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Gabriela da Cunha Souza

DETERMINANTES DA DIVERSIDADE VEGETAL EM BUTIAZAL NA PLANÍCIE COSTEIRA DO RIO GRANDE DO SUL

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Orientador: Prof. Dr. João André Jarenkow

Coorientador: Prof. Dr. Juliano Morales de Oliveira

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Resumo

Ecossistemas campestres interagem positivamente com distúrbios, podendo culminar com o aumento da diversidade e garantir a heterogeneidade ambiental. Em áreas do bioma Pampa, no sul do Brasil, encontra-se um ecossistema dominado por palmeiras do gênero *Butia*, formando os butiazais. Estas áreas estão em risco de extinção devido à conversão para a agricultura, sendo tradicionalmente usadas como pastagens para a criação de gado. O desenvolvimento de um manejo sustentável se constitui em alternativa para a sua manutenção, levando-se em conta a carga animal e as condições de microhabitats encontradas entre aglomerados da palmeira, que se apresentam com densidades distintas. Nesse contexto, o objetivo do estudo foi avaliar como as características do ecossistema butiazal e o manejo pecuário se relacionam com a comunidade vegetal, para garantir a manutenção de suas comunidades. O estudo foi realizado em um remanescente de butiazal de *Butia odorata* (Barb. Rodr.) Noblick com 650 ha, na Planície Costeira do Rio Grande do Sul (Brasil), onde se desenvolve a pecuária de corte. No local, foram realizados levantamentos de composição e cobertura da vegetação em três áreas com distintas densidades de palmeiras adultas, além da amostragem da carga fecal para estimar o uso pelo gado, análise granulométrica e de nutrientes do solo e abertura de dossel. As espécies amostradas foram analisadas de acordo com a composição de formas de crescimento, riqueza de espécies nativas e pela qualidade forrageira por meio da Análise de Caminhos, afim de testar os modelos causais que englobam todas as relações lógicas possíveis entre a vegetação e as variáveis amostradas. Verificamos que o uso pelo gado influencia diretamente a estrutura da vegetação e, por meio de características do solo, também a riqueza de nativas e a cobertura de forrageiras. Já a densidade de palmeiras influencia de forma direta a cobertura de espécies impalatáveis e de forma indireta, pela abertura do dossel, a estrutura, a riqueza de nativas e a cobertura de impalatáveis. Estes resultados podem embasar uma continuidade nos esforços para a adequação da carga animal em escala espacial, considerando as diferentes densidades de butiazeiros, e em escala temporal através do manejo conservativo da carga animal, garantindo a manutenção dos aspectos econômicos e ecológicos.

Palavras-chave: ecossistema campestre, distúrbios, atividade sustentável, análise de caminhos, manutenção de serviços ecossistêmicos, geração de renda.

Abstract

Grasslands ecosystems interact positively with disturbances, which can culminate in an increase in diversity and guarantee environmental heterogeneity. In areas of the Pampa biome, in southern Brazil, there is an ecosystem dominated by palm trees of the genus *Butia*, known as butiazais. These areas are at risk of extinction due to conversion to agriculture, being that traditionally been used for livestock. The development of sustainable management is an alternative for its maintenance, taking into account the animal load and microhabitat conditions found among palm clusters, which present different densities. In this context, the objective of the study was to evaluate how the characteristics of the butiazal ecosystem and livestock management relate to the plant community, to ensure the maintenance of their communities. The study was carried out on a butiazal remnant of *Butia odorata* (Barb. Rodr.) Noblick with 650 ha, in the Coastal Plain of Rio Grande do Sul (Brazil), where beef cattle is developed. On site, surveys were made of composition and vegetation cover in three areas with different densities of adult palms, in addition to sampling the fecal load to estimate livestock use, granulometric and nutrient analysis of the soil and canopy opening. The sampled species were analyzed according to the composition of growth forms, richness of native species and forage quality through Path Analysis, in order to test the causal models that encompass all possible logical relationships between the vegetation and the sampled variables. We found that cattle use directly influences the vegetation structure and, through soil characteristics, also the richness of native species and the coverage of forages. The palm trees density directly influences the unpalatable cover and indirectly, through the tree layer opening, the structure, the native species richness and the cover of unpalatable species. These results can support the continuity in efforts to adapt the animal load on a spatial scale, considering the different densities of palm trees, and on a temporal scale through the conservative and rotative management of the animal load, guaranteeing the maintenance of economic and ecological aspects.

Keywords: grassland ecosystems, disturbances, sustainable activity, path analysis, maintenance of ecosystem services, income generation.

Sumário

Introdução Geral

As formações campestres ocorrem em todos os continentes e ocupam cerca de 26% da superfície da Terra (RAMANKUTTY et al., 2008). Essas formações possuem um longo histórico de uso antrópico, que acarretou modificações em suas coberturas devido à perda de habitat para a agricultura e por superexploração (MAXWELL et al., 2016). Projeções indicam que apenas 7,6% da área original se encontra protegida; portanto, a IUCN, junto à Comissão Mundial de Áreas Protegidas, estão buscando conscientizar o público e organizar políticas para proteger as pastagens naturais (IUCN-WCPA, 2000).

A grande dificuldade para manterem-se áreas campestres protegidas, está no aumento da população mundial, prevista para atingir 9,7 bilhões até 2050 (ONU, 2019). Com o aumento populacional e o desenvolvimento de tecnologias, prevê-se uma maior demanda por alimentos, principalmente os processados e preparados com alto teor de proteína animal e lácteos, aumentando a por aqueles produzidos em campos (OCDE/FAO, 2015). Esse aumento levará a uma degradação desses ecossistemas, e ao ser relacionado com questões políticas e sociais, que não consideram a necessidade de conservação ambiental, encaminha-os à extinção (O'MARA, 2012).

De acordo com Ramankutty et al. (2008), 20% das pastagens nativas foram convertidas em cultivos no mundo, pelo fato de serem áreas propícias para a agricultura. A atual expansão urbana sobre essas áreas tem deslocado a fronteira agrícola para as áreas marginais e de baixa qualidade (BURINGH & DUBAL, 1987; RAMANKUTTY et al., 2002; O'MARA, 2012). Tal tendência configura um risco potencial de colapso na produtividade, sendo preciso avaliar quais as melhores áreas remanescentes, com o objetivo de preservá-las (RAMANKUTTY et al. 2002). Pesquisas avançam no conhecimento de como manter os campos simultaneamente ao desenvolvimento de atividades sustentáveis, como por exemplo, a pecuária, conciliando sua manutenção e a geração de produtos, caso sejam consideradas as características ambientais e de biodiversidade do local e as formas de manejo que serão administradas (OLDEMAN, 1994; O'MARA, 2012).

Os biomas campestres e savânicos são moldados pelo clima e diferenciados entre si pelo conjunto de ecossistemas e grupos de espécies que evoluíram no local, e em pequena escala, respondem a fatores como relevo, solo, perturbação, idade e manejo (GIBSON, 2009). A interação desses fenômenos e processos que ocorrem nas pastagens também pode ser determinante na composição e estrutura das espécies, além das relações de competição, recrutamento e colonização (ALHAMAD & ALRABABAH, 2008). A dominância de espécies, por exemplo, pode se dar pela competição envolvendo fatores bióticos e abióticos (SCHIPPFERS & KROPFF, 2001; ALBERTI et al., 2017). Por outro lado, a maior diversidade de espécies pode se dar por facilitação, com melhoria das condições abióticas por uma espécie que auxiliará o estabelecimento e crescimento de outras ao seu redor, de forma que as interações positivas superem as negativas de competição por recursos (CHENG et al., 2006; LEIVA et al., 2015). Ainda, de acordo com pesquisas atuais (ARCHIBALD & HEMPSON, 2016; OVERBECK et al., 2018; FISCHER et al., 2019), eventos de distúrbio são os principais fatores que influenciam a estruturação da vegetação campestre, uma vez que redefinem a sucessão secundária, modificando propriedades fundamentais em diferentes escalas temporais e espaciais.

Ecossistemas campestres em diversas partes do mundo demonstram uma importante interação positiva com distúrbios como fogo e pastejo quando realizados de maneira sustentável, ao afetar a composição florística local, alterando a diversidade e a heterogeneidade (BRIGGS, et al., 2002; REITALU, et al., 2012; STEVENS et al., 2016; LANGAN et al., 2017). Estudos como o de Baldissera et al. (2010), verificaram que em áreas com pastagem submetidas à ação do fogo e de pastoreio em níveis intermediários, mantém uma alta diversidade local com heterogeneidade espacial (diversidades α e β), uma vez que não são tão frequentes e intensos para limitar a comunidade de plantas à presença de espécies extremamente tolerante a perturbações (oportunistas e ruderais) nem completamente ausente para resultar na predominância de poucas espécies dominantes de gramíneas.

A Hipótese de Distúrbio Intermediário (IDH) (CONNELL, 1978) prevê a possibilidade de coexistência de espécies devido a regimes intermediários de distúrbios. Essa hipótese já mostrou padrões consistentes em diferentes tipologias de vegetação (MOLINO & SEBATIER, 2001; GIEHL & JARENKOW, 2015; GBOGBO et al., 2017; LIU et al., 2019), entre eles as pastagens (YUAN et al., 2016). Entretanto, a frequência e a intensidade dos distúrbios podem ser afetadas dependendo da área, de acordo com a presença de fragmentos vegetacionais com diferentes idades, frequências, intensidades e tipos de distúrbios. Portanto, a história de vida do ecossistema, os distúrbios ocorrentes e suas interações, além de suas relações com fatores abióticos como clima, pode promover respostas diferenciadas, desde gerar uma extinção local em um caso extremo, quando o distúrbio for muito intenso (COLLINS et al., 1995), até acarretar um aumento da biodiversidade quando permite a sucessão e disponibiliza nichos antes ocupados (FISCHER et al., 2019).

Sendo assim, muitos fatores estão relacionados com a composição e estrutura da vegetação em diferentes ecossistemas, fazendo a biodiversidade variar espacialmente devido a suas diferentes histórias de vida (GIBSON, 2009). Para manter um ecossistema que está frequentemente sendo alvo de conversões no uso da terra é preciso ter conhecimento de como as interações estão se processando e como estão se inter-relacionando, de forma que possa conciliar desenvolvimento socioeconômico e ambiental, no caso destinar as pastagens para atividades que serão produtivas e que permitirão a manutenção de seus serviços ecossistêmicos.

O bioma Pampa, no sul do Brasil, com sua característica vegetação campestre biodiversa se desenvolveu durante no passado sob diferentes condições climáticas comparadas as atuais (BEHLING & PILLAR, 2007). Mais recentemente, de acordo com Overbeck et al. (2007) e Robinson et al. (2018), com o clima quente e úmido, há uma tendência a expansão das florestas, porém atividades de seleção de incêndios causadas por comunidades humanas primitivas e grandes pastadores da megafauna, impediram esse processo, garantindo a manutenção da fisionomia campestre.

Outra influência importante das civilizações antigas, foi a dispersão e distribuição de plantas de interesse para a comunidade, um bom exemplo já documentado é o da *Araucaria angustifolia* (ROBINSON et al. 2018), e acredita-se que o mesmo pode ter acontecido para as palmeiras do gênero *Butia* (Arecaceae) (SOSINSKI et al. 2019). Esses ecossistemas com palmeiras podem ser encontrados no Brasil, Argentina, Uruguai e Paraguai, co-ocorrendo em áreas de vegetação campestre, conseguindo se dispersar e colonizar de maneira eficaz algumas regiões, principalmente áreas com solos arenosos, com alta umidade e em relevos suavemente ondulados a planos (GEYMONAT & ROCHA, 2009). Este conjunto compõe uma fisionomia diferenciada, com áreas apresentando um estrato inferior dominado por espécies herbáceas e um estrato superior constituído por essas palmeiras (MARCHIORI, 2004), formando os butiazais. Essa conformação permite a ocorrência de um micro-habitat propenso ao desenvolvimento de diferentes espécies sob as copas interespaçadas dessas palmeiras, uma vez que as mesmas captam a radiação solar incidente e permitem a circulação do vento, limitando parcialmente o aquecimento do solo (ALVES & DEMATTÊ, 1987).

A diversidade vegetal encontrada nos butiazais abrange espécies pertencentes a pelo menos 80 famílias, onde se destacam principalmente poáceas, asteráceas, ciperáceas e fabáceas (RIVAS et al., 2014; MARCHI et al., 2018). Essa composição é típica dos campos, com a presença de espécies de grande potencial forrageiro, além do próprio butiazeiro dado o seu alto valor paisagístico, histórico-cultural e econômico (RIVAS et al., 2014).

Os butiazais são, portanto, uma das formações campestres com aspecto de savanas, que ocorrem no sul do Brasil e sofrem uma série de pressões antrópicas, sendo considerados em risco de extinção como áreas naturais (RIVAS & BARILANI, 2004), devido à expansão de áreas urbanas e da fronteira agrícola, além da remoção ilegal e comercialização de plantas, a implantação de silvicultura e o sobrepastoreio de gado (SOARES & WITECK, 2009). Na Planície Costeira do Rio Grande do Sul, entre os municípios de Tapes e Barra do Ribeiro, há um dos maiores remanescentes de butiazal no Estado, formado por *Butia odorata* (Barb. Rodr.) Noblick, situado em propriedades particulares onde predominam atividades de pecuária em área de butiazal, monocultura de arroz e soja, além da silvicultura de *Pinus* spp. e *Eucalyptus* spp. (BRASIL, 2007).

Essas atividades vêm gerando perda de área e danos à manutenção do butiazal na região e os proprietários demonstram preocupação para a conservação desses remanescentes e têm buscado auxílio para compreendê-los e mantê-los (BARBIERI et al., 2016). Segundo Phalan et al. (2011), o homem tem a capacidade de adaptar suas atividades em relação às mudanças necessárias para garantir a manutenção do ambiente, portanto, há uma forma de conciliar a atividade comercial local com a conservação. No caso do butiazal, são necessárias informações sobre o *pool* de espécies na formação, seu potencial e sua importância ecossistêmica, para entender e buscar as melhores estratégias visando garantir a conservação do ambiente, associado às perspectivas social e econômica da comunidade diretamente dependente na região (HAGEMANN, 2016).

A partir dos dados de Costa et al. (2017), que realizaram o mapeamento do butiazal e o caracterizaram de acordo com a densidade de indivíduos de palmeiras, foi possível verificar seus agrupamentos em uma propriedade particular na região. Estes reconheceram áreas com baixa densidade de butiazeiros, até agrupamentos em que é impossível comprovar por imagens de satélite quantos indivíduos há nos aglomerados, devido ao seu alto número.

A formação de microclimas diferenciados em um mesmo local decorre principalmente em função de variações na cobertura vegetal, que altera a intensidade de variáveis climáticas como radiação solar, temperatura e umidade do ar e do solo e vento (AUSSENAC, 2000). As diferentes densidades de butiazeiros também devem causar essas intervenções, permitindo o estabelecimento de diferentes espécies vegetais de acordo com as variações geradas com as interferências nos fatores abióticos locais. Contudo, como mencionado anteriormente, muitos fatores podem afetar ecossistemas campestres, como os distúrbios causados pelo pastejo do gado.

A pecuária, historicamente, é uma das principais atividades econômicas nos campos do sul do Brasil, e o pastejo decorrente é considerado o principal mantenedor de suas características e propriedades ecológicas (CRAWSHAW et al., 2007; OVERBECK et al., 2007). A utilização do manejo de pecuária como alternativa para a conservação das paisagens campestres é um caminho econômico e socioambiental promissor para o ecossistema (FISCHER et al., 2019; FERREIRA et al., 2020), neste caso, o butiazal.

A pressão de pastejo influencia ecossistemas campestres, quando em baixa intensidade, provocando a evolução do campo para um ecossistema florestal em condições onde o clima favorece o desenvolvimento desse tipo vegetacional (OVERBECK et al., 2007; VELDMAN et al., 2015; ABREU et al., 2017). Quando em alta intensidade, leva a um pastejo não seletivo e à substituição de espécies forrageiras por aquelas de menor qualidade, aumento das ruderais e à exposição do solo (ANDRADE et al., 2015; FEDRIGO et al., 2018). Ainda no caso do butiazal, há o impacto às populações de butiazeiros que perdem sua capacidade de regeneração pelo consumo de suas sementes e plântulas pelo gado (BARBIERI et al., 2016).

As influências do uso pelo gado e da densidade de butiazeiros sobre fatores abióticos locais e/ou diretamente sobre a diversidade vegetal no butiazal, pode afetá-los de acordo com a intensidade do distúrbio e as influências no micro-habitat. Portanto, avaliar esses fenômenos e suas interações sobre uma comunidade vegetacional previamente conhecida pode gerar uma gama de informações que auxilie na elaboração de uma prática de manejo economicamente viável e ambientalmente sustentável para áreas campestres com butiazal.

Justificativa

Considerando a preocupação com a perda gradual das áreas de ecossistema butiazal, que abriga alta biodiversidade, entre as quais espécies com potencial econômico, é necessário buscar informações sobre a importância do mesmo não apenas para a preservação de espécies, mas também para fornecer um fluxo sustentável de bens e serviços ecossistêmicos que atendam às necessidades dos proprietários para subsistência, e da fauna associada para a sobrevivência. Foi comprovado em estudos anteriores que, com um manejo adequado do gado, a regeneração dos butiazeiros é favorecida, permitindo a manutenção da população e de seus recursos fitogenéticos.

Assim, um estudo que leve em consideração as características de densidade de butiazeiros, fatores abióticos e carga animal é fundamental para entender e organizar uma produção de sistema forrageiro nativo sustentável e evitar a invasão de espécies arbóreas nativas e de exóticas, incentivando os proprietários em manter o butiazal e a biodiversidade associada através da atividade econômica.

Objetivos

Nesse contexto, o objetivo geral deste estudo é o de avaliar características do ecossistema butiazal encontrado na região, a composição da comunidade vegetal associada e suas relações com o manejo pecuário, a fim de encontrar subsídios para a manutenção desse ecossistema.

Objetivos específicos

- Determinar a composição vegetal encontrada sob as diferentes densidades de indivíduos adultos de *Butia odorata*;
- Avaliar a intensidade de uso pelo gado nas diferentes densidades de butiazeiros nos diferentes manejos;
- Verificar influência do sombreamento e umidade nas comunidades vegetais, sob butiazeiros nos diferentes manejos;
- Determinar e destacar potencialidades que o manejo pecuário adequado pode proporcionar para a população de butiazeiros e diversidade associada.

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CAPÍTULO 1

Determinants of plant diversity in *Butia* palm grove in Southern Brazil: implications for conservation[1]

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Determinants of plant diversity in *Butia* palm grove in Southern Brazil: implications for conservation

Gabriela Cunha-Souza[1], Juliano M. Oliveira[2] e João André Jarenkow[1]

[1]Department of Botany, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil
[2]Laboratory of Plant Ecology, Universidade do Vale do Rio dos Sinos, São Leopoldo, RS, Brazil

Correspondence: Gabriela da Cunha Souza, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil
E-mail: gabriela.cunha.souza@hotmail.com

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Abstract

Questions: To verify how grazing intensity and palm trees density influence the abiotic and biotic properties of *Butia* palm grove, in order to answer the following questions: (1) Does livestock intensity cause changes in species diversity and composition? (2) Do temperature and humidity associated to the palm trees density affect species diversity and composition? (3) How do the variables in question affect the *Butia* palm grove conditions for better livestock production?
Location: The municipality of Tapes, part of the Center-South region of the Internal Coastal Plain, in Rio Grande do Sul, Brazil.
Methods: Surveys of composition and vegetation cover were carried out in areas with different densities of adult palms, in addition to estimation of use by cattle, granulometric and nutrient analysis of the soil and opening of the tree layer. The sampled species were analyzed according to the composition of the growth forms,

richness of native species and forage quality through Path Analysis, aiming to test the causal models that cover the logical relationships between the vegetation and the sampled variables.

Results: We found that use by cattle directly influences the vegetation structure and, through soil characteristics, also the native species richness and the forages cover. The palm trees density directly influences the unpalatable cover and indirectly, through the canopy opening, the structure, the native species richness and the unpalatable cover.

Conclusion: These results can support a continuity in efforts to adapt the animal load on a spatial scale, considering the different densities of palm trees, and on a temporal scale through the conservative and rotative management of the animal load, guaranteeing the maintenance of economic and ecological aspects.

Keywords: biodiversity, Brazil, subtropical grasslands, disturbances, grazing, land management, land use, livestock husbandry, path analysis, sustainable activity.

Introduction

The most widespread use of world natural grasslands is livestock activity (Gibson, 2009), which can offer food in a sustainable way and a source of income (Milton et al., 2003; O'Mara, 2012). Cattle grazing prevents encroachment of woody plants and succession towards forest, a fact occuring in several regions worldwide (Staver et al., 2011; Archibald & Hempson, 2016). Thus, livestock activity allows the conservation of the ecological and physiognomic properties of grasslands (Overbeck et al., 2016; Buisson et al., 2018).

Population growth and the consequent demand for food have led to a gradual transformation of grasslands in areas for agriculture (Ramankutty et al., 2002; Gavier-Pizarro et al., 2012; O'Mara, 2012), where livestock has become a less influential activity (Bond & Parr 2010; Oliveira et al., 2017). Thus, the grassy ecosystems are the most converted and least preserved, with tropical and subtropical grasslands with 8.5% of protected areas and 23% of converted areas (Watson et al., 2016). This reality calls for measures by governments and actions by society to reduce conversion pressures on ecosystems, aiming to balance development and conservation (Dixon et al., 2014). The availability of information on a local scale about adequate grazing pressure conditions and their possible interactions with habitat productivity (Gaitán et al. 2017; Rota et al., 2017), needs to be increased. Thus, it will be possible to assess the current pasture conditions to define a management strategy capable of optimizing conservation and production aiming at sustainability (Monroe et al., 2016).

Livestock influences the distribution of plant species and their dominance patterns (McDonald et al., 2019). Grazing intensity works as an environmental filter, interfering in the community structure (Overbeck et al., 2016; Buisson et al., 2018; McDonald et al. 2019). Excessive grazing tends to select species of intense growth, fast area coverage and with wide geographical distribution, favoring those with hard and unpalatable leaves, which gives greater resilience and resistance to grazing disturbance (Baldissera et al., 2010; Buisson et al., 2018). On the other hand, at low intensity or grazing exclusion, species with other functional traits, such as woody ones, are favored, decreasing richness by competitive exclusion, a process triggered by an intense successional dynamic favored by global changes that tend to warming (Archibald & Hempson, 2016; Guido et al., 2017; Ferreira et al., 2020).

Among the non-forest ecosystems, our study model is a savanoid formation characterized by an herb layer dominated mainly by grasses and a sparse aggregated tree layer of a palm species, *Butia odorata* (Barb. Rodr.) Noblick, local named "butiazal" - *Butia* palm grove (Barbieri et al., 2016). The palm tree clusters are distributed in variable densities (Costa et al., 2017), affecting the local micro-habitat in a vertical gradient of light, temperature and humidity, which in turn would affect biological processes, like nutrient cycle and the vegetation structure (Rossatto et al., 2018; Chendev et al., 2019). These factors allow the development of a differentiated biota for the provision of a qualified range of services, as a grazing option for livestock, products for fauna and human society and scenic beauty for tourism (Sosinski et al., 2019).

Butia palm grooves has suffered a series of pressures that have led it to almost extinction, since many areas have been converted into crops or forestry systems (MMA, 2007). The remaining areas use livestock as a profitable activity, but extensive production is not allowing the regeneration of palm populations due to being run over and grazing seedlings, while in abandoned areas or with low grazing intensity they are undergoing a succession tending for forests (Sosinski et al., 2019). Locally, public policies are not very efficient in helping to conserve them, showing the little ecological importance attributed to them and the lack of supervision for their legal protection (Sosinski et al., 2019). Livestock in *Butia* palm grove areas, therefore, can prevent the rest of this ecosystem from being lost, serving as income generation and preventing succession. In the search for information on how to maintain *Butia* palm groves by using livestock, this study evaluated the richness of plant species, composition and abiotic factors associated with use by cattle in a butiazal remnant in the Coastal Plain in southern Brazil. The objective of the research was to verify how use by cattle and palm trees density influence the abiotic and biotic properties of butiazal, in order to answer the following questions: (1) Does the intensity of livestock cause changes in species diversity and composition? (2) Do abiotic variables related to the palm trees density affect species diversity and composition? (3) How do the variables in question affect the butiazal conditions for better livestock production?

Materials and methods

Study region

This study was carried out on a property in the municipality of Tapes (RS), in a remnant of butiazal of approximately 650 ha, formed by the species *Butia odorata* (Barb. Rodr.) Noblick¸ where beef cattle activities are carried out.

The municipality of Tapes (30°34'34"S and 51°30'50" W) has an average altitude of 100 m. The regional climate is humid subtropical type Cfa, according to the Köppen-Geiger climate classification, with well-distributed rainfall, with annual averages between 1,250 and 1,500 mm (Alvares et al., 2014). The municipality is part of the Center-South region of the Internal Coastal Plain in Rio Grande do Sul (Waechter, 1995).

The vegetation, in this part of the Coastal Plain, has a predominance of subtropical grasslands formations, conditioned by sandy soils poor in nutrients, high temperatures and light, and constant wind (Waechter 1995). In areas of typical butiazal, the tree layer is dominated by *Butia odorata*, with sporadic occurrences mainly of individuals of Myrtaceae species. In the herbaceous layer, Poaceae, Asteraceae, Fabaceae and Cyperaceae are the families that present the largest number of species (Marchi et al., 2018).

Sampling design

Through remote sensing and high-resolution images, Sosinski et al. (2015) defined patches of adult palms and mapped the density of individuals per hectare in the study area. Based on these images, eighteen 50 x 50 m plots (2,500 m²) were defined, six plots in areas with low density of adult palms (up to 50 ind./ha), six in areas with medium density (90-140 ind./ha) and six in areas with high density (above 200 ind./ha).

Vegetation survey

The tree layer had all individuals sampled with a diameter at breast height (DBH) greater than 10 cm in the 50 x 50 m plot; for the shrub layer, four subplots of 10 x 10 m were considered at each vertex of the plot, in which individuals with height from 1.5 m to DBH less than 10 cm were sampled; and for the herbaceous layer, two 0.5 x 0.5 m subplots were installed at each vertex of the 10 x 10 m ones (totaling eight subplots per 50 x 50 m plot). All sampled individuals were identified at the species level. For shrubs and trees, the DBH were measured and for herbaceous layer the coverage in a visual estimate (%), according to the Causton scale (Causton, 1988), was recorded. The average class coverage value subsequently was adopted in the quantitative analyzes.

Environmental predictors

As vegetation predictors, this study considered the density of adult palms, the use of the area by cattle, the tree layer opening and the physical and chemical composition of the soil, estimated on the scale of the 50 x 50 m plots. Palm density was given by the number of adult palms (DBH> 10 cm) recorded in the plot. The use of the area by cattle was estimated by the fecal mass of cattle present (Tate et al., 2003) in the 10 x 10 m subplots. In summer of 2019, the cattle feces found inside the subplots were collected, dried in an oven at 60 ºC, until reaching constant weight, when it was weighted.

Regarding the soil variables, a 20 cm depth sub-sample was collected in the four 10 x 10 m subplots, which were homogenized and analyzed of clay and organic matter contents, phosphorus and potassium concentrations, pH, cationic exchange capacity and basis saturation. To estimate the tree layer opening, hemispheric photographs were taken 1 m above the ground, with a Nikon Coolpix 5400 camera and Fisheye Nikon Converter FC-E9 x0.2 lens, at a right angle to the sky and facing magnetic North, in each 0.5 x 0.5 m subplot. The photographs were analyzed using the program Gap Light Analyzer, Version 2.0 (Frazer et al., 1999), obtaining the percentage of the tree layer opening, as used by Schnitzler & Closset (2003), the value was estimated average opening per 50 x 50 m plot.

Data analysis

The registered species were classified into families (APG IV, 2016), and also according to the growth form (Whittaker, 1975), the origin (native or exotic), and the forage importance (palatable or unpalatable to cattle, based on Santos et al. 2008, Castilhos et al., 2009, Nabinger et al., 2009 and Valls et al., 2009).

To perform a synthetic description of the variation in the functional composition of the vegetation, we carried out a Principal Coordinate Analysis based on Hellinger's distance matrix (Legendre & Gallagher, 2001) between plots, described by the coverage of the growth forms. Likewise, to summarize the description of the edaphic characteristics, we performed a Principal Component Analysis (PCA) based on the correlation matrix between variables.

We used Path Analysis (Shipley, 2000) to test different models of causal relationships between the abundance of palm trees (matrix *B*), use of cattle (matrix *G*), habitat structure (matrix *H*) and plant diversity (matrix *V*). Twenty models were considered, representing hypothetically valid relationships between these four matrices of variables (Fig. 1). The predictor matrices were represented by the adult palm trees density (matrix *B*), the fecal mass of cattle (matrix *G*), and the tree layer opening, and the scores of the first two axes of the soil PCA (matrix *H*). Matrix *V* was represented by different components of plant diversity: the composition of growth forms, represented by the scores of the first axis of vegetation PCoA; species richness, represented by the number of native species; and forage quality, represented by the total coverage of palatable species and species unpalatable to cattle. The influence of environmental predictors was evaluated for each of these components of plant diversity separately, totaling 60 causal models evaluated.

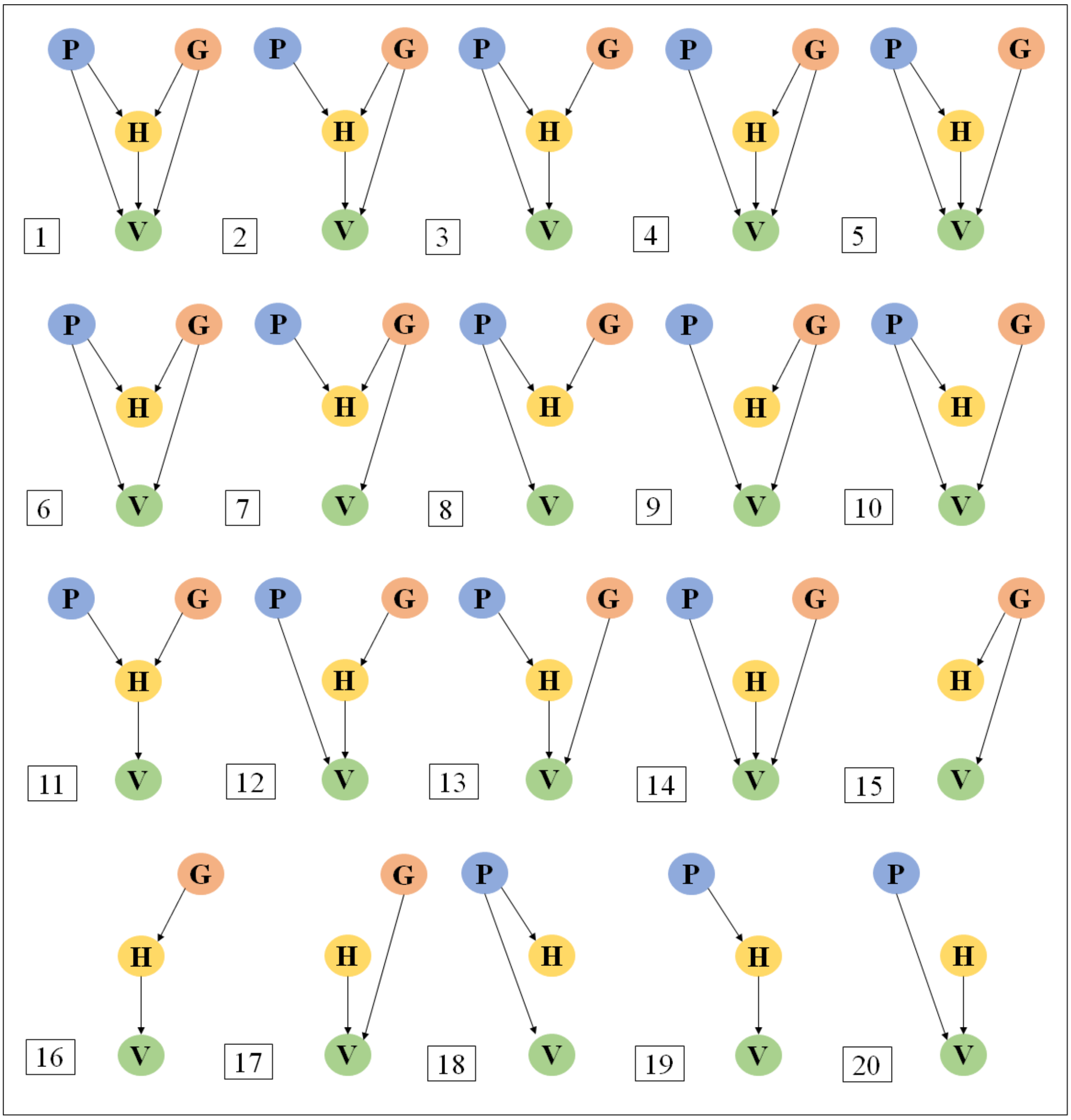

Figure 1. Theoretical causal models of direct and indirect relationships of environmental predictors on vegetation diversity in a study in a *Butia* palm grove in southern Brazil. "P" represents the abundance of palm trees, "G" is use by cattle, "H" is the habitat structure and "V" is the diversity of vegetation.

For each of the 60 models analyzed, the composite probability value (Fisher's C statistic) was calculated, according to which a valid causal model must have a probability value greater than the stipulated tolerance limit (alpha = 0.1) (Pillar et al., 2013). For the models considered valid, linear regressions were performed to determine the path coefficients and the corresponding probability found by permutation for each causal link, and a non-determination coefficient for each response variable (Manly, 2007). Among the valid models, we selected those that had significant path coefficients (alpha = 0.1), for all the causal links involved. When more than one model proved to be valid and with all significant path coefficients, we chose for interpretation the model that presented the largest number of common causal links, that is, causal links represented in most valid models.

Results

Ecological gradients

We sampled a total of 78 plant species for all vegetal components, belonging to 63 genera, from 25 families, the most representative of which are Asteraceae (18 species), Poaceae (13 species), Fabaceae and Rubiaceae with five species each. The species with the greatest coverage in the survey of the herbaceous component were, respectively, *Urochloa decumbens* (5,180 m²/ha), *Aristida laevis* (3,950 m²/ha), *Eryngium horridum* (3,164 m²/ha), *Schyzachyrium tenerum* (2,808 m²/ha) and *Centella asiatica* (2.545 m²/ha). For the shrub component were *Opuntia monacantha* (2.177 m²/ha) and *Varronia curassavica* (1.917 m²/ha), and for the tree component were *Eugenia hiemalis* (1.533 m²/ha) and *Eugenia brevistyla* (933 m²/ha) (a list of taxa and their characteristic are provided in S1 Table).

PCoA revealed in first axis a strong gradient (60% of the total variation) in composition of growth forms, where negative scores corresponded to plots with a high abundance of herbaceous or shrub plants, and positive scores to plots with a high abundance of woody plants (Figure 2A). As for the native species richness, coverage of palatable species and coverage of unpalatable species, the expected values (medians) were 13.2 species/ha, 2,950 m²/ha and 1,988 m²/ha, respectively (Figure 2B-D) (the values of all the metrics of the determinants sampled per plot are provided in S2 Table).

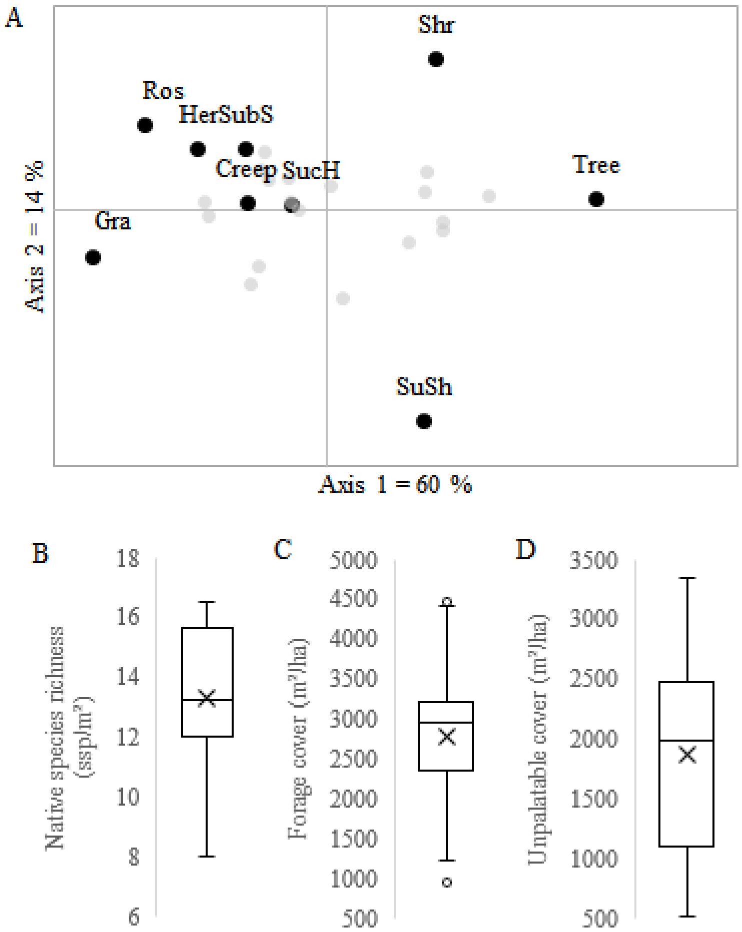

Figure 2. Variation in plant diversity components in a *Butia* palm grove in southern Brazil. Biplot diagram of a Principal Coordinates Analysis on growth forms composition, were grey dots represent sample unit scores and black dots represent the growth forms (A). Boxplots showing variations in native species richness per hectare (B), cover of palatable plant per hectare (C) and cover of unpalatable plant per hectare (D). Legend: "Ros": rossete herbs, "Her": herbs, "SubS": sub-shrubs, "Creep": creeping herbs, "SucH": succulent herbs, "Gra": graminoids, "Shr": srhubs, "SuSh": succulent shrubs.

The PCA of edaphic data revealed in the first axis (42% of the total variation) a gradient of more clayey soils with a high Cation Exchange Capacity (negative scores) to more basic ones, with higher phosphorus contents, and in the second axis (30%) a gradient of reduction in the levels of organic matter and potassium (negative scores) (Figure 3A). As for the other environmental descriptors, the expected values (median) of adult palm trees density, canopy opening and fecal load were, respectively, 154 individuals.ha^{-1}, 86% and 174 kg.ha^{-1} (Figure 3B-D) (S2 Table).

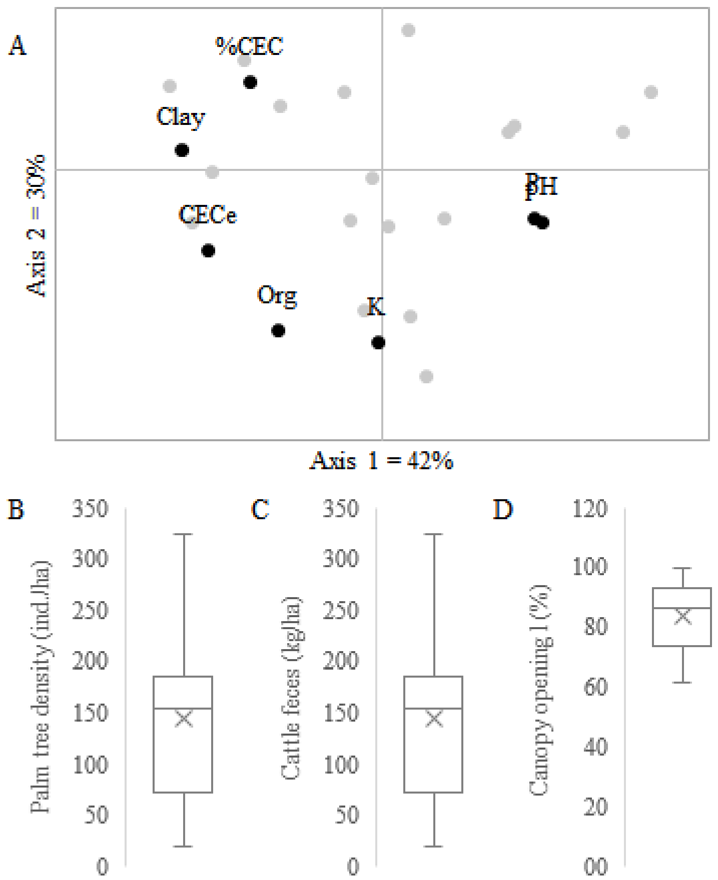

Figure 3. Variation in soil characteristics in a *Butia* palm grove in southern Brazil. Biplot diagram of a Principal Component Analysis on soil composition to the sampled plots, were grey dots represent sample unit scores and black dots represent the soil components (A). Boxplots showing variations in palm trees density per hectare (B), cattle feces (kg) per hectare (C) and canopy opening (%) (D). Legend: "%CEC": Basis Saturation, "CECe": Cationic Exchange Capacity, "Org": Organic Matter, "K": Potassium, "P": Phosphorus.

Causal models

In the analysis of the determinants of composition of growth forms, nine of the 20 models were considered valid (p> 0.1), but only model 13 (Fisher's C = 2.26; GL = 4; p = 0.689) had all the path coefficients significant. This model implies a positive indirect effect of the palm trees density on the forms of growth. The increase in the palm trees density implies less canopy opening (beta = -0.72; p = 0.001) and, consequently, an increase in the cover of woody plants closing the canopy (beta = -0.58; p = 0.019). In addition, this model implies a direct effect of the use by cattle in the composition, where less used plots showed greater woody coverage (beta = -0.48; p = 0.077) (Figure 4).

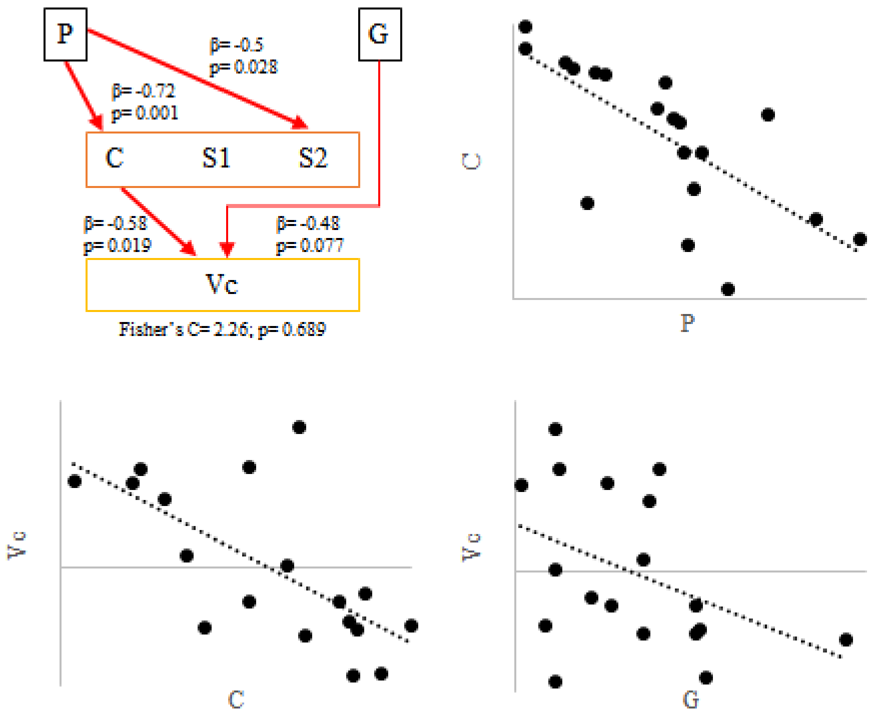

Figure 4. Causal model of growth forms composition (Vc) determined by palm density (P), use by cattle (G) and habitat (C – canopy openness, S1 – soil gradient 1 (PCA axis 1) and Soil gradient 2 (PCA axis 2)), in a *Butia* palm grove in southern Brazil. In the causal model graph, width and color of the arrows represent relationship directions and intensities, were positive (negative) relationships are in blue (red), and stronger (weaker) relationships are in ticker (thinner) arrows. For each arrow, standardized path coefficients (β) and their respective probabilities (p) are shown. Scatter diagrams show pairwise relationships between variables.

In the analysis of the determinants of the native species richness, 13 models were plausible and in 11 of them all the path coefficients were significant (models 1, 2, 3, 5, 6, 8, 10, 11, 13, 14, 16, 17 and 20). The model that included the largest number of common causal links was model 11 (Fisher's C = 7.81; GL = 6; p = 0.252), where the increase in palm density results in less canopy opening (beta = -0.71; p = 0.003) and, consequently, an increase in the native species richness due to the canopy closing (beta = -0.46; p = 0.073). In addition, this model implies an indirect effect of use by cattle on richness through the edaphic gradient of axis 1 of the PCA, where increased use by cattle results in more basic soils with a higher phosphorus content (beta = 0.47; p = 0.044), and consequently in communities with greater native species richness (beta = 0.52; p = 0.034) (Figure 5).

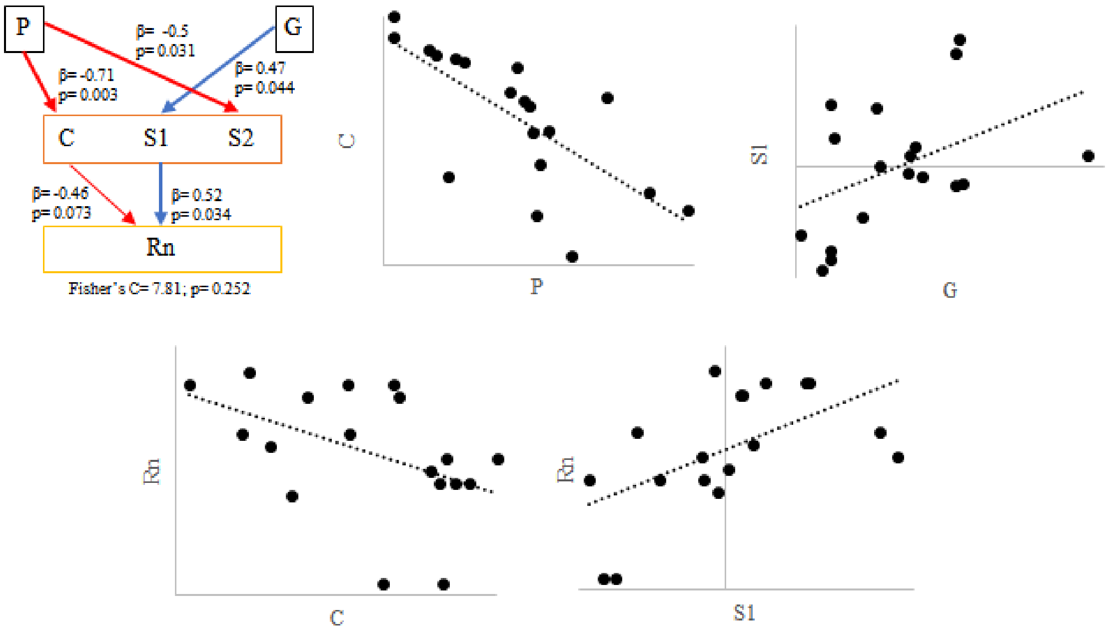

Figure 5. Causal model of native species richness (Rn) determined by palm density (P), use by cattle (G) and habitat (C – canopy openness, S1 – soil gradient 1 and Soil gradient 2), in a *Butia* palm grove in southern Brazil. In the causal model graph, width and color of the arrows represent relationship directions and intensities, were positive (negative) relationships are in blue (red), and stronger (weaker) relationships are in ticker (thinner) arrows. For each arrow, standardized path coefficients (β) and their respective probabilities (p) are shown. Scatter diagrams show pairwise relationships between variables.

In the analysis of forage quality, we obtained 15 plausible models and in two of them all path coefficients were significant, models 3 (Fisher's C = 3.15; GL = 6; p = 0.790) and 11 (Fisher's C = 4.26; GL = 6; p = 0.640). In both models, the increase in the density of palm trees implies a reduction in the canopy opening (beta = -0.71; p = 0.004) and an increase in organic matter and potassium levels in the soil (beta = -0.5; p = 0.036), the increased use by cattle results in more basic soils with a higher phosphorus content (beta = 0.47; p = 0.053). In model 3, the reduction in the coverage of unpalatable species is directly caused by the increase in the palm trees density (beta = -0.5; p = 0.032) (Figure 6). In model 11, the reduction in the coverage of unpalatable species is caused indirectly by the increase in the palm trees density, through the closing of the canopy (beta = 0.51; p = 0.036); in addition, the increased use by cattle leads to a reduction in forage cover, due to the more basic and rich in phosphorus (beta = -0.45; p = 0.062) (Figure 7).

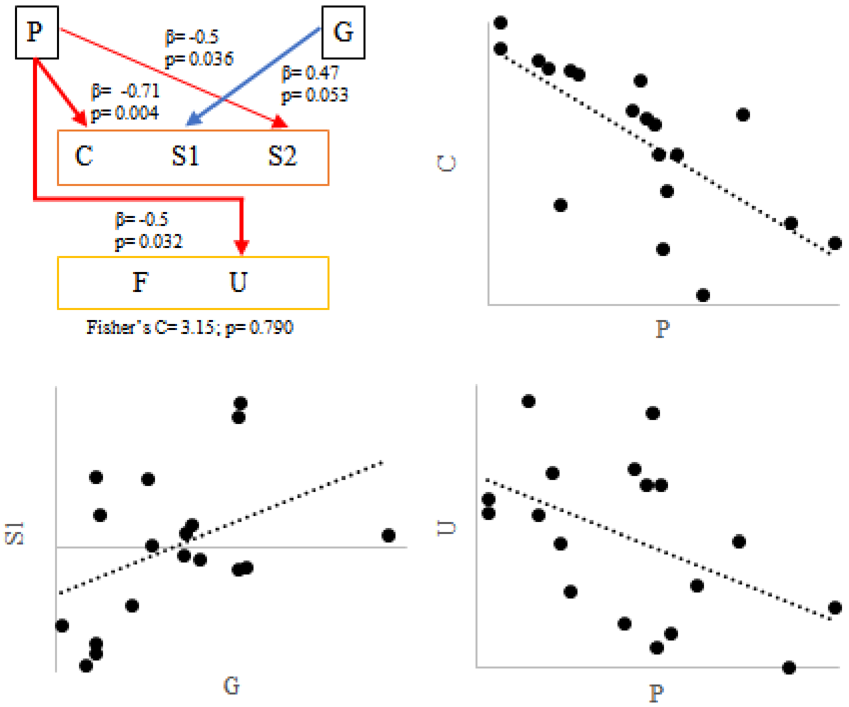

Figure 6. Causal model of forage quality (F: palatable and U: unpalatable) determined by palm density (P), use by cattle (G) and habitat (C – canopy openness, S1 – soil gradient 1 and Soil gradient 2), in a *Butia* palm grove in southern Brazil. In the causal model graph, width and color of the arrows represent relationship directions and intensities, were positive (negative) relationships are in blue (red), and stronger (weaker) relationships are in ticker (thinner) arrows. For each arrow, standardized path coefficients (β) and their respective probabilities (p) are shown. Scatter diagrams show pairwise relationships between variables.

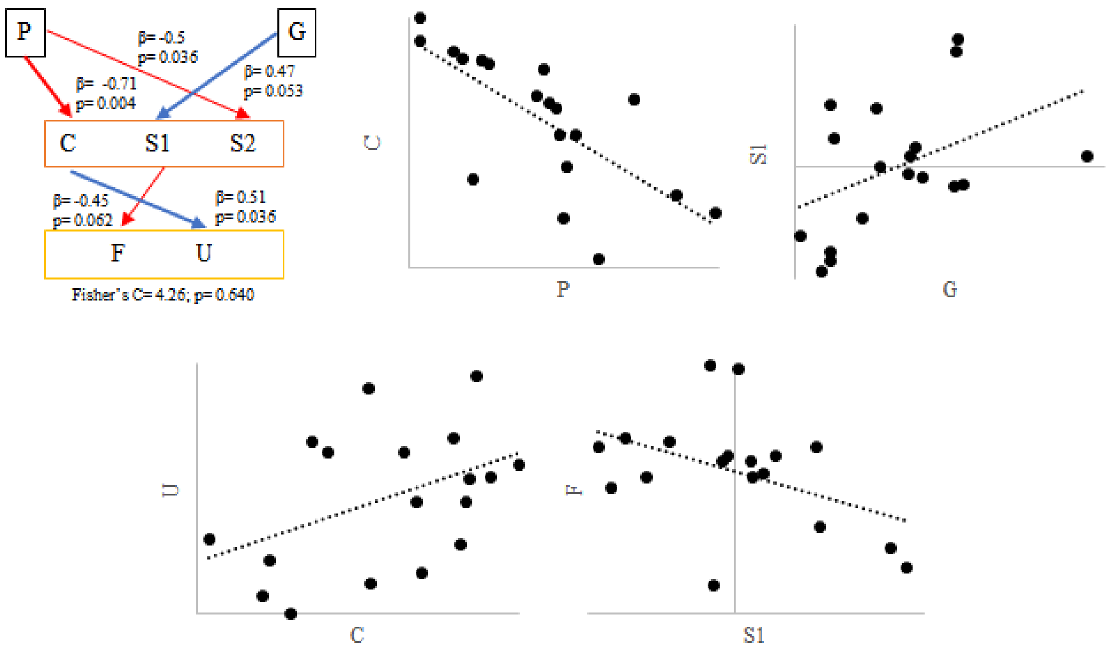

Figure 7. Causal model of forage quality (F and U) determined by palm density (P), use by cattle (G) and habitat (C – canopy openness, S1 – soil gradient 1 and Soil gradient 2), in a *Butia* palm grove in southern

Brazil. In the causal model graph, width and color of the arrows represent relationship directions and intensities, were positive (negative) relationships are in blue (red), and stronger (weaker) relationships are in ticker (thinner) arrows. For each arrow, standardized path coefficients (β) and their respective probabilities (p) are shown. Scatter diagrams show pairwise relationships between variables.

Discussion

Ecological drivers of vegetation diversity in Butia *palm grove*

Many grassy ecosystems around the world occur where the climate promotes the development of both forest and grass species (Staver et al., 2011), in which edaphic characteristics and disturbance regimes are the main modulators of vegetation dynamics (Overbeck et al., 2016; Buisson et al., 2018; Chendev et al., 2019). The use of cattle, as a way of disturb, tends to favor grassland vegetation because woody plants are less resilient to the impacts of animal grazing and trampling, preventing forest succession (Archibald & Hempson, 2016; Zhang et al., 2019). These factors should explain the structural difference we had seen in areas with less use by cattle, where greater coverage of shrub and tree plants was observed.

In grasslands it was also observed that increasing in woody species generates a decrease in local species richness, in addition to competition for nutrients (Guido et al., 2017; Fernández & Altesor, 2019; Ferreira et al., 2020). Therefore, to maintain the grassy ecosystem it is necessary to have an adequate animal load per area, which is enough to prevent the dominance of woody species, which guarantees the development of forages. Cattle have great selectivity for more palatable species in areas with intense use, and can result in decreasing their coverage, providing niches and facilitating the dispersion of less palatable species (Crowley & Garnett, 1998; Buisson et al., 2018), such as *E. horridum* and *A. laevis*, abundant in the study area. The stocking and the period of permanence of the animals in the pastures affect the nutrient cycling by incorporating excreta (Haynes & Williams, 1993), by the trampling of plants and soil compacting (Pulido et al., 2018). The higher pH and Phosphorus values found in areas with more intense use by cattle, we can consider that probably faces and urine are changing the pH, what consequently contributes to the availability of macro and micronutrients in the soil, and providing the Phosphorus consumed in the diet (Haynes & Williams, 1993; Zarekia et al. 2012).

The influence of edaphic variables on the native species richness demonstrates that the system has a pool of local species that is developing when there is greater availability of nutrients (Zarekia et al., 2012). The positive relationship with native species richness, may indicate that the native species which benefit from changes in the soil are woody, returning to the previous discussion about the problem of changing the vegetation structure. As also observed by Gaitán et al. (2017), the high animal load may be negatively influencing cover of forages, in which the stocking is not suitable for the area's forage productivity. An alternative, proposed in the studies of Nabinger et al. (2011) and Monroe et al. (2016), are the right management of forages with fallows and animal load adequate to the ecosystem support capacity, which allows the increase of available biomass, supplying the livestock's food need.

The higher density of palm trees is directly influencing the composition of growth forms. Studies in tropical savannas in Africa (Roques et al., 2001) and South America (Pinheiro et al. 2016; Rossatto et al. 2018), have mentioned that the invasion of shrubs and trees is dependent on the density of pre-existing individuals, and the soil moisture and temperature are affected by them. The presence of adult individuals provides the propagation of seedlings and, consequently, greater recruitment, in addition to the reducing the loss of moisture from the soil surface, thus less competition for water and light stress, facilitates the development of forest species (Roques et al.,2001; Pinheiro et al., 2016). Besides, they can favor nutrient cycling, with the decomposition of plant parts (Lett & Knapp, 2003; Starr et al., 2013; Chendev et al., 2019) and providing resources for the associated dispersing fauna (Corlett & Hau, 2000; Prather et al., 2017). The greater coverage of tree and shrub species observed in areas with a high density of palm trees, may be the consequence of these changes in micro-habitat conditions. Still, the fauna that uses butiazeiros may be dispersing the seeds of these woody species, such as *E. hiemalis* and *O. monacantha*, species observed with the greatest coverage and which have a dispersion mainly of ornithochoric syndrome (Bregman, 1988; Lorenzi, 2002). Areas with less tree layer coverage tend to decrease the competitive potential of woody plants due to the reduction of humidity and excess of light intensity, with the grassy species being better adapted to these environmental conditions (Fernández & Altesor, 2019). The different plant physiological adaptations can be related to the influence on unpalatable species, which may have greater plasticity and survive longer in areas with less light intensity, such as the invasive specie *E. horridum*. The competition for water, light and nutrients, may be benefiting these species adapted to survive and thrive in these different micro-habitats (Montefiori & Vola, 1990).

Implications for conservation

Many studies have been carried out around the world identifying and measuring the importance of disturbances to maintain biodiversity in grasslands (Byington 2011; Laliberté et al., 2012; Archibald & Hempson 2016; Espunyes et al. 2019), as well as in Brazil (Overbeck et al. 2007; Baldissera et al. 2010; Fischer et al. 2019). However, there is a failure to disclose the importance of the influence of these disturbances on potential vegetation and its ecosystem functions (Veldman et al., 2015). Associated with this ability for disturbances, the grasslands in southern Brazil have an indisputable potential to be exploited by the richness of native forage species, adapted to local conditions and capable of sustaining the food base of livestock without the need for exogenous resources (Valls et al., 2009). Therefore, the duality of livestock activity and conservation of the native grassland is an inherent possibility in the ecosystem. Our results indicated that butiazal allows this union, as long as the palm trees density and the available forage quality are considered, and that the maintenance of the palm population itself is respected to guarantee ecosystem services.

The supply of native forage species for feeding the cattle and for maintaining viable production is of fundamental importance for landowners, mainly with a large stocking of cattle that controls the woody species and provides nutrients for the soil.However, Sosinski et al. (2015) and Zhang et al. (2019) found that in ecosystems dominated by a single key specie, the higher load of cattle leads to a decrease in their recruitment. Thus, a paradox is formed when we consider the concern with forest advancement over rural areas, finding disturbances as a way to avoid such a process, but that exactly this solution is preventing the regeneration of palm trees in *Butia* palm grove (Sosinski et al. 2015), precisely the key species of that ecosystem.

Climate change is driving the succession of grasslands to forest ecosystems worldwide (Staver et al., 2011), endangering biodiversity and ecosystem services provided by non-forest ecosystems (Veldman et al., 2015). The aggregation of palm trees in the butiazal provides micro-habitat conditions favorable to woody species encroachment, as previously discussed, threatening the persistence of the *Butia* trees.

Therefore, the planning of management actions aiming the conservation of this ecosystem must be carefully elaborated.

The practice of conservative management, as adopted by Sosinski et al. (2015) which consists of fallow land during winter with a reduced animal load. This action allows that, during its vulnerable stage of germination (winter), the palm tree to develop and establish itself, without being consumed by cattle (Báez & Jaurena, 2000). This can guarantee the persistence of the palm population and the maintenance of the characteristics of this ecosystem. Our results, on the other hand, indicate that the reduction of animal load (less use by cattle) favors the woody plant community.

Alternatives should be proposed to this apparent dilemma of conservation of butiazal in areas for livestock use. First, in areas in which low palm trees recruitment is observed, the practice of conservative management proposed by Sosinski et al. (2015) can guarantee the recruitment of palm trees. Once the individuals are properly established, there is a possibility to increase the animal load in order to control the encroachment of woody species. Studies in South America (Altesor et al., 2006; Macias et al., 2014; Archibald & Hempson, 2016; Gaitán et al., 2017) and Asia (Zhang et al., 2019) show the positive effect of grazing by livestock in containing the woody encroachment. However, studies also ponder on the appropriate grazing intensity, so that any contrary effect does not occur. Sankaran et al. (2008) and Wang et al. (2018) mention that there is a fine line between these positive or negative effects, with the results largely driven by the particular local characteristics, such as soil, climate and species of herbivores that use the site (Mandle & Ticktin, 2012). Therefore, there is a need to search information about the animal load that the local plant community supports, without loss of diversity and/or soil erosion by excessive trampling, for example, and that guarantees the control of the unwanted regenerating woody species. In our study we infer the use by cattle through fecal load, however we do not have an adequate measure of animal load that can better guide livestock practices.

A viable strategy is the rotational management, which consists of making strategic fallows in the properties that suits the vegetation growing season (Vecchio et al., 2019). This rotation makes possible to reduce the food selectivity of the animals and evenly distribute their impact on the area, improving the conditions of the pastures by increasing the vegetation cover and generating greater richness and diversity of species (McDonald et al., 2019). The application of this management in pastures in Africa (Rotich et al., 2018), Australia (McDonald et al., 2019), Europe (Ravetto Enri et al., 2017), and South America (Boavista et al., 2019; Vecchio et al., 2019), showed positive effects, guaranteeing production and avoiding negative consequences such as soil erosion.

Based on our results, areas for rotational management should consider the palm trees density. In the case of low densities, the predominance of native herbaceous species was observed, therefore, these areas can support greater animal load. If areas with higher densities of palm trees, the animal load supported will probably be lower, due to the greater presence of shrubs and trees, requiring more frequent rotations to allow forage regrowth. However, in order to propose the value of this animal load per hectare, advances in agronomic and zootechnical studies with focal attention in local forage species are necessary. In addition, attention in the physiological characteristics of the animal species to be created, so that the ideal values can be quantified going into practice a viable production that can demonstrate positive effects on the maintenance of the *Butia* palm community.

Conclusion

With this study, we obtained indications of the relationship between the sampled predictors and their influences on the composition and richness of plant species in a butiazal. These results can support the continuity of efforts to adapt the animal load on a spatial scale, considering the different densities of palm trees in a temporal scale, through the conservative and rotational management of the animal load. With proper management, the vegetation structure and biomass produced by native forages will be preserved and will remain enough to guarantee the development and performance of the animals, ensuring the maintenance of the economic and ecological aspects sought.

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Supporting information

S1 Table: List of species and their forms of growth, origin, forage quality and coverage per plot of a butiazal in southern Brazil.

S2 Table: The values of all the metrics of the determinants sampled per plot in a butiazal in southern Brazil.

S1 Table: List of species and their forms of growth, origin, forage quality and coverage per plot of a butiazal in southern Brazil.

					Species coverage per plot																	
Species	Family	Growth form	Origin	Forage? Y/N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Aeschynomene falcata (Poir) DC	Fabaceae	Sub-shrub	N	Y	0.0	0.6	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Allophylus edulis (A.St.-Hil., Cambess. & A. Juss.) Radlk.	Sapindaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	1.0	2.0	1.0
Andropogon selloanus Hack.	Poaceae	Graminoid	N	Y	0.1	1.3	1.9	0.0	0.6	0.8	0.6	0.0	1.6	0.0	1.1	1.4	0.6	1.9	0.3	0.0	0.4	0.6
Aristida laevis (Ness) Kunth	Poaceae	Graminoid	N	N	0.6	19.4	8.9	2.6	17.5	10.1	20.0	0.0	9.4	1.9	0.0	9.4	5.6	9.4	23.1	1.3	10.0	28.8
Baccharis articulata (Lam.) Pers.	Asteraceae	Shrub	N	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Baccharis logiattenuata A. S. Oliveira	Asteraceae	Shrub	N	N	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baccharis trimera (Less.) DC	Asteraceae	Shrub	N	N	0.0	0.0	2.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.1
Blepharocalyx salicifolius (Kunth) O. Berg	Myrtaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Calliandra brevipes Benth.	Fabaceae	Shrub	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Casearia sylvestris Sw.	Salicaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Centella asiatica (L.) Urb.	Apiaceae	Creeping herb	E	-	14.3	7.0	2.3	13.1	4.8	8.3	4.4	11.9	6.4	0.6	15.9	1.8	6.0	2.6	3.8	2.8	7.1	1.8
Chaptalia integerrima (Vell.) Burk.	Asteraceae	Rossete herb	N	-	0.5	0.4	0.9	0.0	0.3	1.0	1.3	0.1	0.3	0.6	0.4	0.0	0.4	0.1	1.1	0.0	0.0	0.0
Chascolytrum subaristatum (Lam.) Desv.	Poaceae	Graminoid	N	Y	0.6	0.4	0.8	1.9	4.6	0.3	0.8	0.1	1.8	0.6	0.0	2.3	0.0	0.6	0.0	0.0	2.5	0.6
Chascolytrum uniolae (Nees) Essi, Longhi-Wagner & Souza-Chies	Poaceae	Graminoid	N	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Chevreulia sarmentosa (Pers.) Blake	Asteraceae	Rossete herb	N	-	0.6	5.0	1.4	0.0	1.9	2.3	1.4	2.0	2.5	0.4	0.4	0.0	0.1	0.0	0.5	0.8	0.3	0.8
Chromolaena laevigata (Lam.) R.M.King & H.Rob.	Asteraceae	Shrub	N	-	0.0	0.0	0.0	0.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conyza primulifolia (Lam.) Cuatrec. & Lourteig	Asteraceae	Rossete herb	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.9	0.0	0.0	0.0
Criscia stricta (Spreng.) L. Katinas	Asteraceae	Rossete herb	N	-	0.0	0.0	0.0	0.0	0.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0

Crotalaria tweediana Benth.	Fabaceae	Sub-shrub	N	-	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Daphnopsis racemosa Griseb.	Thymelaeaceae	Shrub	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
Desmodium adscendens (Sw.) DC	Fabaceae	Sub-shrub	N	Y	2.1	1.3	0.0	9.5	2.1	0.9	0.3	0.6	0.8	0.0	0.5	0.4	4.0	0.4	0.6	0.9	0.0	2.8
Desmodium incanum DC	Fabaceae	Sub-shrub	N	Y	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.9	0.3	1.9
Diodella apiculata (Willd. ex Roem. & Schult.)	Rubiaceae	Sub-shrub	N	-	0.8	0.0	0.3	0.0	0.0	0.1	0.3	0.0	0.1	0.0	0.1	0.0	0.8	0.5	0.0	0.1	0.1	0.0
Elephantopus mollis Kunth	Asteraceae	Rossete herb	N	-	3.1	2.9	1.5	4.1	4.4	3.0	3.3	5.0	3.3	3.5	2.3	1.1	3.4	0.6	0.6	5.1	0.4	1.8
Eryngium horridum Malme	Apiaceae	Rossete herb	N	N	5.3	6.4	8.9	7.3	7.0	1.4	0.0	5.1	0.3	16.5	13.3	15.0	0.4	14.8	10.4	16.3	11.3	3.1
Eryngium sanguisorba Cham. Et Schlecht.	Apiaceae	Rossete herb	N	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Erythroxylum argentinum O.E.Schulz	Erythroxylaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	2.0	0.0	0.0
Eugenia brevistyla D. Legrand	Myrtaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	30.0	0.0	5.0
Eugenia hiemalis Cambess.	Myrtaceae	Tree	N	-	2.0	20.0	1.0	73.0	2.0	95.0	0.0	42.0	0.0	0.0	1.0	6.0	40.0	6.0	0.0	145.0	0.0	86.0
Euphorbia selloi (Klotzsch & Garcke) Boiss.	Euphorbiaceae	Herb	N	-	0.0	0.6	0.4	0.1	0.3	0.5	0.6	0.3	0.5	0.8	0.5	0.3	0.4	0.4	0.0	0.6	0.4	0.4
Gamochaeta americana (Mill.) Wedd.	Asteraceae	Herb	N	-	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.3	0.1
Glandularia humifusa (Cham.) Botta	Verbenaceae	Creeping herb	N	-	0.0	0.0	2.5	0.0	1.3	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Guettarda uruguensis Cham. & Schltdl.	Rubiaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Gymnanthes serrata Baill. ex Müll.Arg.	Euphorbiaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
Holocheilus brasiliensis (L.) Cabrera	Asteraceae	Rossete herb	N	-	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Homolepis glutinosa (Sw.) Zuloaga & Soderstr.	Poaceae	Graminoid	N	-	1.3	0.6	0.0	2.0	0.0	0.4	0.0	0.4	0.4	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hypoxis decumbens L.	Hypoxidaceae	Herbs	N	-	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kelissa brasiliensis (Baker) Ravenna	Iridaceae	Herbs	N	-	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kyllinga brevifolia Rottb.	Cyperaceae	Graminoid	N	-	0.8	0.0	0.0	0.1	0.3	0.0	0.3	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lantana camara L.	Verbenaceae	Shrub	E	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0

Lantana fucata Lindl.	Verbenaceae	Shrub	N	-	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithraea brasiliensis Marchand	Anacardiaceae	Tree	N	-	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	2.0	0.0	0.0	5.0	0.0	0.0
Lucilia nitens Less.	Asteraceae	Rossete herb	N	-	0.6	1.1	0.9	1.3	2.5	0.3	2.1	0.8	1.3	1.1	0.1	0.1	0.1	0.6	0.4	0.0	0.3	0.1
Melica rigida Cav.	Poaceae	Graminoid	N	Y	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Mesosphaerum suaveolens (L.) Kuntze	Lamiaceae	Sub-shrub	N	-	0.1	0.0	0.8	0.0	0.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0	2.5	0.0	0.6	0.0	0.0	0.0
Myrsine coriacea (Sw.) R.Br.	Primulaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Myrsine guianensis (Aubl.) Kuntze	Primulaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Myrsine sp.	Primulaceae	Tree	N	-	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Noticastrum calvatum (Baker) Cuatrec.	Asteraceae	Rossete herb	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opuntia monacantha (Willd.) Haw.	Cactaceae	Succulent shrub	N	-	1.0	25.0	0.0	2.0	0.0	5.0	0.0	15.0	16.0	0.0	0.0	0.0	5.0	1.0	0.0	11.0	6.0	11.0
Oxalis brasiliensis Lodd.	Oxalidaceae	Herb	N	-	1.3	0.0	0.1	1.9	0.6	0.8	0.0	0.6	0.1	1.0	0.3	0.0	0.5	0.3	1.3	0.5	0.8	0.0
Oxalis perdicaria (Molina) Bertero	Oxalidaceae	Herb	N	-	0.0	0.0	0.8	0.0	0.0	0.1	0.9	0.5	0.5	0.0	0.8	0.0	0.0	0.4	1.0	0.4	0.0	0.0
Panicum sellowii Nees	Poaceae	Graminoid	N	-	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parodia oxycostata (Buining & Brederoo) Hofacker	Cactaceae	Sucullent herb	N	-	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paspalum ionanthum Chase	Poaceae	Graminoid	N	Y	0.0	0.0	0.0	3.8	0.0	7.5	0.0	13.8	0.0	0.0	7.5	0.0	7.5	11.3	0.0	0.0	0.0	0.0
Petunia integrifolia (Hook.) Schinz & Thell.	Solanaceae	Creeping herb	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Pfaffia tuberosa (Spreng.) Hicken	Amaranthaceae	Erect herb	N	-	0.0	0.0	0.0	0.0	0.6	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Piptochaetium montevidense (Spreng.)	Poaceae	Graminoid	N	Y	0.0	0.0	0.0	2.0	0.3	0.4	0.1	2.5	0.3	0.0	0.0	0.0	0.0	0.0	7.5	0.0	1.3	3.8
Plantago tomentosa Lam.	Plantaginaceae	Rossete herb	N	-	2.6	2.3	1.5	4.6	2.9	2.9	1.1	5.0	2.5	1.6	2.3	0.0	2.1	0.9	0.4	3.6	0.3	0.6
Psychotria carthagenensis Jacq.	Rubiaceae	Shrub	N	-	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhynchospora setigera (Kunth) Boeck.	Cyperaceae	Graminoid	N	-	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhynchospora splendens Lindm.	Cyperaceae	Graminoid	N	-	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhynchospora holoschoenoides	Cyperaceae	Graminoid	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(Rich.) Herter.																						
Rhynchospora barrosiana Guagl.	Cyperaceae	Graminoid	N	-	0.3	0.3	0.0	0.0	0.0	0.1	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0
Richardia brasiliensis Gomes	Rubiaceae	Creeping herb	N	-	0.1	2.5	0.1	2.6	0.4	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.1	1.6	0.1	0.0
Richardia grandiflora (Cham. & Schltdl.) Steud.	Rubiaceae	Creeping herb	N	-	0.3	0.0	0.0	0.0	0.0	0.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.4
Ruellia morongii Britton	Acanthaceae	Rossete herb	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Schizachyrium tenerum Nees.	Poaceae	Graminoid	N	Y	7.8	2.1	1.6	2.0	0.3	3.4	1.9	7.5	10.6	21.3	8.1	1.9	10.0	9.4	3.3	13.4	12.5	9.5
Senecio ceratophylloides Griseb.	Asteraceae	Erect herb	N	N	2.9	0.0	0.0	1.3	0.0	0.0	1.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Senecio selloi (Spreng.) DC.	Asteraceae	Erect herb	N	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0
Setaria parviflora (Poir.) Kerguélen	Poaceae	Graminoid	N	Y	0.3	0.1	0.4	0.0	0.4	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.4	0.0
Solanum mauritianum Scop.	Solanaceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	1.0	0.0	0.0
Sommerfeltia spinulosa Less.	Asteraceae	Sub-shrub	N	-	0.4	1.1	0.9	2.5	3.1	0.6	1.8	0.8	1.5	1.0	0.4	0.0	2.9	0.1	1.0	1.3	0.3	0.1
Sorghastrum pellitum (Hack.) Parodi	Poaceae	Graminoid	N	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	1.3	0.0	0.0	0.0	0.6
Stenachaenium megapotamicum (Spreng.) Baker	Asteraceae	Rossete herb	N	-	0.6	0.1	0.9	0.4	1.3	0.0	0.0	0.0	0.3	0.6	0.3	0.0	0.0	0.0	0.0	1.1	0.3	5.9
Urochloa decumbens Stapf.	Poaceae	Graminoid	E	Y	4.6	24.5	7.8	11.9	17.8	15.5	5.8	1.9	14.4	11.3	14.4	17.5	4.6	19.4	20.6	3.9	26.9	10.6
Varronia curassavica Jacq.	Boraginaceae	Shrub	N	-	6.9	0.0	4.4	10.0	6.3	2.8	0.0	5.0	2.5	0.0	2.5	1.9	18.1	5.0	0.0	13.8	0.1	7.1
Vernonanthura discolor (Spreng.) H.Rob.	Asteraceae	Tree	N	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0

Legenda: Origin: N= native, E= exotic. Forage: Y= yes, N= no.

PS.: The species *Aristida laevis* was considered unpalatable due to its high coverage of adult individuals. According to Nabinger et al. (2009), adult individuals of the species in high offers are rejected by cattle.

Supporting information 2: The values of all the metrics of the determinants sampled per plot in a butiazal in southern Brazil.

Plot	Palm tree density (ind./ha)	Cattle feces (Kg/ha)	Canopy opening (%)	Soil (PCA1)	Soil (PCA2)	Growth form (PCoA1)	Native species richness	Forage cover	Unpalatable cover
	P	G	C	S1	S2	Vc	Rn	F	U
1	180	282.70	81.5	0.73	0.15	-0.14	28	15.50	8.8
2	76	199.31	74.2	-0.03	-0.02	0.05	23	30.25	25.8
3	20	288.61	100.0	0.82	0.30	-0.24	26	12.38	23.0
4	204	142.20	61.5	0.39	0.15	0.36	32	31.63	13.9
5	172	200.91	76.3	0.08	-0.54	-0.25	31	26.88	24.5
6	324	224.41	69.0	-0.06	-0.51	0.42	33	29.63	11.5
7	20	297.01	96.5	-0.10	-0.18	-0.44	24	9.63	21.5
8	284	210.29	71.7	0.13	-0.76	0.29	27	27.38	5.1
9	140	518.44	87.8	0.07	0.52	-0.28	31	29.38	9.9
10	84	59.49	93.2	-0.53	0.00	-0.45	16	33.13	18.4
11	92	45.05	92.8	-0.65	0.32	-0.22	24	31.75	13.3
12	160	61.16	85.7	-0.59	-0.19	0.01	16	25.25	24.4
13	168	7.06	68.1	-0.43	0.42	0.36	28	27.00	7.3
14	148	148.71	91.8	0.01	-0.20	-0.14	25	44.13	26.1
15	56	117.15	94.7	-0.32	0.25	-0.11	24	32.75	33.5
16	240	61.01	87.1	0.40	0.17	0.59	32	19.00	18.5
17	64	282.53	93.7	-0.12	0.30	-0.25	26	44.75	21.3
18	164	67.04	81.3	0.19	-0.17	0.42	32	30.38	32.1

Considerações finais

Neste trabalho pudemos inferir quais os determinantes que influenciam a comunidade vegetal do butiazal, e permitiu contribuir com informações de como realizar o manejo desse ecossistema utilizando-se de uma atividade agropecuária sustentável.

Consideramos a possibilidade de conciliar a manutenção do butiazal com a pecuária, de forma a garantir a persistência desse ecossistema junto a uma geração de renda para proprietários de áreas com a presença de butiazeiros sobre campo nativo. Para tal, verificamos que é necessário ponderar sobre a intensidade de uso pelo gado e a densidade de butiazeiros nos potreiros onde se realizar o manejo.

O uso pelo gado afetou diretamente a composição de formas de crescimento e os componentes do solo, e esses, consequentemente, afetaram a riqueza de espécies nativas e a qualidade forrageira. Já a densidade de palmeiras afetou diretamente a qualidade forrageira e pela mudança na abertura de dossel, afetou a composição de formas de crescimento, riqueza de nativas e também, na qualidade forrageira.

A partir dos resultados, foi possível propor práticas de manejo que podem auxiliar nos objetivos propostos. A utilização, em um primeiro momento, do manejo conservativo permitirá a regeneração da população de butiazeiros, garantindo a manutenção da espécie-chave desse ecossistema. Posteriormente, com a garantia de novos indivíduos das palmeiras estabelecidos, a utilização do manejo rotativo, permitirá que o distúrbio provocado pelo pastejo diminua a expansão de espécies lenhosas que comumente avança sobre os butiazais e acaba por suprimi-lo, e proporcionará uma heterogeneidade do ambiente com o desenvolvimento de espécies forrageiras de qualidade, com biomassa suficiente para suprir a alimentação necessária para o gado.

Essas práticas são propostas como possíveis soluções, entretanto ainda são necessários estudos agronômicos e zootécnicos que busquem informações sobre as espécies presentes em cada local que se deseja manejar e o quanto elas suportam de carga animal por hectare, visando a produtividade do gado e do ambiente.