	*Chascolytrum lamarckianum*	C_3		0.17	0.121	0.11	>.001	0.04				
Poaceae	*Paspalum pauciciliatum*	C_4			0.003		0.05	0.06		0.16		0.18
Poaceae	*Piptochaetium alpinum*	C_3		0.45								
Poaceae	*Stenotaphrum secundatum*	C_4										0.46
Poaceae	*Trachypogon mollis*	C_4			0.001			0.46				
Poaceae	*Aristida filifolia*	C_4			0.006		>.001	0.45				

Poaceae	*Agrostis montevidensis*	C_3		0.15	0.112	0.04	0.01	0.09		0.05	0.02	
Poaceae	*Paspalum compressifolium*	C_4			0.448	0.03						
Poaceae	*Sorghastrum setosum*	C_4					0.44				0.04	0.02
Poaceae	*Piptochaetium lasianthum*	C_3			0.069		0.25	0.18				
Poaceae	*Andropogon ternatus*	C_4			0.075		0.22	0.07		0.10	0.04	
Poaceae	*Eriochloa polystachya*	C_4								0.52		0.01
Poaceae	*Paspalum jesuiticum*	C_4							0.55			
Poaceae	*Axonopus argentinus*	C_4			0.069		0.03	0.48				
Poaceae	*Panicum gouinii*	C_4						0.11		0.10		0.42
Poaceae	*Piptochaetium stipoides*	C_3			0.024		0.45	0.13	0.04			
Poaceae	*Cenchrus clandestinus*	C_4						0.68				
Poaceae	*Gymnopogon spicatus*	C_4			0.184	0.42		0.02			0.11	
Poaceae	*Nassella neesiana*	C_3					0.61	0.15				
Poaceae	*Saccharum villosum*	C_4		0.27			>.001				0.50	
Poaceae	*Phalaris angusta*	C_3						0.01		0.81		
Poaceae	*Paspalum conduplicatum*	C_4			0.776	0.13						
Poaceae	*Schizachyrium spicatum*	C_4		0.29	0.449		0.20	0.01				
Poaceae	*Lolium multiflorum*	C_3					1.10	>.001				
Poaceae	*Bothriochloa laguroides*	C_4			0.017		0.30	0.25	0.46	0.10		0.01
Poaceae	*Aristida venustula*	C_4			0.023		0.79	0.17	0.26			
Poaceae	*Panicum aquaticum*	C_4					0.01				0.50	0.72
Poaceae	*Paspalum glaucescens*	C_4				1.31						
Poaceae	*Chascolytrum subaristatum*	C_3		0.09	0.625	>.001	0.24	0.37			0.01	
Poaceae	*Axonopus suffultus*	C_4			0.023	0.08	0.28	1.04				
Poaceae	*Steinchisma decipiens*	C_3					0.02	0.29		0.69	0.03	0.41
Poaceae	*Schizachyrium hatschbachii*	C_4			0.003	1.45						
Poaceae	*Panicum sp.*	C_4	1.48									
Poaceae	*Aristida laevis*	C_4			0.085		0.78	0.73				

Poaceae	*Vulpia bromoides*	C_3						0.09	1.55			
Poaceae	*Aristida flaccida*	C_4		0.05	1.057	0.69		0.04				
Poaceae	*Leersia hexandra*	C_3					0.01				1.87	
Poaceae	*Axonopus compressus*	C_4		0.52	0.507	0.59	0.23	0.07				
Poaceae	*Trachypogon montufarii*	C_4		0.06	0.805	0.62	0.24	0.10	0.02	0.24		
Poaceae	*Amphibromus scabrivalvis*	C_3							2.13			
Poaceae	*Paspalum maculosum*	C_4			1.300	0.99		0.02			0.05	
Poaceae	*Saccharum angustifolium*	C_4			0.390		1.94	0.16				
Poaceae	*Eragrostis lugens*	C_4		0.03	0.101		0.13	0.07	2.17		0.01	0.01
Poaceae	*Paspalum polyphyllum*	C_4		0.89	0.887	0.81						
Poaceae	*Cynodon dactylon*	C_4					0.37	0.15	0.27	0.26		1.55
Poaceae	*Sporobolus indicus*	C_4			0.022		0.87	0.41	0.82	0.03	0.01	0.53
Poaceae	*Elionurus muticus*	C_4			0.012	1.86	>.001	1.06				
Poaceae	*Eragrostis cataclasta*	C_4						0.51		0.49		2.14
Poaceae	*Axonopus fissifolius*	C_4					0.31	0.04	0.16		2.87	
Poaceae	*Andropogon macrothrix*	C_4		0.86	0.112	2.34	0.02	>.001				0.05
Poaceae	*Eragrostis polytricha*	C_4		0.03	0.825	2.46	0.01	0.33				0.08
Poaceae	*Andropogon selloanus*	C_4			0.048	0.01	0.04	0.51			0.01	3.59
Poaceae	*Setaria parviflora*	C_4			0.451	0.07	0.93	1.23	0.33	0.83	0.20	0.25
Poaceae	*Axonopus obtusifolius*	C_4									4.34	
Poaceae	*Aristida jubata*	C_4			0.485		0.23	3.71				
Poaceae	*Mnesithea selloana*	C_4			0.752	1.04	1.96	0.72			0.07	0.23
Poaceae	*Steinchisma hians*	C_3		0.07	0.341	0.01	1.04	0.48	0.87	0.49	1.26	0.19
Poaceae	*Ischaemum minus*	C_4						0.08		0.88	3.87	
Poaceae	*Eragrostis neesii*	C_4			0.120		0.30	2.29	2.30			0.04
Poaceae	*Danthonia montana*	C_3	4.49	0.61								
Poaceae	*Paspalum indecorum*	C_4					0.29		4.96			
Poaceae	*Schizachyrium microstachyum*	C_4			2.328	2.67	0.08	0.18				0.05

Poaceae	*Eleusine tristachya*	C_4					0.09	0.03	3.04	2.18		0.01
Poaceae	*Dichanthelium sabulorum*	C_3	0.82	0.28	1.149	1.25	0.72	0.70	0.02		0.86	0.31
Poaceae	*Andropogon virgatus*	C_4		3.74	0.003		0.36				2.23	
Poaceae	*Axonopus aff. affinis*	C_4			0.030						0.05	6.55
Poaceae	*Paspalum lepton*	C_4					1.45	0.51		3.95	1.33	1.37
Poaceae	*Sorghastrum pellitum*	C_4	4.83	2.18	0.554	0.01	0.02				1.20	
Poaceae	*Eragrostis plana*	C_4					2.67	0.18		1.58	4.65	0.01
Poaceae	*Tripogon spicatus*	C_4							9.35			
Poaceae	*Luziola peruviana*	C_3					0.25			0.14	6.20	3.34
Poaceae	*Axonopus pellitus*	C_4	0.04	6.27	0.629	3.16						
Poaceae	*Paspalum dilatatum*	C_4			0.137		0.38	0.22		9.43	0.09	
Poaceae	*Paspalum modestum*	C_4		5.71			>.001			5.72		0.43
Poaceae	*Paspalum plicatulum*	C_4		0.01	3.915	4.12	0.78	1.56		1.40	0.42	1.51
Poaceae	*Microchloa indica*	C_4					>.001		14.63			
Poaceae	*Axonopus ramboi*	C_4	16.84									
Poaceae	*Schizachyrium tenerum*	C_4	0.42	7.08	5.156	6.38	0.17	0.27				
Poaceae	*Piptochaetium montevidense*	C_3		0.06	7.023	4.73	3.45	3.11	1.09		0.08	0.23
Poaceae	*Paspalum pumilum*	C_4		6.09	2.233		0.40	0.82		1.54	7.27	13.35
Poaceae	*Axonopus affinis*	C_4		0.40	0.950	0.87	4.79	6.31	0.33	1.65	11.02	6.71
Poaceae	*Andropogon lateralis*	C_4	48.53	33.29	5.719		7.09	3.43			7.66	3.63
Poaceae	*Paspalum notatum*	C_4			7.429	0.23	30.03	35.74	16.65	2.67	5.83	14.80
Polygalaceae	*Asemeia extraaxillaris*				0.001							
Polygalaceae	*Polygala adenophylla*						>.001					
Polygalaceae	*Polygala riograndensis*						>.001					
Polygalaceae	*Polygala duarteana*						>.001					
Polygalaceae	*Polygala timoutoides*			0.01								0.01
Polygalaceae	*Polygala australis*						0.02					
Polygalaceae	*Polygala molluginifolia*						0.03	>.001			0.01	

Polygalaceae	*Polygala sabulosa*			0.12								
Polygalaceae	*Polygala pumila*				0.022	0.08	>.001	>.001	0.04			
Polygalaceae	*Polygala linoides*		0.02	0.02	0.003		0.06	>.001	0.09			
Polygalaceae	*Polygala pulchella*			0.03	0.151	0.03	0.04	0.02	0.02	0.23		0.02
Polygalaceae	*Polygala brasiliensis*		0.02	0.05	0.164	0.15		0.03		0.14		
Polygonaceae	*Polygonum punctatum*						0.01				0.08	0.01
Primulaceae	*Pelletiera verna*						>.001				0.01	
Primulaceae	*Lysimachia filiformis*			0.03	0.001			>.001				
Primulaceae	*Lysimachia arvensis*			0.06			0.01	0.01				
Primulaceae	*Lysimachia minima*			0.01			0.06				0.02	0.02
Primulaceae	*Lysimachia sp.*				0.040	0.88						
Pteridófita	*Pteridófita*						0.03					
Ranunculaceae	*Ranunculus bonariensis*										0.03	
Rhamnaceae	*Discaria americana*				0.006	0.01	0.04					
Rosaceae	*Margyricarpus pinnatus*				0.003							
Rosaceae	*Acaena eupatoria*				0.004	>.001						
Rosaceae	*Geum sp.*				0.052							
Rubiaceae	*Diodella apiculata*							>.001				
Rubiaceae	*Galianthe verbenoides*							>.001				
Rubiaceae	*Spermacoce prostrata*							>.001				
Rubiaceae	*Galium sellowianum*					>.001						
Rubiaceae	*Richardia grandiflora*						>.001					
Rubiaceae	*Galium vile*			0.01			>.001					
Rubiaceae	*Galium sp.*				0.012							
Rubiaceae	*Galium hypocarpium*							0.01				
Rubiaceae	*Borreria tenella*				0.012		>.001	>.001				
Rubiaceae	*Borreria palustris*						>.001				0.01	
Rubiaceae	*Machaonia brasiliensis*								0.02			

Rubiaceae	*Borreria poaya*						0.01	0.01				
Rubiaceae	*Galium megapotamicum*				0.023							
Rubiaceae	*Borreria brachystemonoides*							0.03				0.01
Rubiaceae	*Richardia brasiliensis*					0.01	0.01	0.01				
Rubiaceae	*Galium uruguayense*				0.017		0.02	0.01				
Rubiaceae	*Borreria dasycephala*				0.004		0.02	0.01				0.01
Rubiaceae	*Galium noxium*					0.05						
Rubiaceae	*Spermacoce eryngioides*						0.02	0.01	0.04			
Rubiaceae	*Galium hirtum*				0.001	0.01	>.001	0.01			0.04	
Rubiaceae	*Staelia thymoides*						>.001	0.01		0.10		
Rubiaceae	*Borreria capitata*				0.098	0.02		>.001				
Rubiaceae	*Borreria verticillata*				0.010		0.12	0.04	0.04		0.03	
Rubiaceae	*Galianthe fastigiata*				0.027	0.04	0.04	0.16				0.03
Rubiaceae	*Galium humile*			0.34	0.888	0.09	0.02				0.08	0.04
Rubiaceae	*Richardia stellaris*						0.18	0.32	1.02			
Rubiaceae	*Galium richardianum*				1.497	0.03	0.22	0.10	0.04	0.10	0.01	0.08
Rubiaceae	*Oldenlandia salzmannii*				0.003		0.01	0.02		0.10	1.49	0.94
Rubiaceae	*Richardia humistrata*				2.597	0.01	1.09	2.02			0.04	1.02
Sapindaceae	*Serjania sp.*				0.009							
Sellaginellaceae	*Selaginella sp.*		0.36	0.55			0.06	0.01				
Smilacaceae	*Smilax campestris*				0.001							
Solanaceae	*Solanum pabstii*				0.001							
Solanaceae	*Calibrachoa parviflora*						>.001					
Solanaceae	*Calibrachoa dusenii*				0.001	>.001						
Solanaceae	*Calibrachoa ovalifolia*							0.01				
Solanaceae	*Bouchetia anomala*						0.01					
Solanaceae	*Calibrachoa linoides*					0.01						
Solanaceae	*Calibrachoa heterophylla*											0.01

Solanaceae	*Nierembergia linariifolia*						0.01					
Solanaceae	*Nierembergia micrantha*							0.02				
Solanaceae	*Solanum hasslerianum*						>.001	0.08				
Solanaceae	*Petunia integrifolia*				0.108			0.03				
Solanaceae	*Solanum mauritianum*		0.15									
Solanaceae	*Nierembergia riograndensis*						0.07	0.09				
Solanaceae	*Solanum sisymbriifolium*							0.19				
Solanaceae	*Nierembergia scoparia*								6.18			
Thymelaeaceae	*Daphnopsis racemosa*							0.10				
Turneraceae	*Piriqueta suborbicularis*						>.001					
Turneraceae	*Piriqueta taubatensis*				0.010	0.04	0.04	>.001				
Verbenaceae	*Verbena gracilescens*						0.004					
Verbenaceae	*Glandularia aristigera*						>.001					
Verbenaceae	*Lantana montevidensis*							>.001				
Verbenaceae	*Lantana fucata*					>.001						
Verbenaceae	*Verbena bonariensis*							>.001				
Verbenaceae	*Verbena intermedia*							>.001				
Verbenaceae	*Lippia hieracifolia*						>.001					
Verbenaceae	*Glandularia platensis*						0.01					
Verbenaceae	*Glandularia thymoides*				0.001			0.01				
Verbenaceae	*Lantana megapotamica*							0.01				
Verbenaceae	*Verbena rigida*							0.01				
Verbenaceae	*Lippia alba*				0.003			0.01				
Verbenaceae	*Lippia asperrima*							0.02				
Verbenaceae	*Verbena filicaulis*			0.02								
Verbenaceae	*Lippia arechavaletae*						0.01	0.01				
Verbenaceae	*Lippia villafloridana*						0.03					
Verbenaceae	*Glandularia peruviana*				0.013		0.02	>.001			0.01	

Verbenaceae	*Verbena ephedroides*				0.012	0.03		>.001				
Verbenaceae	*Glandularia catharinae*				0.006	0.04						
Verbenaceae	*Lippia coarctata*						0.06					
Verbenaceae	*Glandularia marrubioides*			0.01	0.006	0.07						
Verbenaceae	*Verbena montevidensis*				0.078			0.06		0.02		
Verbenaceae	*Glandularia tenera*								0.29			
Verbenaceae	*Phyla nodiflora*						0.03			0.36		0.23
Verbenaceae	*Verbena hirta*			0.01	0.048	0.61						
Verbenaceae	*Glandularia selloi*						0.04	0.34			0.02	0.45
Verbenaceae	*Lippia ramboi*				0.001		0.05	0.01		5.72		
Violaceae	*Pombalia bicolor*							>.001				
Violaceae	*Pombalia parviflora*				0.032	>.001			0.11			
Vivianiaceae	*Caesarea albiflora*					>.001		>.001				
Xyridaceae	*Xyris sp.*				0.001							

Appendix S2. Indicator species of *Campos Sulinos* grasslands.

Grassland subtype 1	**Indval**	**P value**
Axonopus ramboi	1.00	0.001 ***
Solanum mauritianum	1.00	0.001 ***
Tibouchina urbanii	1.00	0.001 ***
Calea phyllolepis	0.96	0.001 ***
Mikania paranensis	0.82	0.001 ***
Panicum sp.	0.82	0.001 ***
Barrosoa candolleana	0.81	0.002 **
Gelasine coerulea	0.73	0.002 **
Alstroemeria isabelleana	0.58	0.044 *
Bomarea edulis	0.58	0.044 *
Croton calycireduplicatus	0.58	0.044 *
Grazielia nummularia	0.58	0.033 *
Miconia hyemalis	0.58	0.036 *
Myrcianthes pungens	0.58	0.044 *
Myrsine orentziana	0.58	0.036 *
Nassella sellowiana	0.58	0.036 *
Orthosia scoparia	0.58	0.036 *
Trixis lessingii	0.58	0.033 *
Psidium cattleyanum	0.57	0.022 *
Chascolytrum calotheca	0.56	0.02 *
Krapovickasia urticifolia	0.54	0.027 *
Convolvulus crenatifolius	0.54	0.029 *

Grassland subtype 2	**Indval**	**P value**
Hypochaeris lutea	0.89	0.001 ***
Rhynchospora flexuosa	0.882	0.001 ***
Paspalum maculosum	0.823	0.001 ***
Paspalum polyphyllum	0.815	0.001 ***
Scleria distans	0.766	0.001 ***
Baccharis subtropicalis	0.728	0.001 ***
Habenaria parviflora	0.716	0.002 **
Calydorea crocoides	0.655	0.002 **
Disynaphia ligulaefolia	0.655	0.007 **
Moritzia dasyantha	0.655	0.007 **
Piptochaetium alpinum	0.655	0.007 **
Rhynchanthera brachyrhyncha	0.655	0.002 **
Scleria georgiana	0.655	0.007 **
Eriocaulon leptophyllum	0.647	0.007 **

Eryngium ebracteatum	0.647	0.006 **
Linum brevifolium	0.633	0.006 **
Achyrocline flaccida	0.601	0.007 **
Bulbostylis hirtella	0.588	0.012 *
Eryngium zozterifolium	0.535	0.009 **
Eleocharis nudipes	0.524	0.04 *

Grassland subtype 3	**Indval**	**P value**
Trifolium riograndense	0.613	0.019 *
Hypochaeris radicata	0.605	0.02 *
Paspalum compressifolium	0.574	0.043 *
Plantago guilleminiana	0.535	0.042 *

Grassland subtype 4	**Indval**	**P value**
Mikania decumbens	0.905	0.001 ***
Stenocephalum megapotamicum	0.901	0.001 ***
Croton glechomifolius	0.854	0.001 ***
Paspalum glaucescens	0.853	0.001 ***
Chromolaena latisquamulosa	0.851	0.001 ***
Rhynchospora pungens	0.845	0.001 ***
Aristida flaccida	0.827	0.001 ***
Gyptis pinnatifita	0.821	0.001 ***
Pteridium arachnoideum	0.809	0.001 ***
Lessingianthus hypochaeris	0.805	0.001 ***
Chaptalia mandonii	0.783	0.001 ***
Grazielia multifida	0.769	0.001 ***
Stenachaenium campestre	0.768	0.001 ***
Verbena hirta	0.747	0.001 ***
Schizachyrium hatschbachii	0.733	0.005 **
Stevia alternifolia	0.729	0.003 **
Achyrocline satureioides	0.724	0.002 **
Adesmia sulina	0.707	0.006 **
Lysimachia sp.	0.691	0.006 **
Eriosema tacuaremboense	0.659	0.005 **
Elionurus muticus	0.648	0.011 *
Rhynchospora edwalliana	0.609	0.022 *
Bulbostylis capillaris	0.592	0.02 *
Croton hirtus	0.583	0.025 *
Dichanthelium superatum	0.564	0.015 *
Lucilia lycopodioides	0.564	0.015 *
Eriosema longifolium	0.545	0.045 *

Oxalis tenerrima	0.522	0.034 *
Spigelia stenophylla	0.519	0.05 *
Sisyrinchium scariosum	0.518	0.021 *

Grassland subtype 5	**Indval**	**P value**
Gamochaeta simplicicaulis	0.554	0.045 *

Grassland subtype 6	**Indval**	**P value**
Aristida laevis	0.579	0.036 *
Aristida filifolia	0.562	0.04 *
Chaptalia nutans	0.548	0.032 *
Melica brasiliana	0.531	0.044 *

Grassland subtype 7	**Indval**	**P value**
Tripogon spicatus	0.992	0.001 ***
Berroa gnaphalioides	0.923	0.001 ***
Scoparia montevidensis	0.88	0.001 ***
Cyperus uncinulatus	0.866	0.001 ***
Nierembergia scoparia	0.866	0.001 ***
Microchloa indica	0.864	0.001 ***
Paspalum indecorum	0.857	0.001 ***
Melochia chamaedrys	0.849	0.001 ***
Plantago penantha	0.848	0.001 ***
Vulpia bromoides	0.839	0.002 **
Stenandrium diphyllum	0.793	0.002 **
Eragrostis lugens	0.78	0.002 **
Hypochaeris albiflora	0.763	0.001 ***
Ayenia mansfeldiana	0.728	0.002 **
Amphibromus scabrivalvis	0.707	0.001 ***
Euphorbia serpens	0.707	0.001 ***
Glandularia tenera	0.707	0.003 **
Zornia pardina	0.707	0.003 **
Sporobolus monandrus	0.691	0.002 **
Mimosa paupera	0.688	0.003 **
Gomphrena celosioides	0.679	0.007 **
Nothoscordum gracile	0.677	0.006 **
Axonopus fissifolius	0.622	0.019 *
Fimbristylis sp.nov	0.603	0.024 *
Acmella leptophylla	0.552	0.047 *

Grassland subtype 8	Indval	P value
Sesbania punicea	1	0.001 ***
Lippia ramboi	0.993	0.001 ***
Phalaris angusta	0.982	0.001 ***
Croton parvifolius	0.968	0.001 ***
Symphyotrichum squamatum	0.935	0.001 ***
Pterocaulon angustifolium	0.932	0.001 ***
Eleocharis maculosa	0.875	0.001 ***
Campomanesia aurea	0.872	0.001 ***
Eclipta prostrata	0.837	0.001 ***
Vigna luteola	0.809	0.001 ***
Paspalum dilatatum	0.805	0.002 **
Staelia thymoides	0.79	0.001 ***
Eriochloa polystachya	0.786	0.001 ***
Fimbristylis autumnalis	0.784	0.001 ***
Eleocharis geniculata	0.769	0.001 ***
Oenothera indecora	0.766	0.003 **
Ludwigia peploides	0.759	0.001 ***
Heimia apetala	0.759	0.002 **
Paspalum modestum	0.732	0.001 ***
Phyla nodiflora	0.723	0.003 **
Ischaemum minus	0.714	0.002 **
Eleocharis flavescens	0.699	0.006 **
Lessingianthus sellowii	0.658	0.013 *
Pamphalea heterophylla	0.646	0.007 **
Senecio selloi	0.628	0.024 *
Paspalum pauciciliatum	0.616	0.021 *
Noticastrum diffusum	0.563	0.016 *
Cuphea carthagenensis	0.511	0.043 *

Grassland subtype 9	Indval	P value
Eleocharis viridans	0.798	0.001 ***
Mecardonia procumbens	0.704	0.006 **
Eleocharis sellowiana	0.635	0.01 **
Rhynchospora emaciata	0.629	0.009 **
Cyperus haspan	0.628	0.009 **
Eleocharis montana	0.577	0.001 ***
Leersia hexandra	0.568	0.013 *

Grassland subtype 10	Indval	P value

Hydrocotyle bonariensis	0.805	0.001 ***
Axonopus aff *affinis*	0.726	0.002 **
Pterocaulon cordobense	0.651	0.007 **
Rhynchospora brittonii	0.622	0.013 *
Andropogon leucostachyus	0.616	0.008 **
Eleocharis bonariensis	0.564	0.033 *

Grassland subtypes 1+2	**Indval**	**P value**
Selaginella sp.	0.785	0.001 ***
Danthonia montana	0.775	0.001 ***
Andropogon lateralis	0.746	0.001 ***
Sorghastrum pellitum	0.665	0.01 **

Grassland subtypes 1+4	**Indval**	**P value**
Sisyrinchium vaginatum	0.682	0.005 **

Grassland subtypes 2+3	**Indval**	**P value**
Trichocline catharinensis	0.698	0.004 **

Grassland subtypes 2+4	**Indval**	**P value**
Euphorbia peperomioides	0.91	0.001 ***
Axonopus pellitus	0.906	0.001 ***
Chevreulia revoluta	0.884	0.001 ***
Andropogon macrothrix	0.753	0.004 **
Noticastrum decumbens	0.691	0.004 **
Lucilia linearifolia	0.646	0.011 *
Hypochaeris catharinensis	0.639	0.012 *
Bulbostylis sphaerocephala	0.576	0.039 *
Oxalis perdicaria	0.566	0.036 *
Glandularia marrubioides	0.53	0.041 *
Hieracium commersonii	0.523	0.049 *

Grassland subtypes 2+5	**Indval**	**P value**
Carex phalaroides	0.826	0.001 ***

Grassland subtypes 2+7	**Indval**	**P value**
Eryngium elegans	0.551	0.026 *

Grassland subtypes 2+8	**Indval**	**P value**
Polygala brasiliensis	0.655	0.004 **

Grassland subtypes 2+9	**Indval**	**P value**
Chascolytrum poomorphum	0.587	0.044 *

Grassland subtypes 2+10	**Indval**	**P value**
Rhynchospora barrosiana	0.668	0.011 *
Acisanthera alsinaefolia	0.508	0.046 *

Grassland subtypes 3+4	**Indval**	**P value**
Eragrostis polytricha	0.85	0.001 ***
Crotalaria hilariana	0.762	0.001 ***
Lucilia acutifolia	0.676	0.009 **
Pterocaulon alopecuroides	0.602	0.037 *

Grassland subtypes 4+7	**Indval**	**P value**
Polygala pumila	0.625	0.01 **

Grassland subtypes 5+6	**Indval**	**P value**
Nassella neesiana	0.612	0.029 *

Grassland subtypes 5+7	**Indval**	**P value**
Soliva sessilis	0.801	0.001 ***
Eryngium echinatum	0.626	0.028 *
Ruellia morongii	0.601	0.021 *

Grassland subtypes 6+7	**Indval**	**P value**
Richardia stellaris	0.827	0.001 ***

Grassland subtypes 6+8	**Indval**	**P value**
Krapovickasia flavescens	0.676	0.007 **

Grassland subtypes 6+10	**Indval**	**P value**
Andropogon selloanus	0.792	0.001 ***
Glandularia selloi	0.651	0.007 **
Stylosanthes leiocarpa	0.607	0.014 *

Grassland subtypes 7+8	**Indval**	**P value**
Eleusine tristachya	0.772	0.002 **

Grassland subtypes 7+10	**Indval**	**P value**
Bulbostylis scabra	0.822	0.001 ***

Grassland subtypes 8+10	**Indval**	**P value**
Eragrostis cataclasta	0.891	0.001 ***
Pycreus polystachyos	0.769	0.002 **
Bacopa monnieri	0.707	0.002 **
Jaegeria hirta	0.707	0.002 **
Fimbristylis complanata	0.692	0.004 **
Panicum gouinii	0.673	0.005 **
Nymphoides indica	0.658	0.004 **
Eleocharis minima	0.654	0.014 *
Cynodon dactylon	0.64	0.008 **
Pluchea sagittalis	0.52	0.04 *

Grassland subtypes 9+10	**Indval**	**P value**
Oldenlandia salzmannii	0.783	0.001 ***
Panicum aquaticum	0.781	0.002 **
Gratiola peruviana	0.673	0.011 *
Desmodium adscendens	0.642	0.011 *
Eragrostis bahiensis	0.612	0.012 *

Grassland subtypes 1+2+4	**Indval**	**P value**
Scleria sellowiana	0.615	0.024 *

Grassland subtypes 1+2+7	**Indval**	**P value**
Bryophyta spp.	0.894	0.001 ***

Grassland subtypes 2+3+4	**Indval**	**P value**
Chromolaena ascendens	0.878	0.001 ***
Baccharis pentodonta	0.789	0.001 ***
Axonopus compressus	0.619	0.019 *

Grassland subtypes 2+3+9	**Indval**	**P value**
Rhynchospora rugosa	0.7	0.006 **

Grassland subtypes 2+3+10	**Indval**	**P value**
Galium humile	0.781	0.001 ***

Grassland subtypes 3+4+6	**Indval**	**P value**
Stylosanthes montevidensis	0.686	0.01 **
Schizachyrium microstachyum	0.639	0.039 *

Grassland subtypes 3+4+7	**Indval**	**P value**
Bulbostylis juncoides	0.649	0.016 *

Grassland subtypes 3+4+10	**Indval**	**P value**
Baccharis articulata	0.71	0.003 **

Grassland subtypes 3+5+6	**Indval**	**P value**
Pfaffia tuberosa	0.756	0.001 ***

Grassland subtypes 3+5+7	**Indval**	**P value**
Evolvulus sericeus	0.852	0.001 ***
Piptochaetium stipoides	0.742	0.001 ***
Aristida venustula	0.722	0.002 **
Trifolium polymorphum	0.648	0.006 **
Baccharis coridifolia	0.614	0.016 *

Grassland subtypes 5+6+8	**Indval**	**P value**
Eryngium horridum	0.687	0.007 **

Grassland subtypes 5+6+9	**Indval**	**P value**
Scutellaria racemosa	0.684	0.009 **

Grassland subtypes 5+7+9	**Indval**	**P value**
Borreria verticillata	0.645	0.01 **

Grassland subtypes 5+8+9	**Indval**	**P value**
Eragrostis plana	0.654	0.008 **

Grassland subtypes 6+8+10	**Indval**	**P value**
Steinchisma decipiens	0.816	0.001 ***

Grassland subtypes 8+9+10	**Indval**	**P value**
Centella asiatica	0.869	0.001 ***
Lobelia hederacea	0.8	0.002 **
Juncus microcephalus	0.712	0.004 **
Luziola peruviana	0.678	0.006 **

Grassland subtypes 1+2+3+4	**Indval**	**P value**
Schizachyrium tenerum	0.947	0.001 ***

Grassland subtypes 2+3+4+6	**Indval**	**P value**
Chaptalia exscapa	0.731	0.003 **

Grassland subtypes 2+3+5+6	**Indval**	**P value**
Chascolytrum subaristatum	0.789	0.001 ***

Grassland subtypes 2+3+5+7	**Indval**	**P value**
Chaptalia runcinata	0.734	0.003 **

Grassland subtypes 2+3+6+8	**Indval**	**P value**
Agrostis montevidensis	0.703	0.007 **

Grassland subtypes 2+5+6+7	Indval	P value
Herbertia lahue	0.659	0.006 **

Grassland subtypes 2+8+9+10	Indval	P value
Paspalum pumilum	0.883	0.001 ***

Grassland subtypes 3+4+6+8	Indval	P value
Lucilia nitens	0.802	0.001 ***

Grassland subtypes 3+4+6+10	Indval	P value
Chrysolaena flexuosa	0.608	0.04 *

Grassland subtypes 3+5+6+8	Indval	P value
Aspilia montevidensis	0.751	0.009 **

Grassland subtypes 3+5+6+10	Indval	P value
Richardia humistrata	0.905	0.001 ***
Mnesithea selloana	0.863	0.001 ***

Grassland subtypes 5+6+7+8	Indval	P value
Oxalis eriocarpa	0.735	0.002 **
Bothriochloa laguroides	0.734	0.001 ***

Grassland subtypes 5+6+7+10	Indval	P value
Eragrostis neesii	0.854	0.001 ***
Eryngium nudicaule	0.621	0.018 *

Grassland subtypes 5+6+8+9	Indval	P value
Facelis retusa	0.709	0.004 **

Grassland subtypes 5+6+8+10	Indval	P value
Juncus capillaceus	0.755	0.001 ***
Plantago myosuros	0.715	0.001 ***

Cuphea glutinosa	0.677	0.011 *

Grassland subtypes 5+8+9+10	**Indval**	**P value**
Paspalum lepton	0.671	0.009 **

Grassland subtypes 6+7+8+10	**Indval**	**P value**
Agalinis communis	0.644	0.008 **

Grassland subtypes 7+8+9+10	**Indval**	**P value**
Kyllinga brevifolia	0.782	0.001 ***

Grassland subtypes 2+5+6+7+9	**Indval**	**P value**
Plantago tomentosa	0.691	0.004 **

Grassland subtypes 2+6+8+9+10	**Indval**	**P value**
Gamochaeta filaginea	0.676	0.006 **

Grassland subtypes 3+4+5+6+7	**Indval**	**P value**
Piptochaetium montevidense	0.955	0.001 ***

Grassland subtypes 3+4+5+6+9	**Indval**	**P value**
Hypochaeris chillensis	0.664	0.019 *

Grassland subtypes 5+6+7+8+10	**Indval**	**P value**
Cyclospermum leptophyllum	0.853	0.001 ***
Sporobolus indicus	0.835	0.001 ***
Galium richardianum	0.752	0.002 **

Grassland subtypes 5+6+7+9+10	**Indval**	**P value**
Conyza bonariensis	0.605	0.031 *

Grassland subtypes 1+2+3+4+8+9	**Indval**	**P value**
Chaetogastra gracilis	0.804	0.001 ***

Grassland subtypes 2+3+4+5+6+7	**Indval**	**P value**
Wahlenbergia linarioides	0.738	0.002 **

Grassland subtypes 2+3+4+5+6+9	**Indval**	**P value**
Hydrocotyle exigua	0.721	0.01 **

Grassland subtypes 2+3+5+6+7+10	**Indval**	**P value**
Chevreulia sarmentosa	0.862	0.001 ***

Grassland subtypes 2+5+7+8+9+10	**Indval**	**P value**
Kyllinga vaginata	0.767	0.001 ***

Grassland subtypes 3+5+6+7+8+10	**Indval**	**P value**
Kyllinga odorata	0.754	0.004 **

Grassland subtypes 5+6+7+8+9+10	**Indval**	**P value**
Setaria parviflora	0.927	0.001 ***

Grassland subtypes 1+2+3+4+6+8+10	**Indval**	**P value**
Baccharis crispa	0.907	0.001 ***

Grassland subtypes 2+3+4+5+6+7+9	**Indval**	**P value**
Chevreulia acuminata	0.79	0.002 **

Grassland subtypes 2+5+6+7+8+9+10	**Indval**	**P value**
Sisyrinchium micranthum	0.874	0.001 ***

Grassland subtypes 3+4+5+6+8+9+10	**Indval**	**P value**
Paspalum plicatulum	0.926	0.001 ***
Dichondra sericea	0.909	0.001 ***

Grassland subtypes 3+5+6+7+8+9+10	**Indval**	**P value**
Paspalum notatum	0.956	0.001 ***
Steinchisma hians	0.869	0.001 ***
Desmodium incanum	0.821	0.001 ***

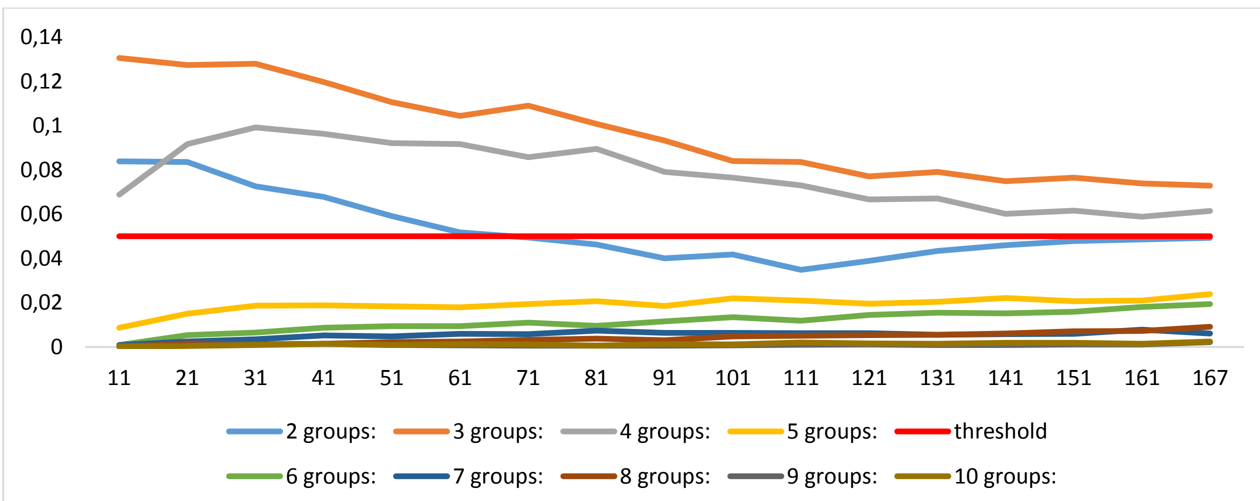
Grassland subtypes 1+2+3+4+5+6+9+10	**Indval**	**P value**
Dichanthelium sabulorum	0.932	0.001 ***

Grassland subtypes 2+3+5+6+7+8+9+10	**Indval**	**P value**
Hypoxis decumbens	0.799	0.001 ***

Grassland subtypes 2+3+4+5+6+7+8+9+10	**Indval**	**P value**
Axonopus affinis	0.897	0.017 *
Gamochaeta americana	0.87	0.025 *

Appendix S3. Evaluation of sampling sufficiency and significance for group partition levels

	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	167
2 groups	0.0839	0.0835	0.0726	0.0678	0.0591	0.0518	0.0495	0.0462	0.04	0.0418	0.0348	0.0389	0.0434	0.0459	0.0478	0.0486	0.0493
3 groups	0.1305	0.1274	0.1279	0.1197	0.1106	0.1044	0.109	0.1007	0.0932	0.084	0.0836	0.0771	0.0791	0.0749	0.0765	0.0738	0.0728
4 groups	0.0688	0.0917	0.0991	0.0962	0.0921	0.0916	0.0857	0.0895	0.0791	0.0765	0.073	0.0666	0.0671	0.0601	0.0616	0.0588	0.0614
5 groups	0.0086	0.015	0.0186	0.0188	0.0183	0.0179	0.0193	0.0207	0.0185	0.022	0.021	0.0195	0.0203	0.0221	0.0207	0.021	0.0239
6 groups	0.0009	0.0053	0.0065	0.0086	0.0094	0.0094	0.0109	0.0095	0.0115	0.0135	0.0119	0.0145	0.0155	0.0152	0.0159	0.018	0.0193
7 groups	0.0009	0.0025	0.0035	0.0052	0.0047	0.0059	0.0057	0.0073	0.0064	0.0064	0.0062	0.0062	0.0055	0.0057	0.0059	0.0078	0.0061
8 groups	0.0002	0.0016	0.0011	0.0014	0.0021	0.0024	0.0031	0.0037	0.003	0.0047	0.0051	0.0054	0.0055	0.0061	0.007	0.0072	0.0091
9 groups	0.0006	0.0005	0.0011	0.0014	0.0009	0.0007	0.0006	0.0005	0.0006	0.0007	0.001	0.0011	0.0009	0.0008	0.0012	0.0012	0.0021
10 groups	0.0001	0.0004	0.0009	0.0015	0.0009	0.0013	0.0012	0.0005	0.0013	0.0012	0.002	0.0016	0.0015	0.0019	0.0018	0.0015	0.0024
threshold	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05



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Author contributions

V.D.P, E.V.M and G.E.O. conceived the research idea and sampling design; B.O.A, C.L.B., G.E.O, E.D.M., R.G.R., C.V.E., D.B.L., E.N.G, E.D.S., F.P.T., M.S.V, P.J.J.S., P.M.A.F, R.T., R.H., S.C. and I.I.B collected data; S.A.L.B., A.A.S., C.V.E. and I.I.B. identified collected plant material; B.O.A., C.L.B., G.E.O. and V.D.P. performed statistical analyses; B.O.A., C.L.B., G.E.O. and I.I.B. wrote a first version of all manuscripts; all authors discussed the results and commented on the manuscript.

CAPÍTULO II

The influence of environmental drivers in the South Brazilian Grasslands

Abstract

South Brazilian Grasslands can be found in a transitional area from subtropical to tropical clime, belonging to two different phytogeographic provinces: the Pampean and Paraná province. Whereas two adjacent phytogeographic provinces have pronounced differences in species richness, composition and vegetation structure, this study aims to investigate which climatic and soil variables have a high relevance for shaping vegetation patterns. The study area comprises grassland ecosystems in the Brazilian southern region Pampa and Atlantic Forest biomes. We adopted a stratified, nested sampling design with strata defined by geomorphology features. We delimited and used for the survey one 2 km x 2 km Sampling Unit (SU). Each SU was composed of three Sample Plots (SPs) (70 m x 70 m). To sample grassland vegetation at each SP, we systematically allocated nine quadrants of 1m² each. To obtain climatic variables, we used georeferenced database provide by National Institute of Meteorology, soil variables were collected through three sample in each SP. We explored the relationship between grasslands and environmental factors trough the Canonical Correspondence Analysis (CCA) and variation explained by the set of environmental features by Redundancy Analysis (RDA). The CCA shows that environmental variables related to precipitation and soil organic matter explain the distribution of the sample plots of Highland grasslands. On the other hand, Pampa grasslands had temperature extremes and variables related to fertility, while the percentage of explanation of soil and climate variables recorded by RDA was small.

Key words: Southern Brazilian Grasslands, environmental drivers, grasslands diversity, vegetation patterns.

Introduction

The occurrence of plants at a given place depends on dispersal and the presence of environmental conditions suitable for the species in question (Whittaker 1972). The role of the environment in shaping species diversity patterns has long motivated ecological and biogeographically research on local to global scales (Pottier et al. 2013). Among abiotic drivers, climate and soil properties are recognized as the main constrains for the distribution of species (Dubuis et al. 2013). The species composition of grasslands depends on a broad range of factors and processes, which range from climate and soil to disturbances (Blair et al. 2014). Grasslands in general are sensitive to climatic changes, because grassland vegetation is particularly limited by precipitation~~s~~ and temperature patterns as well as management (Soussana & Luscher 2007, Wilcox et al. 2017). In subtropical grasslands where the co-existence of C_3 and C_4 species is a distinct characteristic (Overbeck et al. 2007), trends associated with climate change, e.g. elevated CO_2 and global warming, have effects on the quantum yield of C_3 and C_4 photosynthesis, changing the composition of grasslands (Lattazani 2010) and leading to increased plant productivity (Soussana & Luscher 2007). Human use of grasslands, e.g. by overgrazing, afforestation, agricultural has also modified grasslands throughout the world by causing changes not only in species composition, but also in ecosystem functioning (Koch et al. 2016, Leidinger et al. 2017). To be able to face the challenges of reconciling environmental changes with the sustainable use of grasslands, it is important to analyze how environmental drivers influence the main vegetation types and diversity of communities e.g. (Rodriguez-Rojo et al. 2017, Gárcia-Madrid et al. 2016, Fischer et al. 2014).

South Brazilian Grasslands (SBG) found in a transitional area from subtropical to tropical clime, belong to two different phytogeographic provinces: the Pampean and the Paraná province (Cabrera & Willink 1980), this separation also reflects on plant species composition in grasslands of the region (Bonilha et al. submitted). Taken together, these grasslands span from 25°S to 33°S latitude, and 49°O to 53°O longitude, covering about 576.774,31 km^2. While they are dominant vegetation type in the southern part of the region, they form enclaves of grasslands in a region increasingly dominated by forests in the northern part, where forests have been expanding over grasslands in the past 5.000 years (Behling 2002). This large grassland region not only includes climatic gradients, but also a considerable heterogeneous topography and distinct geological substrates. In the northern half of the region, in the Highland regions of Rio Grande do Sul, Santa Catarina and Paraná state, the grasslands formations are located on the South-Brazilian Plateau (IBGE 2004), with the highest peaks above 1.900 m, characterized by soils of low fertility mostly derived from basalt. The low southeastern mountains are granitic hills with an altitude of up to 450 m, of soft relief, with less resistance to weathering than the rocks on the plateau. The central depression, situated between the Plateau and the southeastern mountains is a sedimentary basin with diverse sedimentary rocks, altitude ranges from 30 to 100 meters. The coastal region, geologically ~~it is~~ the youngest part of the SBG, formed by unconsolidated sediments, where sandy soils predominate and altitude does not exceed 30 meters (Boldrini 1997, Streck et al. 2008, Boldrini 2009, Hasenack et al. 2010 unpubl).

While a number of studies have assessed the role of different environmental drivers on a local or sometimes regional scale (e.g. Setubal & Boldrini 2012, Menezes et al. 2016, Silva Filho et al. 2017), no more general analyses have been conducted so far. For the south

Brazilian coastal region Menezes et al. (2016) found that climate was responsible for most of the variation, while edaphic filters did not exercise much influence on plant community assembly at a broad scale. For grasslands in Uruguay, just to the south, Lezama et al. (2006) showed that edaphic and geomorphological factors are determinant of floristic gradients.

Here, we aimed to quantify the relative role of spatial and environmental drivers for composition patterns of South Brazilian grasslands. Further, we aimed to determine whether climatic or edaphic variables had higher relevance for grassland structure. Since Highland and Pampa grasslands, i.e. the grasslands situated in two adjacent phytogeographic provinces, have pronounced differences in species richness, composition and vegetation structure, we expected that climatic variables should have a high relevance for shaping vegetation patterns, but that the largest part of the climatic variation should be shared with space. We also analyzed the two regions separately, and here expected to find a higher contribution of edaphic features for the Pampa, with its high heterogeneity regarding geological and soil conditions, and higher relevance of climatic features along the latitudinal gradient in the Highland region.

Material and Methods

1.1.Sampling design

We carried out a vegetation survey spanning the grassland region in the Brazilian states of Rio Grande do Sul, Santa Catarina and Paraná (Figure 1). We adopted a stratified, nested sampling design; with strata defined by geomorphology features ~~see~~ (Andrade et al., 2015). Each stratum was then divided in Thiessen polygons, resulting in polygons of approximately 86.7 km^2. Within each of these second level strata, we randomly selected a number of polygons roughly proportional to the extent of each regional grassland type. In each selected polygon, we delimited and used for the survey one 2 km x 2 km Sampling Unit (SU). Each SU was composed of three Sample Plots (SPs) (70 m x 70 m). These SPs were located in a way to represent topographic variations of the respective landscape. To sample grassland vegetation at each SP, we systematically allocated nine quadrants of 1m² each. In this way, 85 sample plots were surveyed in the Pampa grasslands in the state of Rio Grande do Sul, and 66 sample plots in Highland grassland enclaves within the Atlantic Forest biome in the states of Rio Grande do Sul, Santa Catarina and Paraná.

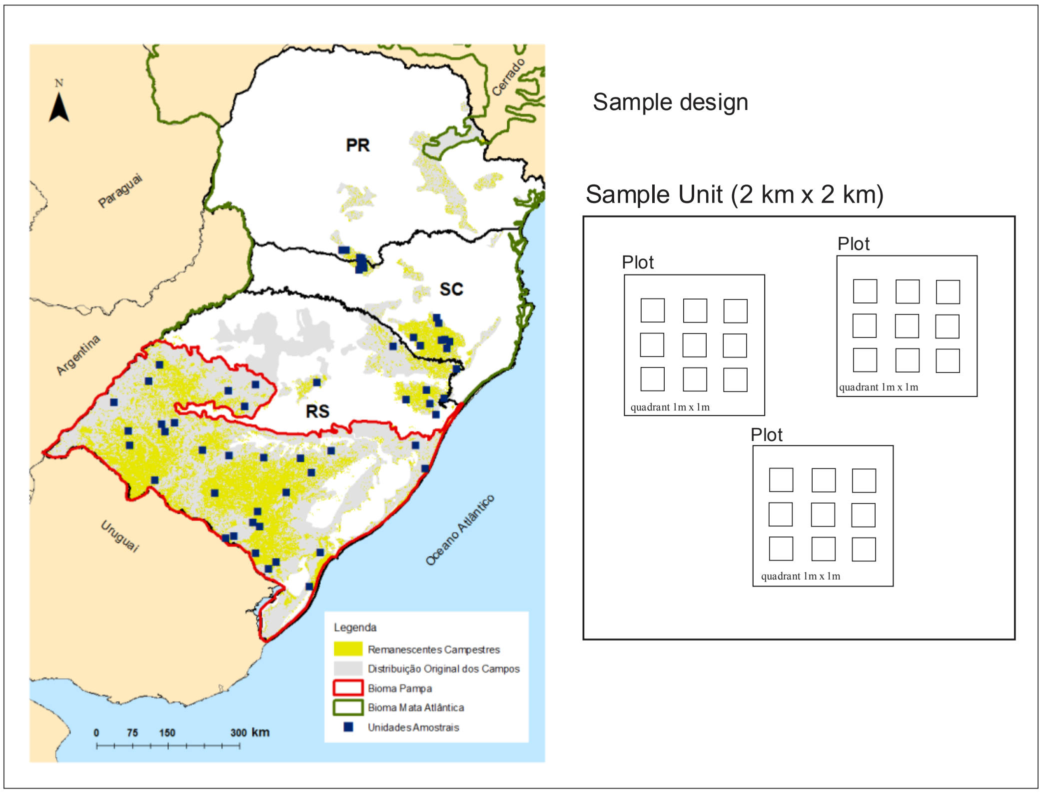

Figure 1. Map of distribution of 56 Sample Units in the South Brazilian grassland region and illustration of the sampling design of this study.

Vegetation data

In each quadrant we recorded all vascular plant species found and estimated their cover using a decimal scale similar to Londo's (1976) (i.e. a scale estimating plant cover in 10% intervals, with the first interval being divided into three subclasses: <1%, 1-5%, 5-10%). Plant family classification followed APG IV (2016) for angiosperms. For the results of vegetation survey see Bonilha et al. submitted. For each SU, we calculated the average cover of species of nine quadrants.

1.3 Environmental data

The geographical coordinates were recorded form each sample plot. We used Principal Coordinates of Neighboring Matrices (PCNMs) to obtain the geographic distances between the given coordinates (Borcard *et al*. 2011).

For climatic data, we used the raster databases available at the National Institute of Meteorology (INMET, www.inmet.gov.br) which is based on data from 61 meteorological stations (1961-1990). Data was interpolated and converted into maps using Quantum GIS (QGIS Development Team, 2015). We selected 15 climatic variables, mostly those representing the extreme conditions (Table 1). For soil data, we collected, per sample plot, three composite soils samples of the first 10 cm, which were then analyzed for chemical properties according to standard methods from Embrapa (1997). The variable altitude was also used.

Table 1. Environmental variables (climatic and edaphic) used as predictors of plant community in Southern Brazilian Grasslands.

Climatic Variables	Edaphic variables
Temperature	**Soil physical**
Coldest month temperature (°C) Tmin	Clay (%)
Evaporation in the lowest precipitation month EvP	Soil Organic Matter (SOM)

Hottest month temperature (°C) Tmax	**Soil chemistry**
Month with maximum value of relative humidity of air (°C) Urmax	Calcium (Ca^{+2})
Thermal amplitude (°C) Trange	pH(H_2O)
Precipitation	Phosphorus (P) (mg dm^3)
Month with maximum accumulated precipitation (mm) Precmax	Potassium (K^+) (mg dm^3)
Month with minimum accumulated precipitation (mm) Precmin	
Precipitation in the month of greatest evaporation (mm) PE	**Relief**
Precipitation in the month of greatest wind intensity (mm) PvIV	Altitude
Precipitation on hottest month (mm) PT	
Precipitation on windiest month (mm) PvIv	
Range of precipitation (mm) Precrange	
Wind intensity in the month of lowest rainfall IVvP	

1.2.Data analysis

We analyzed the relationship between grasslands communities and environmental variables through Canonical Correspondence Analysis (CCA), calculated with the vegan package on the platform R (https://carn.r-project.org). Redundancy analyzes (RDA) were used to verify the fraction of explanation of the predictors variables on the distribution of vegetation in the Southern Brazilian Grasslands. Matrix of vegetation data were submitted to Hellinger's transformation and predictor variables were previously transformed by log (x + 1). The selection of the ~~best~~ set of variables that best explains the variation in vegetation data was perform by the *packfor forward* selection method (Dray et al. 2011). The selection of variables with the minimum of collinearity were performed by methods available in package vegan on the platform R (https://carn.r-project.org). We conducted CCA using the entire data set, i.e. all SUs and all species, and additionally conducted separate analyses for the subsets containing only the Pampa grassland and only the Highland grassland SUs and species.

Results

The CCA shows two groups along the first axis, clearly dividing Pampa and Highland grasslands sites. Both climatic and soil variables were associated with the first axis of the ordination. SUs in the Pampa grasslands were related to maximum and minimum temperature extremes, which was expected ~~since~~ due to the higher continentality of the region in comparison to the Highland grasslands. The positive relation to macronutrient content of soil and higher pH values indicates higher fertility of Pampa grasslands. Highland grasslands were associated with climatic variables related to precipitation, percentage of clay and altitude (see Appendix S1 for see scores of environmental variables). Three plots appeared as outliers from Highland grasslands along the second axis. Of these plots, situated at the extreme east of the Plateau in RS state, this sample plot was recorded in an environment with greater rarity under extremely humid conditions, and vegetation composition is distinct due to lack of grassland management. Other sample plots that are located in Highland grasslands were plotted together with Pampa grasslands, represent a transition between the two grasslands communities. General values for the Highland grasslands of higher SOM, lower temperature variation and higher humidity, highest soil fertility and extremes of temperature in Pampa grasslands were observed in Table 2.

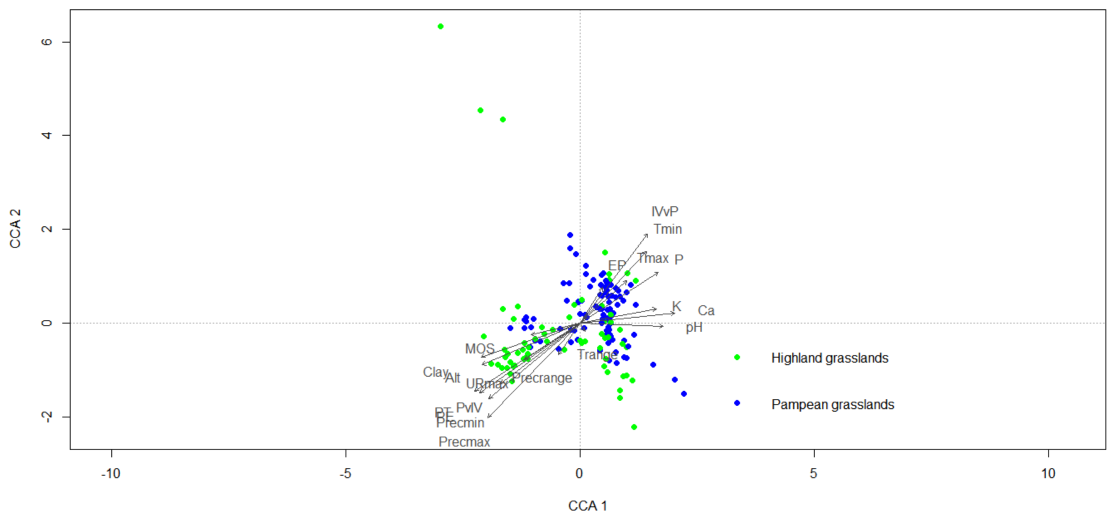

Figure 2. Canonical Correlation Analysis (CCA) of the 167 sample plots from South Brazilian Grassands, which are classified by environmental variables (6 edaphic variables and 12 climatic variables). Axes 1 and 2 respresent 31% and 25% of the variation in the data, respectively.

When we considered only the Pampa grasslands, explanation of the first two CCA axes was higher than for the overall patterns for SBG. The first axis represents longitudinal variation, the lower scores of the first axis of CCA was associated with the coastal region, as expected related to environmental variables of high precipitation and humidity. On the opposite side, sites of the central western plateau were associated with high macronutrient content and percentage of clay, due to soils of basaltic origin. The second axis separated the southwestern region from the southeastern mountains, corresponding to an altitude gradient. The southwestern region was associated with environmental variables related to temperature indicating the effect of continentally. Again, there were three outliers: SUs situated in a region with fragile, sandy soils, and a specific flora (Freitas et al. 2009). Overall the mean values of macronutrients were higher for the southern plateau.

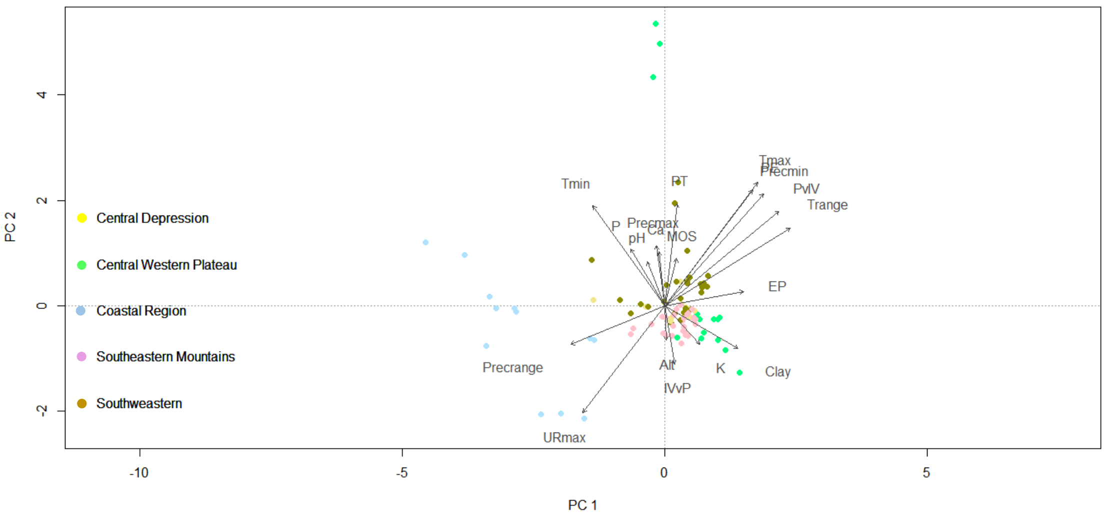

Figure 3. Canonical Correlation Analysis (CCA) of the 85 sample plots from Pampa grasslands (South Brazilian Grassands), which are classified by environmental variables (6 edaphic variables and 12 climatic variables). Axes 1 and 2 respresent 42% and 35% of the variation in the data, respectively. The sample units represent regional geomorphology.

For the Highland grasslands, plots farther in the southern plateau were positively related to a higher range of precipitation (Prec range), coldest month temperature (Tmin) and the macronutrients Potassium (K^+), Phosphorus (P). The Palmas Plateau was related to minimum accumulated precipitation (Prec min), coldest month temperature (Tmin) and thermal amplitude (Trange). The distribution of the grasslands reflects a latitudinal gradient, besides the influence of altitude, which increases from south to north.

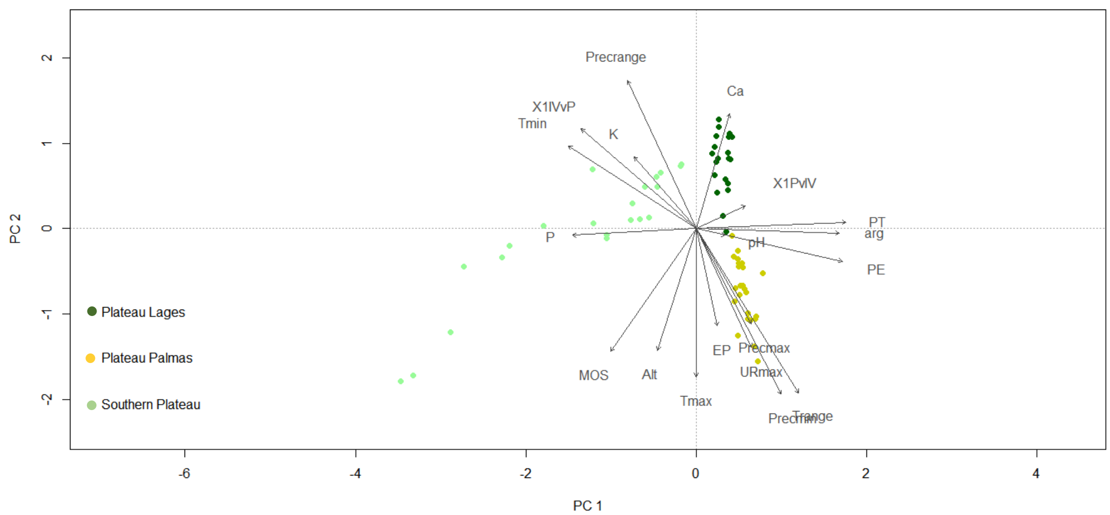

Figure 4. Canonical correlation analysis (CCA) of the 66 lansdcape sample units from Highlands grasslands (South Brazilian Grassands), which are classified by environmental variables (6 edaphic variables and 12 climatic variables). Axes 1 and 2 respresent 43% and 35% of the variation in the data, respectively. The sample units represent regional geomorphology.

In the RDA analysis for the entire data set, forward selection identified five edaphic variables with a significant contribution: percentage of clay, pH, Potassium (K^+), Phosphorus (P), soil organic matter (SOM) and altitude. Of twelve climatic variables previously selected, four were excluded after the collinearity test: Tmax, Precrange, PT, PE. For Pampa grasslands RDA forward selection procedure identified percentage of clay, pH, Potassium (K^+), Calcium (Ca^{+2}) and altitude. Of the climatic variables, again four were excluded by collinearity test: Trange, Precmin, PE and Premax. Highland grasslands RDA forward selection procedure identified percentage of clay, Potassium (K^+). Phosphorus (P), soil organic matter (SOM), pH (H_2O) and height. The climatic variables were excluded by collinearity test were Trange, Tmax, Precrange, Precmin and IVvP.

In the variation partitioning of species composition data in South Brazilian Grasslands, soil variables explained a small proportion of variation of vegetation while the effect of climatic variables was slightly higher, and the ~~special~~ spatial variables were the most important component. The major parts of explanation by climate and soil were structured in space. For the Pampa grasslands, the overall pattern was similar, but with a higher percentage of explanation by climatic variables and a very small contribution of climate and soil structured in space. In the Highland region, the individual contribution of space lost some importance, but soil and climate structured in space had the highest contribution in explaining vegetation patterns. In all three RDA procedures, the individual contributions of soil and climate variables and the combination of soil, climate and space where highly significant (see Appendix S1).

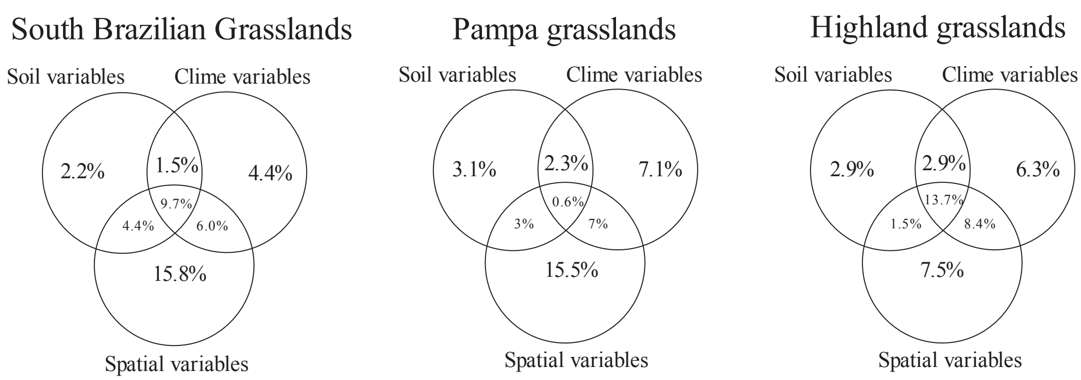

Figure 5. Venn diagram showing the fraction of exclusive and shared explanation of soil, climate and spatial variables in the explanation of the variation of the South Brazilian Grasslands.

Discussion

A previous study (Bonilha et al. submitted) had already indicated that grasslands in the two distinct phytogeographic provinces that together constitute the *Campos Sulinos* grasslands are floristically distinct. This study used the same vegetation data set but explored for the first time the drivers behind these patterns. In the overall analysis, higher precipitation and higher soil organic matter content appear as principal variables that separate sites in the Highland region from the Pampa region. Sites in the Pampa were related to higher temperature and more fertile, less acidic soils (Figure 2). As expected, climate was an important driver for compositional patterns, with an important contribution of spatial structuring as well.

For Pampa grasslands, chemical soil features had a surprisingly small influence on vegetation patterns, as evidenced by the results of the RDA. The influence of climate was almost twice as high, but still lower than that of spatial variables that acted by themselves or together with climatic variables. Accordingly, the CCA reflected principal geomorphological differences of the region, but did not distinguish the different geomorphological regions of the Pampa: the grasslands from the coastal region, on recent quaternary sediments, were separated from the other regions along the first CCA axis, while the other regions did not separate themselves that clearly (Figure 3). Sites on the central western plateau were related to deep soils varying from low to high fertility and presented high percentage of clay, due to basaltic origin. The southwestern region, on basaltic substrate, was related to high content of macronutrients and some climatic variables. The basaltic layer decreases from the southwest direction, until sandstone outcrops appear, which contributes to the heterogeneity of grasslands in this region (Streck et al. 2008). Overall, high relevance of variables related to precipitation and air humidity may also indicate that the potential to retain water could be more important for vegetation patterns than soil fertility itself. For the basaltic grasslands in

Uruguay, environmental variables such as soil depth and texture, i.e. factors that control the availability of water, were associated with floristic gradients by Lezama et al. (2006).

For the Highland grasslands, a clear gradient of plots in South-North direction appears along the first axis (Figure 4). Almeida (2009) suggests that soil characteristics of low percentage of macronutrients and high percentage of organic matter are associated with climatic variables, since the cold and humid climate induces the accumulation of soil organic matter while facilitating the leaching process of nutrients.

In general, considering the SBG and phytogeographic units separately, the percentage of explanation of environmental variables was small. Menezes et al. (2016) recorded 11% environmental explication by assembly grasslands on coastal region. Obviously, not only climatic and edaphic variables shape current vegetation patterns. For our study region, the importance of different management practices – or even historic management practices – has been previously recognized (Overbeck et al. 2007). In our study, the large majority of study sites were in private areas with intermediate grazing intensity, but it was not possible to control for this. One important issue related to management needs discussion, in the Highland grasslands, fire has historically been an relevant component of grassland management, in contrast to the Pampa region (Boldrini 1997, Overbeck et al. 2018). The use of fire itself is a consequence of the distinct climatic conditions that influenced vegetation patterns: higher humidity in the region leads to biomass accumulation during the warmer period of the year, and fires are used to remove dry standing biomass at the end of the winter, thus allowing for regrowth of the dominant grasses. It is well known that the regular use of fire will select for different species than those typical for areas only with grazing, especially regarding the dominant growth form of grasses, but also, for instance the relation of C_3 and C_4 grasses (Overbeck & Pfadenhauer 2006).

Overall our results agree with phytogeographic patterns recorded by Cabrera & Willink (1980), providing a more detailed approach to environmental variables in South Brazilian Grasslands. The Highland grasslands have a distribution pattern limited by the Southern Brazilian Plateau, due to altitudinal zonation and latitudinal situation. The altitude influences climatic conditions which in turn affect edaphic characteristics. While Pampa grasslands due to their geological heterogeneity, with altitudes from sea level up to 450 m, present greater thermal amplitude, this was attributed to continentality effects.

Although the exploratory analyses showed separation of grasslands communities in SBG corresponding to the floristic patterns already registered, and environmental characteristics of the southern Brazilian Plateau were related to this separation, percentage of explanation of soil and climate variables recorded by RDA was small. Our results indicated the need to include variables such as fragmentation, grazing, and different management strategies in Pampa and Highland grasslands for clearer patterns. For Pampa grasslands, a more refined scale sampling from soil variables may help to clarify the relationship between plant communities and geomorphological heterogeneity.

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Supporting information to the paper Bonilha et al. 2018. Environmental descriptors that determine the grassland species abundance on South Brazilian Grasslands.

Appendix S1.

Scores for constraining variables, in Canonical Correlation Analysis (CCA) from South Brazilian Grasslands, Pampa and Highlands grasslands. Legend: Precmax: month with maximum accumulated precipitation, Precmin: month with minimum accumulated precipitation, PE: precipitation in the month of greatest evaporation; PT: precipitation on hottest month, PvIv: precipitation on windiest month, Alt: altitude, Urmax: month with maximum value of relative humidity of air, Precrange: range of precipitation, SOM: soil organic matter; Trange: thermal amplitude, EvP: evaporation in the lowest precipitation month; Tmax: hottest month temperature, Tmin: coldest month temperature; IVvP Wind intensity in the month of lowest rainfall.

Southern Brazilian Grasslands	Axis 1	Axis 2
Precmax	-0.5119	-0.4613
Precmin	-0.4986	-0.3602
PE	-0.546	-0.3264
PT	-0.571	-0.3164
PvIv	-0.434	-0.2874
Alt	-0.5217	-0.1854
URmax	-0.3027	-0.1692
Precrange	-0.1208	-0.1581
Clay	-0.5232	-0.147
SOM	-0.2556	-0.0505
Trange	0.0283	-0.0418
pH	0.4376	-0.0255
Ca	0.4978	0.0348
K	0.4022	0.05618
EP	0.1274	0.17868
Tmax	0.2592	0.20395
P	0.4263	0.23806
Tmin	0.3691	0.35047
IVvP	0.3786	0.44562
Pampa Grasslands	**CCA1**	**CCA2**
URmax	-0.4049	-0.448
IVvP	0.04557	-0.2567

Clay	0.33886	-0.1638
K	0.16925	-0.1567
Precrange	-0.4276	-0.1555
Alt	0.00634	-0.1528
EP	0.35437	0.06039
pH	-0.0871	0.18888
MOS	0.06435	0.20738
Ca	-0.0262	0.23718
P	-0.166	0.24019
Precmax	-0.0396	0.26501
Trange	0.58341	0.31489
PvIV	0.54117	0.38744
Tmin	-0.3493	0.41537
PT	0.07148	0.45099
Precmin	0.48094	0.46602
PE	0.43435	0.48595
Tmax	0.45841	0.51755
Highland grasslands	CCA1	CCA2
Clay	0.67413	0.04246
pH	0.01147	-0.1524
P	-0.6324	-0.2755
K	-0.4343	-0.0743
MOS	-0.4111	-0.619

Alt	-0.1571	-0.3914
Ca	-0.0137	0.433
Trange	0.5405	-0.4711
Precmax	0.32328	-0.4722
Precrange	-0.5238	0.2908
Precmin	0.57853	-0.5145
IVvP	-0.4489	0.13814
PvIV	0.10953	-0.0274
PT	0.66562	0.24833
EP	0.26805	-0.4243
PE	0.47931	-0.023
URmax	0.43535	-0.2428
Tmin	-0.5655	0.04512
Tmax	0.05189	-0.6846

Appendix S2.

Results of the redundancy analysis (RDA) and partial RDA for South Brazilian Grasslands.

South Brazilian Grasslands		**Df**	**Variance**	**F**	**P**
veg + soil	a + b	6	0.14611	6.8235	0.001
veg + clime	b + c	8	0.17875	6.5655	0.001

veg + spatial	b + d	25	0.32166	4.6244	0.001
veg + soil + clime + spatial	a + b + c + d	39	0.40375	4.2578	0.001

Pampa grasslands					
veg + soil	a + b	5	0.07979	2.8909	0.001
veg + clime	b + c	8	0.13954	3.4683	0.001
veg + spatial	b + d	13	0.20989	3.6004	0.001
veg + soil + clime + spatial	a + b + c + d	26	0.32142	3.3196	0.001

Highland grasslands					
veg + soil	a + b	6	0.19039	3.8715	0.001
veg + clime	b + c	7	0.26094	5.2345	0.001
veg + spatial	b + d	9	0.27358	4.2514	0.001
veg + soil + clime + spatial	a + b + c + d	22	0.42056	3.2437	0.001

Appendix S3.

Código	**Nome**	**Latitude**	**Longitude**
83783	Campo Mourão	24°03'S	52°22'W

83813	Castro	24°47'S	50°00'W
83842	Curitiba	25°26'S	49°16'W
83826	Foz do lguaçu	25°33'S	54°34'W
83775	Guaíra	24°05'S	54°15'W
83834	Guarapuava	25°24'S	51°28'W
83836	Irati	25°28'S	50°38'W
83811	Ivaí	25°00'S	50°51'W
83769	Jacarezinho	23°09'S	49°58'W
83766	Londrina	23°19'S	51°08'W
83767	Maringá	23°24'S	51°55'W
83860	Palmas	26°29'S	51°59'W
83844	Paranaguá	25°32'S	48°31'W
83837	Ponta Grossa	25°06'S	50°10'W
83867	Rio Negro	26°06'S	49°48'W
83025	São Mateus do Sul	25°52'S	50°23'W
83828	Toledo	24°24'S	53°44'W
83931	Alegrete	29°41'S	55°31'W
83980	Bagé	31°20'S	54°06'W
83941	Bento Gonçalves	29°09'S	51°31'W
83919	Bom Jesus	28°40'S	50°26'W
83959	Caçapava do Sul	30°31'S	53°29'W
83963	Cachoeira do Sul	30°02'S	52°53'W
83942	Caxias do Sul	29°10'S	51°12'W

83912	Cruz Alta	28°38'S	53°36'W
83964	Encruzilhada do Sul	30°32'S	52°31'W
83915	Guaporé	28°55'S	51°54'W
83881	Iraí	27°11'S	53°14'W
83929	Itaqui	29°07'S	56°32'W
83916	Lagoa Vermelha	28°13'S	51°30'W
83885	Marcelino Ramos	27°27'S	51°54'W
83880	Palmeira das Missões	27°53'S	53°26'W
83914	Passo Fundo	28°13'S	52°24'W
83985	Pelotas	31°47'S	52°25'W
83967	Porto Alegre	30°03'S	51°10'W
83995	Rio Grande	32°02'S	52°06'W
83936	Santa Maria	29°42'S	53°42'W
83997	Santa Vitória do Palmar	33°31'S	53°21'W
83953	Santana do Livramento	30°50'S	55°36'W
83909	Santo Ângelo	28°18'S	54°15'W
83957	São Gabriel	30°20'S	54°19'W
83907	São Luiz Gonzaga	28°24'S	55°01'W
83966	Tapes	30°50'S	51°35'W
83948	Torres	29°21'S	49°43'W
83927	Uruguaiana	29°45'S	57°05'W

83918	Vacaria	28°33'S	50°42'W
83921	Araranguá	28°53'S	49°31'W
83898	Camboriú	27°00'S	48°38'W
83887	Campos Novos	27°23'S	51°12'W
83883	Chapecó	27°07'S	52°37'W
83897	Florianópolis	27°35'S	48°34'W
83872	Indaial	26°54'S	49°13'W
83865	Irineópolis	26°15'S	50°48'W
83891	Lages	27°49'S	50°20'W
83924	Laguna	28°29'S	48°48'W
83922	Orleans	28°20'S	49°20'W
83864	Porto União	26°14'S	51°04'W
83874	São Francisco do Sul	26°15'S	48°39'W
83920	São Joaquim	28°18'S	49°56'W
83923	Urussanga	28°31'S	49°19'W
83858	Xanxerê	26°51'S	52°24'W

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Considerações finais

Os campos do sul do Brasil são diversos, com mais de 2000 espécies descritas apresentam muitas formações vegetais devido à grande variabilidade de aspectos geomorfológicos. A produção de pesquisas relacionadas aos campos ganha cada vez mais importância diante do desafio de vincular a conservação desses ecossistemas ao uso sustentável. Neste contexto a rede SISBIOTA, possibilitou pela primeira vez que levantamentos quantitativos e qualitativos em escala regional fossem realizados na região sul do Brasil. Em um contexto de pesquisa dos ecossistemas campestres tão amplo e complexo, este trabalho pretende contribuir de forma pontual com descrição da padrões florísticos gerais e variáveis ambientais para dos campos do sul do Brasil. Os Campos Sulinos compartilham características que justificam sua denominação, porém apresentam diferentes padrões em relação a composição e diversidade de espécies, que podem em parte ser explicados através da influência de variáveis ambientais.