

UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL  
FACULDADE DE AGRONOMIA  
PROGRAMA DE PÓS-GRADUAÇÃO EM ZOOTECNIA

**RECUPERAÇÃO DE PASTAGENS NATURAIS DEGRADADAS POR  
SOBREPASTEJO, POR MEIO DO DIFERIMENTO**

JEAN KÁSSIO FEDRIGO

Zootecnista/UDESC  
Mestre em Zootecnia/UFRGS

Tese apresentada como um dos requisitos à obtenção do Grau de Doutor em  
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JEAN KÁSSIO FEDRIGO  
Zootecnista e  
Mestre em Zootecnia

## **TESE**

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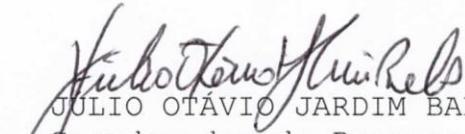
## **DOUTOR EM ZOOTECNIA**

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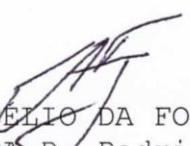
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Pela Banca Examinadora

Homologado em: 17.06.2015  
Por

  
CARLOS NABINGER  
PPG Zootecnia/UFRGS  
Orientador  
  
PAULO CÉSAR DE FACCIO CARVALHO  
PPG Zootecnia/UFRGS

  
JULIO OTÁVIO JARDIM BARCELLOS  
Coordenador do Programa de  
Pós-Graduação em Zootecnia

  
GERHARD ERNEST OVERBECK  
PPG Botânica/UFRGS

  
JOSÉ ACÉLIO DA FONTOURA JÚNIOR  
UNIPAMPA D. Pedrito

  
PEDRO ALBERTO SELBACH  
Diretor da Faculdade de Agronomia

## DEDICATÓRIA

*“No te rindas, aún estás a tiempo  
 De alcanzar y comenzar de nuevo,  
 Aceptar tus sombras,  
 Enterrar tus miedos,  
 Liberar el lastre,  
 Retomar el vuelo.*

*No te rindas que la vida es eso,  
 Continuar el viaje,  
 Perseguir tus sueños,  
 Destubar el tiempo,  
 Correr los escombros,  
 Y destapar el cielo.*

*No te rindas, por favor no cedas,  
 Aunque el frío queme,  
 Aunque el miedo muerda,  
 Aunque el sol se esconda,  
 Y se calle el viento,  
 Aún hay fuego en tu alma  
 Aún hay vida en tus sueños.*

*Celebrar la vida y retomar los cielos.  
 Porque cada día es un comienzo nuevo,  
 Porque esta es la hora y el mejor momento”*

Retirado do Poema *No te rindas*, de Mário Benedetti

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Ao Alex, Gi e Davi Augusto família que eu amo e sempre serão meu incentivo

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## Recuperação de pastagens naturais degradadas por sobrepastejo, por meio do diferimento<sup>1</sup>

Autor: Jean Kássio Fedrigo

Orientador: Carlos Nabinger

**Resumo –** A herbivoria em pastagens naturais apresenta papel de destaque no direcionamento das dinâmicas vegetacionais, determinando modificações na estrutura da vegetação, nos padrões de biodiversidade e na produtividade do sistema. Essas alterações, que de modo geral contribuem para a sustentabilidade dos ecossistemas em níveis moderados de intensidade de pastejo, podem dar origem a processos de degradação ambiental quando a lotação animal utilizada é superior à capacidade de suporte das pastagens. O objetivo do presente trabalho foi avaliar a capacidade de recuperação dos padrões de diversidade, composição botânica, biomassa de forragem, altura do pasto, interceptação luminosa e do banco de sementes de uma pastagem natural degradada por sobrepastejo, por meio do diferimento, tomando como base uma área de referência. Três tratamentos baseados em exclusões estacionais do pastejo (Diferimento de Primavera, Diferimento de Outono e Pastoreio Contínuo) com três repetições foram aplicados simultaneamente em áreas manejadas por um longo período com duas intensidades de pastejo: severa e moderada (utilizada como área de referência). A pastagem manejada com pastejo severo apresentou rápida alteração na composição botânica e nos padrões de diversidade em resposta ao diferimento. Depois de dois anos de exclusões temporárias do pastejo, a composição botânica da vegetação estabelecida e do banco de sementes dessa área sofreu alterações nos grupos funcionais de gramíneas na direção das espécies características da comunidade vegetal sob pastejo moderado. Também foram verificados importantes incrementos na biomassa de forragem, altura e interceptação luminosa. A comunidade vegetal sob pastejo moderado apresentou maior equilíbrio entre diferentes grupos funcionais de plantas, especialmente entre espécies com hábitos de crescimento prostrado e cespitoso. Essa condição favoreceu o aparecimento de estrutura espacial na distribuição das espécies de plantas, maior diversidade, riqueza e melhores condições estruturais do pasto. O diferimento realizado na moderada intensidade de pastejo proporcionou dominância de espécies cespitosas, determinando decréscimo na diversidade e riqueza de plantas. As épocas de diferimento apresentaram padrões de resposta semelhantes dentro de cada intensidade de pastejo, com magnitude superior para o diferimento de primavera. Os resultados revelam a importância do diferimento do pastejo como uma ferramenta para a recuperação de pastagens degradadas por sobrepastejo.

**Palavras chave:** intensidade de pastejo, banco de sementes do solo, diversidade taxonômica, grupos funcionais.

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<sup>1</sup>Tese de Doutorado em Zootecnia – Plantas forrageiras, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil (128p.), Abril, 2015.

## Restoration of overgrazed natural grassland by temporary grazing exclusions<sup>1</sup>

Author: Jean Kássio Fedrigo

Advisor: Carlos Nabinger

**Abstract** - The herbivory on natural grasslands has a prominent role in driving vegetation dynamics, determining changes in vegetation structure, biodiversity patterns and primary and secondary productivity. These changes, which generally contribute to the ecosystems sustainability at moderate grazing intensities, can cause environmental degradation when the stocking rate used is higher than the pasture carrying capacity. The objective of this study was to evaluate the efficiency of temporary grazing exclusion to restore diversity, botanical composition, forage biomass, sward height, light interception and soil seed bank from a natural grassland degraded by overgrazing based on a reference area. Three treatments based on seasonal grazing exclusions (spring deferment, autumn deferment and continuous stocking) with three replications were applied simultaneously in areas managed for a long period with two grazing intensities: severe and moderate (used as reference area). The pasture managed under severe grazing showed a rapid change in botanical composition and diversity patterns in response to grazing exclusions. After two years of temporary grazing exclusions, grass functional groups of the established vegetation and soil seed bank from overgrazed pasture changed toward the characteristic species of plant community under moderate grazing. We also verified significant increases in forage biomass, sward height and light interception. The plant community under moderate grazing intensity showed better balance between different functional groups of plants, especially among species with prostrate and cespitose growth habits. This condition favored the spatial structure of appearance in the distribution of plant species, greater diversity, species richness and better structural pasture conditions. The grazing exclusion in moderate intensity grazing provided dominance tussock species, determining decrease in the diversity and richness of plants. The deferment periods showed similar response patterns within each grazing intensity with higher magnitude for spring deferment. These results reveal the importance of grazing exclusion as a tool for the recovery of degraded pastures by overgrazing.

**Key words:** grazing intensity, soil seed bank, taxonomic diversity, functional groups.

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<sup>1</sup>Doctoral thesis in Forage Science – Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. (128p.), April, 2015.

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## LISTA DE ABREVIATURAS

CS	Continuous stocking
FM	Forage mass
GI	Grazing intensity
H	Sward height
MGI	Moderate grazing intensity
NMDS	Non-metric multidimensional scaling
PAR	Photosynthetically active radiation
PARinc	Photosynthetically active radiation incidente
PARint	Photosynthetically active radiation intercepted
PART	Photosynthetically active radiation transmitted
RF	Removal of grazing during fall
RS	Removal of grazing during spring
SGI	Severe grazing intensity
SLI	Sward light interception
SSB	Soil seed bank

*Grupos funcionais das gramíneas:*

CAEG	Cool, annual, erect and good forage value
CAEM	Cool, annual, erect and moderate forage value
CPEG	Cool, perennial, erect and good forage value
CPEH	Cool, perennial, erect and high forage value
WAEM	Warm, annual, erect and moderate forage value
WAEG	Warm, annual, erect and good forage value
WPEG	Warm, perennial, erect and good forage value
WPEL	Warm, perennial, erect and low forage value
WPEM	Warm, perennial, erect and moderate forage value
WPPG	Warm, perennial, prostrate and good forage value
WPPM	Warm, perennial, prostrate and moderate forage value

## **CAPÍTULO I**

## **1. INTRODUÇÃO GERAL**

A necessidade de aumento na produção de alimentos à população, que deverá chegar a 9 bilhões até 2050 (Roberts, 2011), impõe às lideranças globais o desafio de um criterioso aproveitamento dos recursos naturais, e que este seja realizado de maneira produtiva e ao mesmo tempo sustentável. Em meio a essa problemática, a produção animal em pastagens destaca-se como uma prática ecologicamente correta da produção de alimentos devido à sua capacidade em transformar a celulose em alimento de grande valor protéico para a espécie humana. Nos últimos anos, no entanto, essa atividade foi responsabilizada por danos ambientais que comprometeriam a qualidade dos padrões de vida atuais no planeta. Há linhas de pensamento que acreditam que a exploração pecuária ameaça a biodiversidade e está estreitamente relacionada às mudanças climáticas globais, desmatamento e escassez hídrica. Esses questionamentos são essenciais ao processo de evolução do conhecimento humano na busca de métodos de produção mais eficazes para suportar a demanda de alimentos da sociedade, sem comprometer as futuras gerações.

O fato é que a exploração pecuária pode gerar tanto benefícios quanto prejuízos para a sustentabilidade do planeta. Ela pode desencadear a degradação do ambiente bem como atuar como indústria de geração de alimento e de serviços ecossistêmicos capazes de solucionar grande parte dos problemas ambientais que preocupam a geração atual. Muitos trabalhos têm sido desenvolvidos nos últimos anos visando priorizar tais benefícios e a maioria deles aponta que o manejo adequado das pastagens proporciona equilíbrio entre a produção de alimento e a conservação do meio ambiente. A abordagem dos trabalhos científicos em pastagens, anteriormente destacada unicamente como fonte barata de alimento para ruminantes reorienta-se na perspectiva de compreender o seu papel na conservação da biodiversidade, sequestro de carbono, regulação de ciclos biogeoquímicos, mitigação da poluição e proteção do solo.

O controle da intensidade de pastejo é considerado um fator de manejo chave que permite tanto o aumento na produção animal e na rentabilidade da pecuária quanto a prestação de serviços ambientais (Nabinger et al., 2012). Na região sul do Brasil, estudos de longa duração em pastagens naturais sugerem que intensidades de pastejo moderadas proporcionam melhores resultados produtivos (Mezzalira et al., 2012), incrementam a biodiversidade (Boldrini, 1993; Fischer, 2013) e possibilitam menores emissões de gases de efeito estufa por produto animal gerado (Cezimbra, 2015). Apesar desses importantes avanços obtidos nas últimas décadas, sabe-se que o

processo de degradação de pastagens devido ao sobrepastejo é um problema que cresce anualmente na região sul e muitos dos serviços ambientais prestados por essas áreas deixam de ser efetivos.

O potencial de recuperação natural das áreas sobrepastejadas é, no entanto, ainda pouco conhecido e esta informação poderia auxiliar na tomada de decisão para eventuais necessidades de ações de recuperação complementares. A capacidade de recuperação natural dessas áreas irá depender do grau de degradação do ambiente, das condições climáticas e do histórico de evolução com a presença de herbívoros (Papanastasis, 2009). Nosso objetivo neste trabalho é compreender a capacidade de recuperação natural das pastagens naturais do Bioma Pampa após pastejo intenso por um longo período, por meio do diferimento, numa abordagem que contemple a produção primária do pasto, as respostas funcionais das espécies de plantas e o banco de sementes do solo.

Esta Tese é apresentada em quatro capítulos. O Capítulo I apresenta uma revisão bibliográfica sobre o processo de degradação de pastagens e alternativas de baixo aporte de insumos para a recuperação. No Capítulo II é apresentado um artigo com os principais efeitos da exclusão temporária do pastejo na vegetação e no banco de sementes do solo numa pastagem sobrepastejada e com pastejo moderado. No Capítulo III enfocamos a diversidade de espécies vegetais e sua relação com a capacidade de recuperação via sucessão ecológica dessas pastagens. Por fim, no Capítulo IV são apresentadas as considerações finais com implicações de técnicas de manejo para a recuperação de pastagens degradadas e indicações de futuros trabalhos neste tipo de ambiente.

## 2. REVISÃO BIBLIOGRÁFICA

### **2.1 Contexto do sobrepastejo em pastagens naturais**

O ecossistema pastagens cobre aproximadamente 3,5 bilhões de hectares, o que representa 26% da superfície terrestre e 70% da área agrícola, contendo cerca de 20% dos estoques de carbono do solo (FAOSTAT, 2009; Ramankutty et al., 2008). Além deste significante estoque que representa 50% a mais que a quantidade estocada pelas florestas (FAO, 2010), as pastagens contribuem na mitigação das mudanças climáticas globais por meio da sua capacidade de sequestro de carbono de 0.1 a 0.3 Gt por ano (Lal, 2004).

Nas últimas décadas, grande parte desses ecossistemas campestres utilizados economicamente como recurso forrageiro para a criação de herbívoros domésticos, passaram por um processo de substituição por outras formas de uso da terra. Apesar disso, dados da FAO (2010) destacam que a pecuária ainda é o ramo da agropecuária que mais cresce no mundo (compõe mais de 50% do PIB agropecuário em muitos países em desenvolvimento), evidenciando-se assim uma clara tendência de aumento da lotação animal nas áreas de pastagens remanescentes. Como consequência, grandes porções de pastagens em todos os continentes têm sido degradadas devido ao sobrepastejo (Oldeman, 1994).

Dentro desta tendência global situa-se a vegetação original das pastagens naturais que constituem os Campos (Allen et al. 2011), que historicamente forma um ambiente diverso (Boldrini, 1997) e com grande potencial para produção agropecuária (Nabinger et al., 2009). Este bioma compreende pastagens subtropicais localizadas no Sul do Brasil, Uruguai, nordeste da Argentina e parte do Paraguai, cobrindo cerca de 500.000 m<sup>2</sup> que representam o substrato forrageiro para 65 milhões de ruminantes domésticos (Berreta, 2001). A utilização ineficiente deste recurso associado a crescentes pressões de ordem econômica constituem as principais ameaças à sua conservação, processo resultante da substituição da vegetação nativa por outras formas de uso da terra, destacando-se os cultivos arbóreos e de grãos (Overbeck et al., 2007). Esta crescente pressão sobre vegetação nativa foi responsável pela perda anual de 135 mil hectares de pastagens naturais nas últimas duas décadas somente na porção brasileira e 110 mil hectares na porção uruguaia. Associada à essa descaracterização da paisagem original, é essencial destacar que o sobrepastejo é muito comum nas áreas remanescentes e origina perdas de biodiversidade, erosão do solo, susceptibilidade à invasão biológica, tendo como consequência a perda de serviços ecossistêmicos (Cruz et al., 2010).

Muitos fatores podem contribuir para a degradação das pastagens, incluindo causas naturais como períodos de seca prolongados, ou

interferências antrópicas como manejo inadequado do pastejo (Manzano & Návar, 2000). A vegetação nativa é capaz de se manter em equilíbrio com os animais silvestres devido às migrações que os mesmos fazem de uma área para outra deixando a área recém utilizada em diferimento, mas pode sofrer grandes distúrbios com a criação de animais domésticos (Fernandez et al., 2008; Tsubo et al., 2012; Nabinger et al., 2009). O sobrepastejo, principal causa da degradação de pastagens em todo o mundo (Mainguet, 1994; Daily, 1995) é causado pela utilização de um número de animais superior ao que pode ser suportado pela pastagem. Inúmeros estudos demonstram que o sobrepastejo pode causar alterações nas propriedades químicas, físicas e biológicas do solo (Ajorlo et al., 2011), na vegetação (Pei et al., 2008) e na ciclagem de nutrientes (Milchunas & Lauenroth, 1993; Manzano & Návar, 2000). Num primeiro momento, o pastejo severo ocasiona redução na altura e modificações na vegetação, assim como na cobertura da comunidade de plantas (Su et al., 2005). Com a remoção das plantas e seus resíduos que serviam como proteção ao solo, num segundo momento inicia-se o processo de compactação devido ao pisoteio dos animais, reduzindo a infiltração de água no solo, o que aumenta as chances de erosão e perdas de nutrientes (Dadkhah & Gifford, 1980).

## **2.2 Consequências do sobrepastejo em pastagens naturais: resultados de pesquisas com ofertas de forragem**

O entendimento das modificações nos processos ecossistêmicos fundamentais determinados pelo sobrepastejo constituem a base para a implementação de programas de recuperação. Nesta perspectiva, a definição da capacidade de suporte de ecossistemas pastoris por meio de estudos fundamentados no grau de intensidade de pastejo possibilita elucidar grande parte dessas alterações. O ajuste da oferta de forragem (OF) consiste em uma das formas de manejear a intensidade de pastejo (Nabinger, 1998), compreendendo a relação entre a quantidade de matéria seca por unidade de área e o número de unidades animais.

O presente trabalho insere-se numa linha de pesquisa baseada na utilização de diferentes ofertas de forragem (kg MS/100 kg PV dia, %) em pastagem nativa para a recria de novilhas de corte. Esta linha de pesquisa vem sendo desenvolvida desde 1986 pelo Departamento de Plantas Forrageiras e Agrometeorologia da UFRGS, e trouxe importantes contribuições científicas e tecnológicas em torno do potencial produtivo e na utilização sustentável da pastagem natural.

Já nos primeiros anos do experimento foram verificados benefícios da utilização de ofertas de forragem moderadas para a produção de forragem e desempenho animal (Maraschin et al., 1997). Observa-se na Figura 1 que tanto o ganho por animal como o ganho por área são superiores na OF moderada e inferiores em níveis extremos, especialmente na OF 4%, onde há a redução desses ganhos pela metade. Neste tratamento com maior intensidade de pastejo (4% de OF) ocorre maior proporção de solo descoberto, com massa de forragem variando entre 500 e 700 Kg de MS/ha e altura do estrato pastejado de 2 a 5 cm.

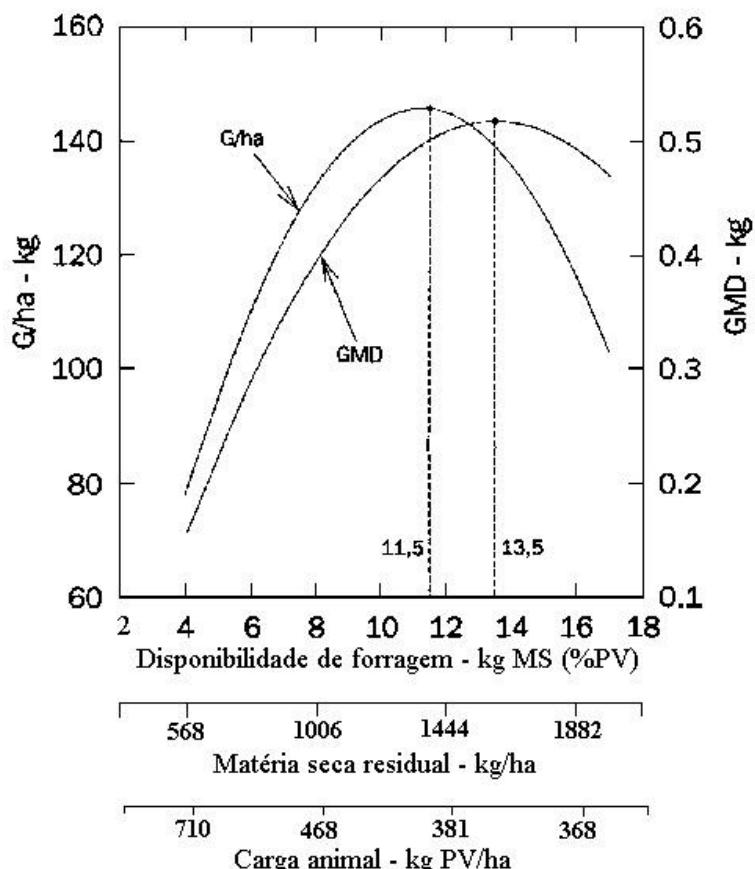


FIGURA 1. Efeito do nível de oferta de forragem sobre o desempenho de novilhos (G/ha – ganho por área kg PV/ha e GMD – ganho médio diário kg) em campo nativo e algumas características do pasto na Depressão Central do RS. adaptado de Maraschin et al., 1997).

A menor produção por área com a utilização de nível baixo de oferta de forragem (4% de OF) deriva de uma estrutura do pasto com menor quantidade de folhas verdes no dossel vegetal, determinando menor captação de energia luminosa, ou seja, menor fixação de carbono atmosférico. Esta limitada utilização da radiação solar foi demonstrada por Nabinger (2001) (Tabela 1), o qual estimou através do balanço de energia nos diferentes níveis de oferta de forragem do protocolo experimental apresentado por Maraschin et al. (1997), que ao passar de uma oferta de 12% (pastejo moderado) para 4% (área sobrepastejada), ocorre uma diminuição de 80% na eficiência do uso da radiação solar para produção de pasto. Quando esta relação foi estabelecida em função da produção animal, a diminuição de eficiência foi de 89%.

O reflexo dessa limitada captura de carbono é a diminuição substancial da taxa de crescimento do pasto (Figura 2) e, por consequência, da produção anual de forragem.

A manutenção dessa menor área de folhas na OF 4% (pastagem mais baixa), em comparação com o pastejo moderado, traz consequências também sobre o solo. Esta pastagem sobrepastejada apresenta normalmente menor acúmulo de material senescente tanto na parte aérea como subterrânea, impactando na menor cobertura do solo e assim aumentando as chances de

erosão (Bertol et al., 1998). Além disso, ocorre diminuição nos estoques de carbono total do solo, diminuição na taxa e na capacidade de armazenamento de água (Figura 3) e, da biomassa microbiana, resultando em menor fertilidade geral do solo.

Tabela 1. Eficiência de uso da radiação incidente em função de diferentes níveis de oferta de forragem (kg de MS/100 kg de peso corporal) a que foi submetida a pastagem natural na Depressão Central do Rio Grande do Sul (adaptado de Nabinger, 1998).

Eficiência de uso da radiação solar incidente	Oferta de forragem			
	4	8	12	16
Energia incidente/energia em MS produzida/ha	0,20	0,33	0,36	0,32
Energia incidente/energia em ganho de peso/ha	0,009	0,016	0,017	0,013

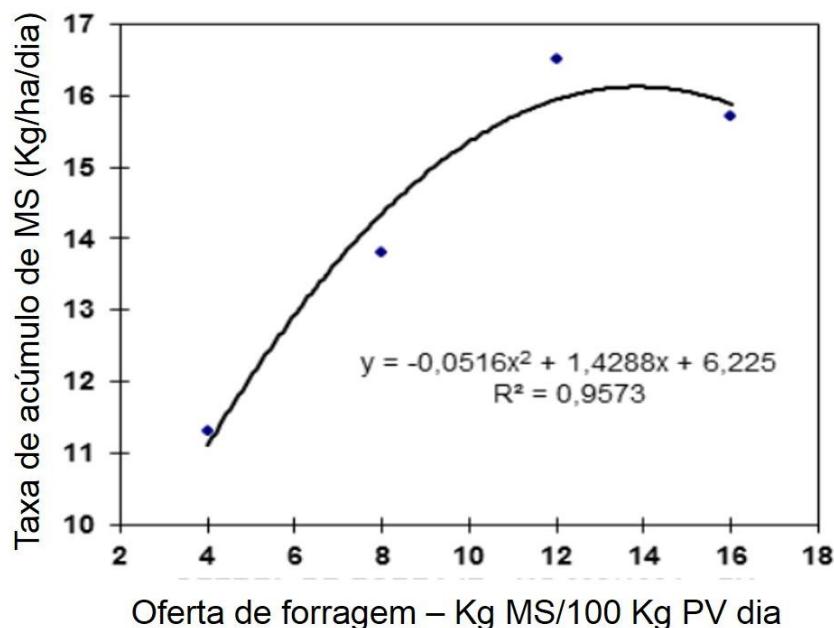


FIGURA 2. Taxa diária (média de primavera, verão e outono) de produção de forragem em pastagem natural sob distintas ofertas (kg MS/100 Kg PV/dia) (adaptado de Maraschin, 1997).

As consequências das ofertas de forragem sobre a diversidade de espécies também foram descritas neste protocolo experimental. De acordo com Carvalho et al. (2003) e Pinto (2011), a OF 4% apresenta valores inferiores de diversidade, comparativamente às ofertas de forragens mais conservadoras (a partir de 8%) (Figura 4). Conforme Maraschin (2001), no ambiente com menor oferta ocorre eliminação quase total das espécies de inverno, além de espécies formadoras de touceira, como *Andropogon lateralis*, *Eryngium horridum* e *Aristida* spp.

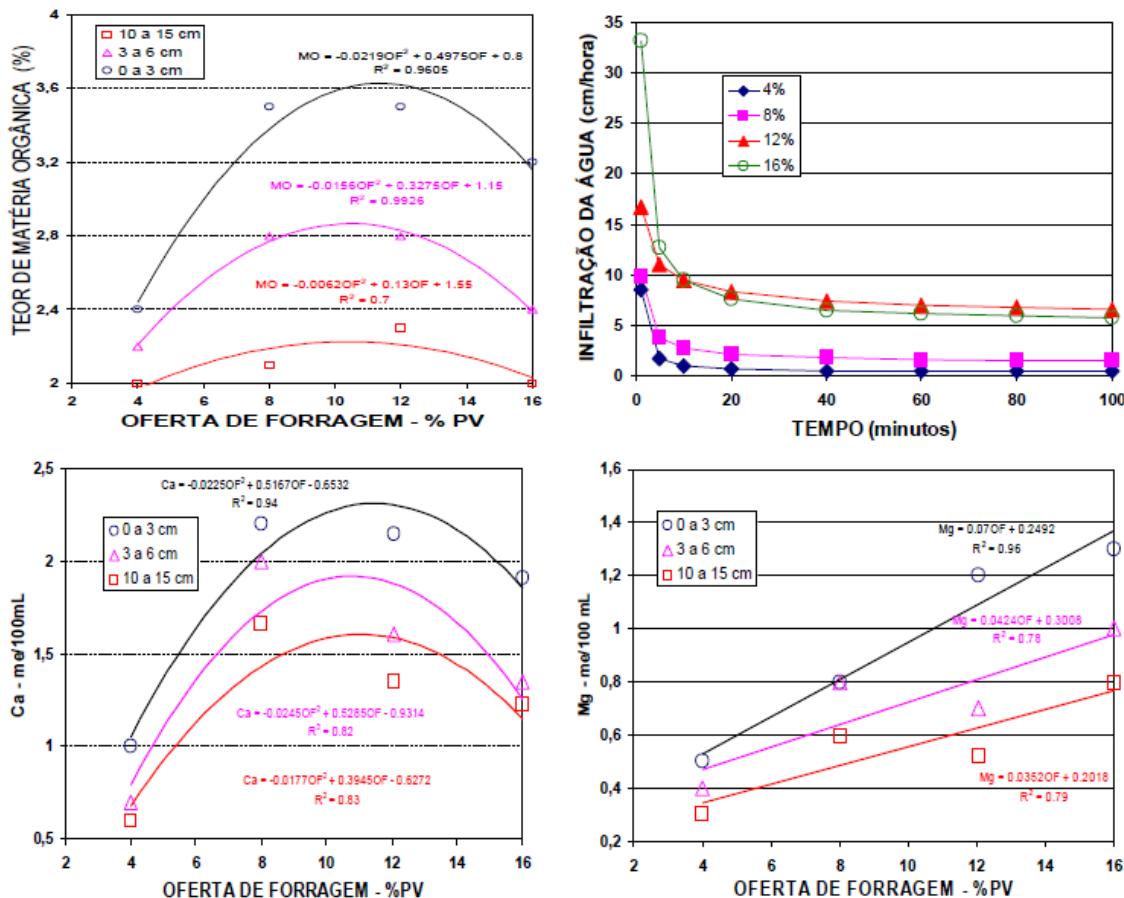


Figura 3. Efeitos dos diferentes níveis de oferta de forragem em pastagem natural na Depressão Central do Rio Grande do Sul sobre a matéria orgânica, taxa de infiltração de água e concentração de Ca e Mg no solo (Bertol et al., 1998).

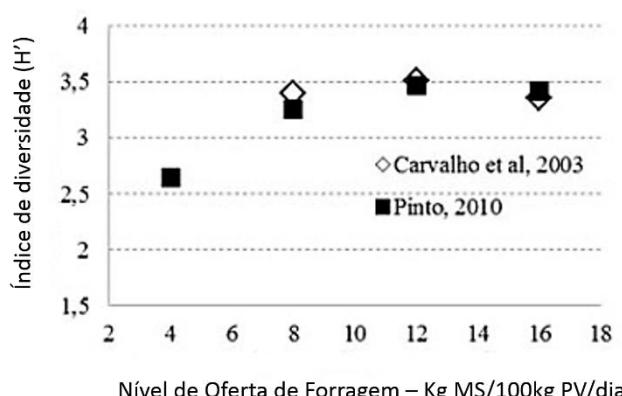


FIGURA 4. Índice de diversidade da pastagem natural sob distintas ofertas de forragem na região da depressão central do Rio Grande do Sul (Carvalho et al., 2003; Pinto, 2011).

Após verificar esses importantes efeitos de ofertas de forragem moderadas sobre o ecossistema pastoril, a partir de 1998 foram incorporados

novos tratamentos ao desenho experimental original, visando moldar a estrutura do pasto durante o período da primavera. Os trabalhos de Soares et al. (2005), Aguinaga (2004) e Pinto et al. (2008), demonstram que a variação estacional da oferta de forragem para 8% na primavera e a sua manutenção de 12% no restante do ano tem impactos positivos na produção primária e secundária (Tabela 2). Os autores verificaram ganhos superiores a 260 Kg/ha/ano apenas com esse manejo da estrutura do pasto, sem aplicação de qualquer insumo adicional.

Tabela 2. Eficiência de uso da radiação incidente em função de diferentes níveis de oferta de forragem a que foi submetida a pastagem natural na Depressão Central do Rio Grande do Sul (adaptado de Nabinger, 1998).

Oferta pretendida (kg MS/100 kg PV)	Estações do ano				Total anual
	Primavera	Verão	Outono	Inverno	
4	71,9	36,3	20,1	-10,7	117,7
8	110,3	49,7	23,5	-2,6	180,8
12	111,7	51,1	30,5	-4,2	189,1
16	89,9	30,3	31,9	-3,3	148,8
8-12	<b>160,3</b>	<b>52,5</b>	<b>37,8</b>	<b>12,2</b>	<b>263,0</b>

O reconhecimento de intensidades de pastejo que asseguram maior potencial produtivo do ecossistema em estudo permitiu grandes avanços no processo produtivo e ecológico dessas pastagens naturais, servindo como referência para o manejo das pastagens da região. Ao mesmo tempo, possibilitou a compreensão do processo degradativo da pastagem com a utilização de intensidades de pastejo elevadas, levando-se em consideração tanto as produções primária e secundária, composição florística e diversidade vegetal, além das características físicas e químicas do solo. As características dessa pastagem sobrepastejada inserem-se na definição de pastagem degradada descrita por Han et al. (2008): “a pastagem é considerada degradada quando ocorre uma diminuição na diversidade de espécies de plantas, altura de plantas, cobertura vegetal e a produtividade”.

### 2.3 Recuperação de pastagens naturais degradadas

A recuperação é definida como uma intervenção destinada a facilitar o reparo de um ecossistema ou paisagem (Hobbs & Harris, 2001) que passou por um processo de degradação, dano ou destruição. Os objetivos vinculados à sua utilização podem variar desde o reestabelecimento de espécies características de uma comunidade vegetal desejada (Young, 2000), até melhorias de atributos ecossistêmicos fundamentais, como estabilidade do solo, função hidrológica e integridade biótica (Herrick et al., 2006). No caso de pastagens naturais, esses objetivos normalmente incluem o aumento da

produtividade, valorização da diversidade das espécies nativas, controle de espécies invasoras e aumento de habitats para a fauna nativa. Para isso, é fundamental o estabelecimento de parâmetros que permitam a identificação da degradação do ambiente e de ecossistemas passíveis de utilização como áreas de referência (Aronsen et al. 1993).

Projetos para o reestabelecimento das funções ecossistêmicas presentes nos estados alvo devem considerar os processos que levaram à degradação das pastagens. Nesta perspectiva, Prober & Thiele (2005) sugeriram quatro etapas para o sucesso de um programa de recuperação: i) identificar ecossistemas alvo e as suas características antes da degradação; ii) compreender as causas das alterações; iii) definir estratégias para recuperar os processos originais e a biodiversidade; iv) definir um manejo alternativo que permita a manutenção do novo padrão estabelecido.

### **2.2.1 Definição de ecossistemas alvo**

A identificação de ecossistemas alvo envolve uma criteriosa avaliação das características e potencialidades locais, aspecto essencial para a formulação de objetivos claros e embasados em estratégias biologicamente possíveis, economicamente viáveis e socialmente aceitáveis (Hobbs, 2007). No entanto, a definição desses sistemas referência bem como o monitoramento da efetividade das técnicas de restauração são aspectos de natureza complexa, sendo que os resultados alcançados em um ecossistema específico possuem características próprias, não permitindo totalmente a sua transferência para outros locais (Hobbs & Norton, 1999). Os fatores que influenciam a dinâmica dessas respostas envolvem a composição do ecossistema, estrutura, função, heterogeneidade e resiliência (Hobbs & Norton, 1996). Cada ecossistema alvo apresenta, portanto, características inerentes ao seu processo de formação e deve ser selecionado com base nos resultados almejados pelo programa de recuperação.

Monaco et al. (2012) classificaram os ecossistemas alvo em três tipos, com características contrastantes advindas da sua condição histórica de utilização:

Referência histórica do ecossistema: é definido como um estado original do ecossistema, sem alterações advindas da ação antrópica, com a composição de espécies e condições abióticas intactas. Apesar da atividade humana estar envolvida, ao menos indiretamente, em todos os ecossistemas terrestres (Vitousek et al., 1997) este conceito é especialmente utilizado em áreas de reservas e parques nacionais de conservação. Nos Campos naturais do Sul do Brasil, debates surgem com relação aos reais ganhos ecossistêmicos decorrentes da manutenção de áreas ausentes de manejo antrópico, visto que na ausência de pastejo ou fogo ocorrem perdas em diversidade florística e estrutural (Overbeck et al., 2009).

Ecossistemas emergentes: De acordo com a definição de Hobbs et al. (2013), “os ecossistemas emergentes são sistemas constituídos de componentes bióticos, abióticos e sociais (e suas interações) que, devido a influência da atividade humana, diferem dos ecossistemas nativos. Possuem tendências de auto-organização e manifestam propriedades emergentes sem a presença de manejo intensivo”. Esse novo padrão resulta da ação humana na

confecção dos chamados agro-ecossistemas, que exibem novas funções e estados de organização das comunidades de plantas. Esses sistemas alternativos podem ser adotados quando um ecossistema natural não pode ser utilizado como uma referência adequada, devido a restrições ecológicas, sociais ou econômicas. Deve-se dar prioridade a sistemas alvo emergentes que possibilitam a prestação de serviços ecossistêmicos e asseguram resiliência após distúrbios.

Sabe-se que a interferência humana está acentuando a proporção desses “novos” ecossistemas a taxas sem precedentes e existe, portanto, a necessidade de gerenciar esse novo modelo de maneira responsável. No entanto, medidas cautelares devem ser tomadas com a adoção desses sistemas de referência, muitas vezes com poucas evidências de persistência, auto-organização e de real prestação de serviços ecossistêmicos. Simberloff et al. (2015) comentam que, ecossistemas emergentes adotados como modelo para projetos de recuperação em detrimento de ecossistemas naturais podem, em alguns casos, representar uma ameaça à conservação da biodiversidade, prestação de serviços ecossistêmicos e adaptabilidade frente a flutuações climáticas.

Ecossistemas híbridos: Os ecossistemas híbridos apresentam elementos dos ecossistemas naturais, porém com composição de espécies ou alguns elementos de ecossistemas antropizados. Eles se diferenciam dos chamados “ecossistemas emergentes” pelo fato de ainda terem capacidade de retorno das características fundamentais predominantes em ecossistemas nativos, em detrimento dos sistemas emergentes que não possibilitam retorno às condições originais (Hobbs et al. 2009). Um exemplo de um ecossistema híbrido seria uma pastagem nativa com interferências antrópicas ligadas ao manejo do pastejo. No caso do presente trabalho, foi utilizada como área de referência uma pastagem nativa manejada com intensidade de pastejo moderada. Essa condição de pastejo moderado, em detrimento de intensidades de pastejo extremas, possibilitou uma melhor prestação de serviços ecossistêmicos, como a produção de forragem de qualidade para um melhor desempenho animal (Mezzalira et al., 2012), diversidade de espécies (Pinto, 2011; Carvalho et al., 2003), além cobertura e qualidade do solo (Bertol et al., 1998).

### **2.2.2 Influências de estratégias de manejo e características históricas locais para recuperação de pastagens degradadas**

Para a recuperação de pastagens degradadas normalmente são utilizadas técnicas que incluem a fertilização, correção de acidez, introdução de espécies nativas ou exóticas, irrigação e controle de espécies invasoras com herbicidas (Ballesteros et al., 2012; Kirmer et al., 2012). Estas práticas ditas “ativas” de recuperação são fundamentais para o reestabelecimento da produção primária da pastagem e, dependendo das particularidades de cada região ou sistema de produção, podem ser a única alternativa para a recuperação em estágios avançados de degradação. Estudos recentes, no entanto, mostram que a exclusão temporária do pastejo tem se mostrado como uma maneira efetiva de recuperação, incluindo o reestabelecimento da vegetação original e de propriedades do solo (Wu et al., 2009; Shang et al.,

2013).

A efetividade da recuperação natural da pastagem por meio de ajustes na intensidade de pastejo irá depender das condições em que a pastagem se encontra. De acordo com Whisenant (1999), a recuperação espontânea da pastagem, via sucessão ecológica promovida pela exclusão do pastejo, irá depender fundamentalmente do estado de conservação de alguns processos primários como a qualidade dos solos e a dispersão de propágulos de plantas, além de adequada umidade do solo (Wang et al., 2013).

Grime (2002) demonstra que a disponibilidade de nutrientes no solo é um aspecto relevante na resiliência de ecossistemas, o que certamente implica no sucesso da recuperação de pastagens naturais degradadas. Quando submetidos a pressões acentuadas de pastejo, ecossistemas que não apresentam acentuada limitação nos recursos de nutrição mineral apresentam uma rápida produção de sementes, levando a uma limitada produtividade, porém com grande resiliência. Já em ecossistemas com limitação de nutrientes, há diminuição na produtividade, na decomposição do mantilho (o que leva a uma menor taxa de mineralização da matéria orgânica) e na resiliência dos ecossistemas.

Papanastasis (2009) demonstra que o papel do manejo do pastejo na recuperação de pastagens é mais significativo em áreas que possuem um histórico de longo prazo com a presença de herbívoros. Cingolani et al. (2005) demonstrou que ecossistemas naturais que co-evoluíram com a presença desses animais apresentam uma gama superior de recursos estratégicos para proporcionar a recuperação dessas áreas depois de pastejos intensos. A presença de herbívoros nessas áreas é tão importante, que inclusive alguns processos ecossistêmicos poderiam não ser reestabelecidos em programas de recuperação caso os animais fossem excluídos completamente da pastagem por um longo período (Papanastasis, 2009). Uma evidência acerca dessa característica foi reportada por Loydi et al. (2012), que observaram que as pastagens naturais dos Pampas da Argentina apresentaram grande potencial de recuperação após um longo período de alta intensidade de pastejo utilizando-se somente o derrimento para a reabilitação das mesmas. Os autores atribuíram a rápida recuperação ao grande potencial produtivo das pastagens da região e ao histórico de co-evolução com o pastejo, e concluem que é possível a restauração dessas áreas sem a utilização de insumos externos.

O processo de co-evolução entre as pastagens naturais do Sul do Brasil e os herbívoros, no entanto, é ainda desconhecido. Na época da introdução do gado pelos jesuítas nas Missões do Rio Grande do Sul (século XVII), os animais pastadores da região eram de pequeno porte e realizavam pressão de pastejo localizada (Behling et al., 2009). Há, entretanto, evidências de que esses campos originalmente sustentavam uma megafauna pastadora durante o Plioceno superior e, mais recentemente, grandes mamíferos pastadores (espécies semelhantes ao cavalo (Eqüídeos) e lhama (Camelidae)) até cerca de 8,5 mil anos atrás (Sherer & Da Rosa, 2003, Scherer et al, 2007). Mesmo com a presença de tais indícios, é necessária uma melhor compreensão da real intensidade de pastejo exercida nessas áreas, para assim inferir sobre uma possível co-evolução desses ecossistemas com o pastejo.

### 2.2.3.1 O dferimento de pastagens como estratégia de recuperação de pastagens degradadas

O processo de domesticação de animais selvagens por meio do controle da herbivoria implica na tentativa de mimetizar e suprir algumas das condições ambientais nas quais os herbívoros evoluíram. O dferimento de pastagens é uma característica natural que os próprios herbívoros selvagens o fazem, quando migram de uma região para outra (Nabinger et al., 2009) em busca de melhores condições estruturais do pasto. Isso faz com que a área em exclusão do pastejo acumule forragem, estratégia que também é utilizada em estabelecimentos agropecuários no manejo de pastagens visando a reserva de pasto para períodos do ano de menor produção. Apesar de tal finalidade ser o principal motivador da utilização desta técnica, o dferimento pode contribuir para o estabelecimento de sistemas de produção mais sustentáveis advindos de maior provisão de importantes serviços ecossistêmicos, como cobertura do solo, acúmulo de matéria orgânica e produção de sementes.

O dferimento tem efeitos benéficos mais evidentes na recuperação de pastagens sobrepastejadas do que em locais que apresentem boas condições produtivas (Sampson, 1951). O principal incremento visível é, evidentemente, o acúmulo de massa de forragem, que deve ser realizado em épocas favoráveis de crescimento vegetal para ser utilizada em época desfavorável. Nabinger et al. (2009) também relatam que o pastejo dferido pode servir de excelente meio para adequar a lotação em função da produção estacional das pastagens naturais, ao constituir áreas de reserva de forragem em pé. Na região da Campanha do estado do Rio Grande do Sul, por exemplo, o dferimento de primavera permite acumular forragem para o período normalmente seco, que ocorre a partir de dezembro. Já em regiões que apresentam baixa produção de forragem durante o período de inverno, por existir poucas espécies forrageiras de produção hibernal, o dferimento no final de verão-outono, permite acumular forragem para final de outono e início de inverno.

De acordo com Nabinger et al. (2009), o dferimento pode atender a vários objetivos. Baseado na distinta fenologia das espécies que compõe o campo nativo, é possível estimular a ressemeadura de espécies forrageiras desejáveis das quais se tenha interesse em que aumentem a sua participação na pastagem. A exclusão do pastejo realizada na primavera favorece a produção de sementes de inúmeras espécies nativas de inverno, como brizas (*Chascolytrum* spp), flechilhas (*Nasella* spp e *Piptochaetium stipoides*), cevadilhas (*Bromus catharticus* e *Bromus auleticus*), trevo polimorfo (*Trifolium polimorphum*), trevo-carretilha (*Medicago polymorpha*), babosas (*Adesmia* spp). Além das supracitadas, inúmeras espécies forrageiras de ciclo estival que apresentam florescimento no final da primavera podem ser beneficiadas com o dferimento neste período, destacando-se importantes gramíneas forrageiras do gênero *Paspalum* (*P. notatum*, *P. dilatatum*, *P. nicrae* e *P. urvillei*) e leguminosas como estilosantes (*Stylosantes* spp). O dferimento realizado no final de verão-outono apresenta como característica o favorecimento também das espécies de ciclo estival acima citadas, além de leguminosas como *Desmodium* spp, *Macroptilium prostratum*, entre outras.

O dferimento também pode melhorar a qualidade do solo. Uma das

possíveis consequências da utilização de altas intensidades de pastejo por um longo prazo é a degradação dos recursos edáficos. A compactação do solo causada pelos animais em pastejo determina redução no crescimento da pastagem devido a diminuição da umidade do solo, que é ocasionada pela infiltração mais lenta da água e perdas por escorrimento superficial (Moraes & Lutosa, 2006). A exclusão do pastejo pode contribuir para a recuperação dessas áreas, por meio de estímulo ao desenvolvimento radicular, aumento da cobertura de solo e do mantilho, que podem inclusive determinar acúmulo de matéria orgânica. Rodrigues et al. (2010) verificaram um aumento de 35% na biomassa de raízes encontradas em profundidades maiores que 10 cm por ocasião do deferimento de outono. Ataide (2015) verificou que o deferimento aplicado na primavera proporciona aumento da biomassa aérea e subterrânea quando aplicado em ambientes com longo histórico de sobrepastejo. O autor conclui que esta prática pode contribuir para a resiliência da comunidade de plantas frente a condições climáticas desfavoráveis.

#### **2.2.4 Papel do banco de sementes**

O potencial para a recuperação de pastagens degradadas, especialmente em ecossistemas constituídos basicamente por espécies de ciclo anual, depende também da composição do banco de sementes do solo (Bakker & Berendse, 1999). Pakeman & Small (2005) comentam que o banco de sementes tem grande participação na sucessão secundária da comunidade depois de distúrbios tanto de longa como de curta duração.

Já nas pastagens do sul do Brasil, constituídas em sua grande maioria por espécies perenes, o banco de sementes tem apresentado um papel limitado na sucessão secundária da vegetação. Os trabalhos de Vieira (2013) e Minervini-Silva (2014) são unâimes em apontar que o banco de sementes das pastagens naturais do sul do Brasil apresenta pouca importância na recuperação da vegetação nativa de áreas alteradas. Essa conclusão ocorreu devido à grande concentração de espécies ruderais e poucas espécies predominantes na vegetação estabelecida em pastagens bem manejadas.

A relação entre o banco de sementes e a vegetação estabelecida apresenta normalmente diminuição de semelhanças de acordo com o aumento da estabilidade da vegetação. Vieira (2013) observou que intensidades de distúrbios crescentes favorecem o aparecimento de espécies ruderais tanto no banco de sementes como na vegetação, aumentando, então, a semelhança. Em pastagens naturais típicas e bem manejadas, por outro lado, as espécies dominantes na vegetação estabelecida foram em sua maioria ausentes no banco de sementes, embora este ainda tenha apresentado muitas espécies ruderais. Isso acontece porque a ausência de distúrbios favorece a reprodução clonal das plantas, enquanto que situações de estresse favorecem espécies com maior reprodução sexual (Matus et al., 2005).

A vegetação estabelecida do bioma Pampa é dominada por gramíneas, com mais de 80% de cobertura do solo (Minervini-Silva, 2014; Boldrini, 2009; Pinto et al., 2011). Existe a necessidade, portanto, de se estudar exclusivamente a dinâmica desta família botânica no banco de sementes em resposta a diferentes estratégias de manejo. Mesmo sabendo que as espécies ruderais apresentam dominância no banco de sementes, é necessário o

conhecimento das respostas dos principais grupos de gramíneas no banco de sementes e as estratégias de manejo que possibilitem o seu incremento.

### **2.2.5 Diversidade e padrões espaciais da comunidade**

A presença de herbívoros em pastagens altera a estrutura e composição das mesmas. Laca (2011) comenta que a desfolhação, o pisoteio e a concentração de nutrientes na matéria fecal e urina promove heterogeneidade adicional à variação natural do solo, o que não necessariamente indica uma condição indesejável. Num primeiro momento, a desfolhação influencia a diversidade de plantas devido à redução da competição (Collins et al., 1998), oportunizando o crescimento de algumas espécies que seriam suprimidas (Adler et al., 2001).

A hipótese de distúrbio intermediário (*intermediate disturbance hypothesis*) descrita por Connell (1978) mostra que a diversidade de plantas é superior em níveis intermediários de intensidade de pastejo. Já o modelo do equilíbrio dinâmico (Houston, 1979) sugere que intensidades de pastejo moderadas apresentam efeitos positivos na diversidade em ambientes altamente produtivos e negativos em sistemas com baixo potencial de produção. Posteriormente, esses modelos foram reformulados por Milchunas (1988), que adicionou o histórico de evolução com herbívoros numa perspectiva regional. O modelo propõe que intensidades intermediárias de pastejo em locais de clima sub-úmido com longo histórico de evolução com a herbivoria ocorre a formação de duplo estrato, com a presença de touceiras e uma vegetação inferior composta por espécies mais palatáveis e prostradas, o que favorece a maior diversidade de plantas. Com a excessiva intensidade de pastejo nestes ambientes, o modelo propõe a predominância de espécies de hábito prostrado e homogeneização da vegetação, diminuindo-se a diversidade.

McNaughton et al. (1983) verificaram que o pastejo cria diferentes padrões de distribuição das plantas em escalas espaciais, o que também determina importante efeito na biodiversidade. A modificação dos padrões espaciais das plantas pode alterar também as interações inter e intraespécificas, os padrões de dispersão de propágulos e tornar habitats impróprios para fauna com requisitos estruturais específicos (Tirado & Pugnaire, 2003). Agregações interespécificas podem levar a uma coexistência de patches de plantas com tipos funcionais contrastantes (Schamp et al., 2008), e afetar inúmeros processos locais da comunidade, como decomposição do mantelho, eficiência no uso de recursos e produção de biomassa. A descontinuidade dessas zonas homogêneas é, portanto, importante para a estrutura dos ecossistemas pois influencia a sua diversidade, sucessão e a estabilidade. Existem, no entanto, poucas informações que predizem os efeitos do pastejo na distribuição espacial das espécies em ambientes pastoris (Navarra & Quintana-Ascencio, 2012).

Os efeitos do pastejo nos padrões espaciais da vegetação podem ser investigados por meio da verificação da existência ou não de dependência espacial, que é determinada pelas relações dos valores de uma determinada variável em diferentes locais. Dependência espacial significativa indica um padrão não aleatório, enquanto que a independência espacial implica em

aleatoriedade da distribuição. Segundo Adler et al. (2001), dependências espaciais fortes estão associadas a uma distribuição heterogênea, enquanto que a dependência espacial fraca está relacionada com homogeneidade ou vegetação não estruturada.

### **2.2.6 Utilização de grupos funcionais de plantas para guiar a recuperação de pastagens**

A classificação de plantas de acordo com tipos funcionais permite o agrupamento de espécies que respondem de maneira similar a um fator ambiental específico, como o pastejo, disponibilidade de nutrientes e características climáticas (Lavorel et al., 1997; McIntune & Lavorel, 2001). A relevância desta abordagem para o manejo de ecossistemas tem sido bastante reconhecida nos últimos anos, pois possibilita a criação de “uma linguagem comum” na divulgação dessas respostas. Esta classificação, em detrimento da simples constatação da identidade taxonômica, além de possibilitar uma maior abrangência dos resultados gerados e viabilizar a comparação de respostas em diferentes locais, é um padrão necessário para o desenvolvimento de previsões dos efeitos de manejo.

A identificação das relações entre os tipos funcionais de plantas e fatores ambientais é um objetivo tradicional na área de ecologia de plantas. De acordo com Díaz et al. (2002), os tipos funcionais podem ser utilizados para monitorar a estrutura e função dos ecossistemas, avaliar impactos ecológicos, além de determinar seu estado de conservação e capacidade de provimento de serviços ecossistêmicos e, com isso, propor estratégias de manejo apropriadas. Neste contexto, Burylo et al. (2014) e Lavorel & Garnier (2002) atestam que a utilização de grupos funcionais é também uma ferramenta promissora para guiar práticas de recuperação de uma comunidade de plantas ou ecossistemas degradados. Desta forma, alterações na composição botânica das pastagens decorrentes de fatores ambientais específicos, e consequentemente dos serviços ecossistêmicos por elas prestados, são situações que poderiam ser previstas com a utilização de grupos funcionais, possibilitando, a escolha de métodos adequados de recuperação.

As respostas funcionais das plantas ao pastejo foram descritas por Díaz et al. (2007). De maneira geral, as plantas com hábito de crescimento ereto tendem a responder negativamente ao pastejo, ao passo que plantas prostradas respondem positivamente. Ao mesmo tempo, o pastejo favorece o desenvolvimento de espécies estoloníferas e rosetadas, em detrimento de espécies cespitosas. Em ecossistemas úmidos, a palatabilidade também é outro aspecto que foi influenciado pelo pastejo, ocorrendo normalmente melhoria deste atributo com maior intensidade de pastejo, em decorrência de uma rápida renovação dos tecidos das plantas.

O conhecimento dessas alterações é um aspecto que permite elucidar as causas das alterações funcionais em pastagens sob pastejo severo, e direcionar práticas de recuperação na direção do sistema alvo desejado. Numa situação de modificação funcional de comunidades de plantas mediada pelo sobrepastejo, por exemplo, o monitoramento do sucesso de um programa de recuperação específico, como a remoção do pastejo, poderia ser realizado por meio da verificação da existência de modificações funcionais na

comunidade de plantas e, principalmente, suas relações com os ecossistemas alvo.

## HIPÓTESE DO TRABALHO

A exclusão temporária do pastejo é uma alternativa para a recuperação de pastagens naturais degradadas por sobrepastejo, por determinar modificações na composição botânica e no banco de sementes na direção de sistemas de referência apropriados (pastagem natural manejada com moderada intensidade de pastejo por um longo período) e por favorecer a produção primária e a interceptação luminosa. Essas respostas podem variar com a época de dferimento quando ocorre a co-existência de plantas fenologicamente distintas.

## OBJETIVOS

- Verificar a capacidade de resiliência de uma pastagem natural do Bioma Pampa submetida ao sobrepastejo por um longo período, e analisar os resultados tomando como base um sistema de referência (pastagem natural manejada com pastejo moderado por um longo período).
- Compreender o papel da exclusão do pastejo em diferentes estações do ano nas mudanças da composição botânica, dos tipos funcionais, da biomassa de forragem, da altura e da interceptação luminosa em pastagens com intensidade de pastejo severa e na área de referência.
- Verificar o efeito do diferimento nas alterações dos padrões de similaridade entre as espécies do banco de sementes do solo e aquelas presentes na vegetação estabelecida.
- Estudar o efeito da exclusão do pastejo em diferentes estações do ano na diversidade e na riqueza de espécies vegetais em áreas sob pastejo moderado e intenso por um longo período, e suas relações com o agrupamento espacial das plantas.

## CAPÍTULO II

### **Plant community and soil seed bank responses to temporary grazing exclusion in overgrazed subtropical rangeland<sup>1</sup>**

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<sup>1</sup> Elaborado de acordo com as normas do periódico *Rangeland Ecology & Management* (Apêndice 1)

## **Plant community and soil seed bank responses to temporary grazing exclusion in overgrazed subtropical rangeland**

### **ABSTRACT**

Adequate grazing management is increasingly recognized as a tool to improve key ecosystem services in grasslands throughout the world. However, land degradation is advancing over wide areas due to overgrazing and restoration techniques frequently includes intensive improvements (i.e., irrigation, fertilization, introduction of forage crops). We investigated the impact of temporary grazing exclusion on the South Brazilian *Campos* grassland aiming at restoration of the vegetation composition, aboveground biomass, sward height, light capture, and at understanding the role of the soil seed bank to restore these lands. Vegetation was assessed in seasonal enclosures established in spring 2011 and fall 2012 in pastures that had been a) overgrazed and b) subjected to moderate grazing (target restoration system), for more than 25 years. After two years of short periods of grazing exclusions regardless the time of the year, we observed in the overgrazed pasture a directional change towards the dominant grasses from well-managed grasslands. This shifts in community structure led to changes in aboveground biomass, sward height and light capture, mainly when grazing exclusion was applied during spring. Further, many important grasses for livestock production composed the soil seed bank in excluded areas. Alternatively, pastures under moderate grazing intensity did not respond to grazing exclusion during the experimental period according the studied parameters. Our findings reveals the importance of the temporary grazing exclusion as a useful tool for the restoration of overgrazed natural grasslands.

### **KEY WORDS**

Restoration, *Campos* grasslands, sward light interception, aboveground biomass,

grazing intensity.

## **INTRODUCTION**

Grazing by livestock is the main changing process of vegetation structure on natural grasslands (Yan et al. 2013, Díaz et al. 2007), determining also important modifications on environmental services provided by this ecosystem (Lemaire 2007). It is well known that grazing effects can differ according to edaphoclimatic characteristics and the evolutionary history of grazing (Milchunas et al. 1988, Cingolani et al. 2005). When the intensity of this disturbance is in equilibrium with the carrying capacity of the pasture, it allows both conservation of biodiversity and livestock productivity (Maraschin 2001, Nabinger et al. 2011). However, this synergism can be drastically altered when overgrazing occurs (Müller et al. 2013), which is the main cause of pasture degradation of worldwide lands (Oldeman 1994, Zhang et al. 2014).

Ecological restoration is one strategy for ecosystem services re-establishment in degraded areas, and the common first step involves the implementation of optimal stocking regimes (Campbell et al. 2006). The reduction in grazing intensity or temporary grazing exclusions are the starting points for the vegetation recovery, giving the plants the opportunity to grow, to produce seeds and accumulate reserves (Nabinger et al. 2009).

The importance of the soil seed bank to restoration of degraded natural grasslands is a controversial point in South America studies (Garcia 2005, Haretche & Rodríguez 2006, Vieira 2013), due to the low similarities with aboveground components. These studies usually report large participation of ruderal species in the seed bank, in contrast to the low amount of seeds from predominant species of the

established vegetation. However, the specific dynamic study of these plant families dominant in the aboveground vegetation is crucial for evaluating the potential for recovery degraded areas.

The *Campos* grasslands are a typical example where overgrazing degradation process occurs. These grasslands extend over large parts of Southern Brazil, Uruguay, northeastern Argentina and part of Paraguay. They are characterized by a high floristic diversity, with approximately 2500 plant species only for the Brazilian portion (Boldrini et al. 2010). Even though these grasslands provide valuable economic and ecosystem services, they are critically threatened by changes in land use (Díaz et al. 2007). The constant economic pressures to make these lands more productive, has led to the conversion of grasslands in croplands, causing biodiversity losses and landscape fragmentation. At the same time, most of the remaining native grasslands are overgrazed (Bilanca & Miñarro, 2004). This leads to decreases in the abundance of the best forage species, modification of soil properties, causing, ultimately, losses in both biodiversity and productivity.

The process to restore these degraded grasslands usually involves vegetation improvements by fertilization, introduction of species, irrigation or control of invasive species with herbicides (Ballesteros et al. 2012; Kirmer et al. 2012). These active recovery practices are fundamental to pastures rehabilitation and can be the only way to recovery in advanced degradation stages. However, when degradation is restricted to biotic functions or when abiotic functions has not been irreversibly damaged (Papanastasis 2009), spontaneous vegetation succession or natural recovery is an alternative approach to restoration, maintaining natural processes like biodiversity and natural habitats of many native birds and mammals (Zalba & Cozzani 2004). Our

proposal is to understand if pastures with long overgrazing period, but without problems regarding water deficits, as in the case of *Campos* grasslands, have the potential for recovery of ecosystem functionality to levels found in reference systems (i.e, well managed grassland) by a passive restoration method.

This work aims to assess the role of the temporary grazing exclusion for vegetation successional changes, plant functional types and pasture primary production in grasslands with a long history of overgrazing. Our hypothesis was that the pastures of the study area shows great resilience, and that even several years under intense disturbance, would response quickly and positively to removal of cattle. Moreover, we expect to observe a directional change in species composition and soil seed bank towards species typical for areas under moderate grazing intensity (target ecossistem). We predicted that the seasons of grazing exclusions would influence the efficience of these responses due the coexistence of species with differents growing season.

## METHODS

### **Site description, treatments and experimental design**

This experiment was conducted in the context of a long-term experiment with different grazing intensities at the Research Station of the Federal University of Rio Grande do Sul (lat 30°05'S, long 51°40"W, and 46 m a.s.l.), Brazil. The climate at the experimental site is humid subtropical, with an annual average precipitation of 1440mm, evenly distributed throughout the year, and mean air temperature between 9 and 25°C (Bergamaschi & Guadagnin, 2003). A soil water deficit above the climate normal tendency occurred during the first months of the experiment (Fig. 1). The soils are classified as Rhodic Paleudult and Typic Plinthudult classes (US Department of

Agriculture 1999).

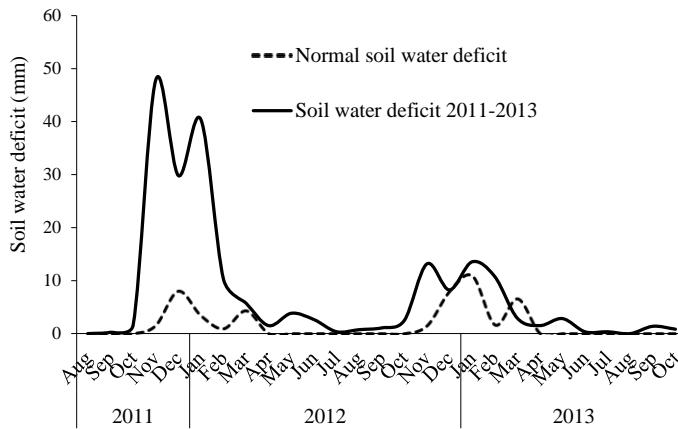


Figure 1. Soil water deficit during the experimental period.

Since 1986, the experimental area has been managed with continuous stocking (see Mezzalira *et al.* 2012 for details of the entire protocol). Treatments consisted of two levels of grazing intensities adjusted by contrasting daily forage allowances: 1) Severe: 4 kg of dry matter per 100 kg of animal's body weight per day throughout the year and 2) Moderate: 8 kg of dry matter per 100 kg of animal's body weight per day during spring and 12 during the remainder of the year. Stocking rates were adjusted every 28 days using the put and take technique (Mott and Lucas, 1952). The Severe grazing intensity treatment has resulted in an overgrazed pasture during the course of the experiment, while the moderate treatment is the grazing intensity with best aboveground net primary productivity and animal performance (Soares *et al.* 2005, Mezzalira *et al.* 2012). The historical results attested the degradation process of the grassland under severe grazing intensity: the forage and animal production in this grazing intensity was respectively 1190 and 70 kg/ha/year of forage dry matter and live weight, in contrast to the moderate grazing intensity that produced 3867 and 260 Kg/ha/year, respectively (Soares *et al.* 2005, Mezzalira *et al.* 2012). Severe grazing also

affected the soil physical and chemical properties (decreased soil water infiltration, porosity, aggregation and organic matter content, and increased soil bulk density) (Bertol et al. 1998, Conte et al. 2011), and diversity of botanical species (Carvalho et al. 2013).

In each of the two grazing intensities selected for this study, the following grazing exclusions treatments were applied: removal of grazing during spring (RS), removal of grazing during fall (RF) and control (continuous stocking all year round) (CG). The experiment was performed from spring 2011 (November, 25) until end of fall 2013 (July, 14). Therefore two periods of grazing exclusion occurred for both RS and RF. Experimental units were plots of 8 x 15m, allocated in completely randomized design with three replicates within each grazing intensity.

### **Analysis of vegetation composition**

Five permanent square of 1m<sup>2</sup> (sub-plots) were systematically fixed, nested within each plot. Vegetation sampling was conducted five times during the time of the experiment: a start point (before the implementation of the treatments) and two annual assessments (after spring and after autumn, during two years). All species were identified and their absolute coverage was visually estimated by using a decimal scale (Londo, 1976). Specimens that could not be identified in the field were collected outside the sample units and identified by consulting the specific taxonomic literature and specialists of the families in question.

Grass species were classified as proposed by Rosengurtt (1979), which is the most widely accept guide in the management of natural grasslands in Uruguay and South Brazil. The taxonomic species were classified into functional groups according to

growth season (cool or warm), life cycle (perennial or annual), growth habit (erect or prostrate) and forage value (high, good, moderate and low). These plant functional traits were selected based in the common plant responses to grazing, as proposed by Díaz et al. (2007). The first letter of each parameter was used to codify the species groups, i.e.: WPEL group consists of species growing in warm season, perennial life cycle, erect growth habit and low forage value (see Appendix 1 for grass species in each group). These species groups were used also for classification of species from the soil seed bank.

### **Analysis of sward structure: Forage mass, sward height and sward light interception**

The sward structure parameters were evaluated monthly in each sub-plot, and all measurements were carried out with non-destructive methods. The double sampling technique described by Wilm et al (1944) was used to estimate forage mass (FM), and sward height (H) was measured with sward stick (Barthram 1985) taken five measurements per sub-plot. The sward light interception (SLI) was measured by using a portable sensor of photosynthetically active radiation (PAR), proposed by Carassai (2010). The SLI was estimated considering PARint (intercepted) and PARinc (incident) by the expression:

$$\text{SLI} = \text{PARint}/\text{PARinc}$$

The PARint was calculated as function of PARinc and PART (transmitted through culture to the ground) by the expression:

$$\text{PARint} = \text{PARinc} - \text{PART}$$

### **Analysis of soil seed bank**

The soil seed bank (SSB) was sampled at the end of February (2013), i.e. shortly

before the end of the experiment. The aim was to quantify the viable seeds stored in the soil before the germination of cool season species (starts about April to June) and after a peak of seeds dispersal of warm season species (November until the end of January). The samples were collected in each sampling unit, aiming to identify changes in the SSB among treatments and to relate them to mid-term changes in aboveground botanical composition. Following the methods recommended by Roberts & Nielson (1982), we collected 3 cylindrical soil cores (5 cm diameter) at each sample unit from the top soil layer (0-10 cm).

The three sampled soil cores of each sample unit were crumbled, freed of stones and vegetative materials and combined to form a single sample. Each sample was air dried and placed in aluminum trays with addition of vermiculite to retain moisture. The samples were placed in a greenhouse with daily irrigation. The seedlings were identified and plucked every 20 days and the unidentified seedlings were replanted for later identification. The samples were assessed for a period of 12 months.

### **Data analysis**

Non metric multidimensional scaling (NMDS) plot was used to detect main patterns in plant community composition and SSB related to grazing intensities and the temporary removals of grazing. The NMDS was performed on the matrix of species relative abundances using the meta-MDS function in the R vegan package (Oksanen et al., 2013) by Bray-Curtis dissimilarity distances. Species with less than 1% average cover were excluded from the analyses, both for vegetation composition and SSB. We examined the relationships of environmental variables (grazing intensities and grazing exclusion) to the plant species structure in the diagram ordinations using the envfit vegan function. This function correlates the environmental variables with the ordination

scores and then finds the direction for maximum correlation for vectors.

Regarding to vegetation structure features, seeds species density and richness, we tested the effect of different grazing exclusions within each grazing intensity by mixed linear models, considering sub-plots nested within plots. We used the lme package (Pinheiro et al. 2010) in the R software. We performed all models based on homogeneous Gaussian distribution as this distribution satisfied residual normality. When differences among treatments were detected, means were compared by the Tukey test ( $P < 0.05$ ).

## **RESULTS**

### **Composition of soil seed bank and established vegetation**

Established vegetation and SSB showed similar response patterns to the grazing intensities (Figure 2). The NMDS ordinations ( $P < 0.01$ ) indicated a clear difference for both species composition and soil seed bank between plots under low and moderate grazing intensity.

Grazing exclusions did not cause important changes in established vegetation and SSB in the moderate grazing intensity, however it significantly altered the species composition under severe grazing intensity (Figure 2). This response was similar in both seasons of grazing exclusion (spring and fall).

Soil seed bank comprised 62 vascular plant species, all of them also found in the established vegetation, which presented 198 species. A total of 6,558 seedlings germinated during this study. The severe grazed site had a higher number of emerged seedlings (14,373 seedlings/m<sup>2</sup>) compared with the moderate grazed site (11,012 seedlings/m<sup>2</sup>). There were no differences in number of seedlings under grazing exclusion treatments. On the other hand, total seed richness and grass species richness

increased significantly due to grazing exclusions (figure 3).

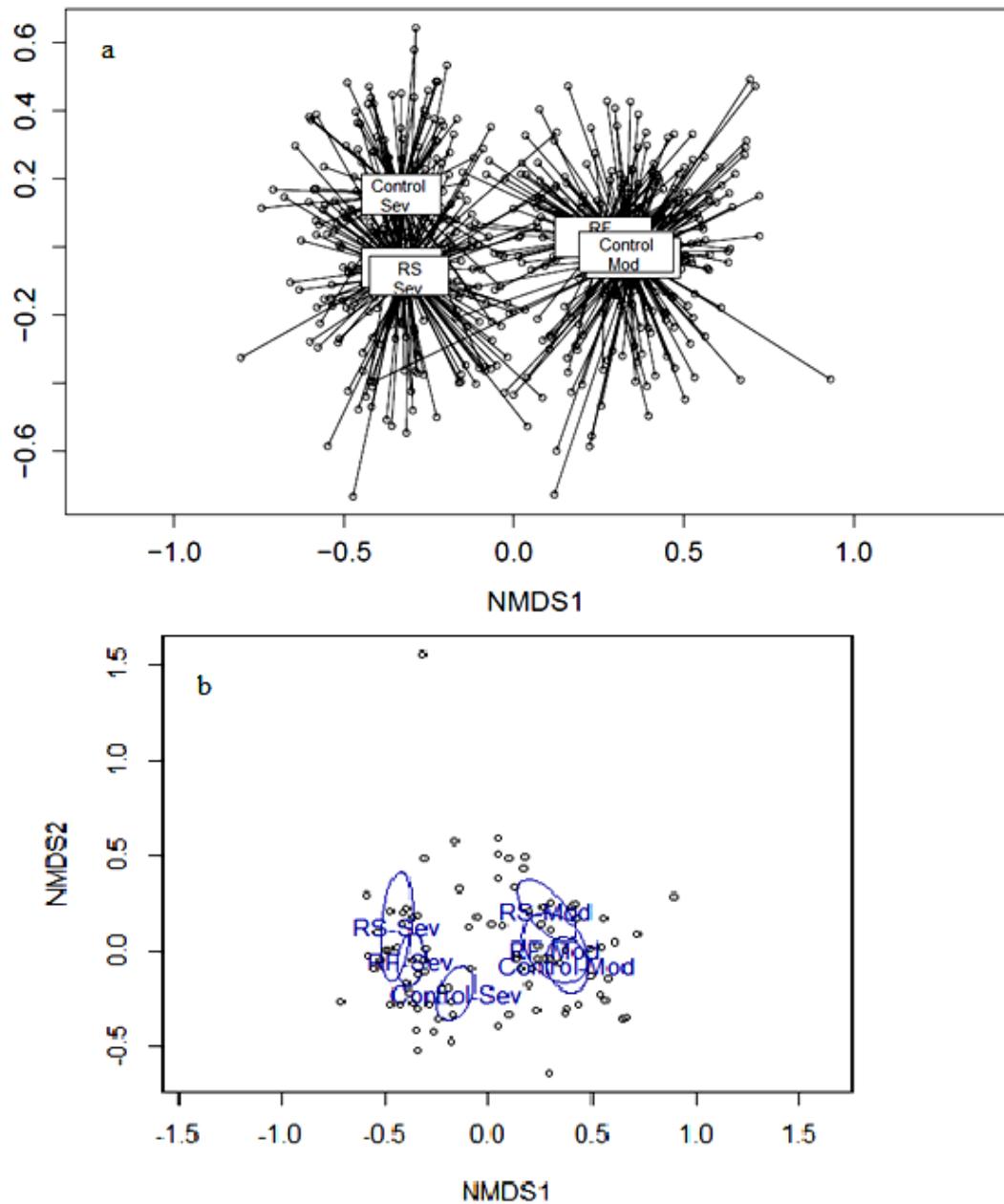


Figure 2. NMDS ordination diagram of the first two dimensions based on Bray-Curtis dissimilarities for established vegetation composition (stress= 0.15) (a) and soil seed bank (stress= 0.13) (b). Sample units were represented by black points, and to the treatments associated to them were calculated 95% confidence intervals obtained by ordiellipse command of Vegan Package. Abbreviations represent combinations between

grazing intensities (Sev= Severe grazing intensity and Mod = Moderate grazing intensity) and grazing exclusions (RF= fall grazing removal, RS= spring grazing removal and Control= continuous stocking during all the year).

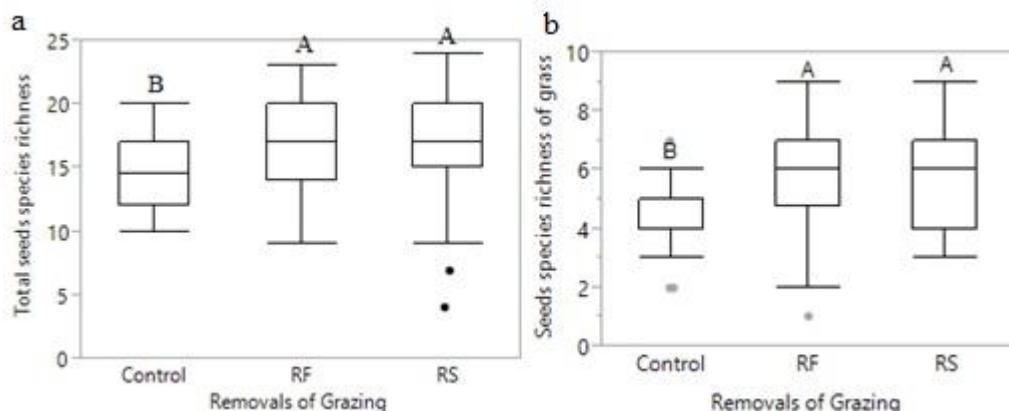


Figure 3. Total seeds species richness (a) and grass species richness (b) per plot from the soil seed bank. Different letters means significant differences between grazing exclusions ( $P<0.05$ ). The box-plots present the median, 25% – interquartiles, and maximum and minimum values.

Regarding to the biological type, grasses are the group with largest contribution in the established vegetation and also represented an important role in the SSB with 2878 seeds/m<sup>2</sup>  $\pm$ 257 (figures 4a and 4b). This implies the need for a more detailed study of species taxonomic and functional groups from this botanical family, dominant in the established vegetation and with good representation in SSB.

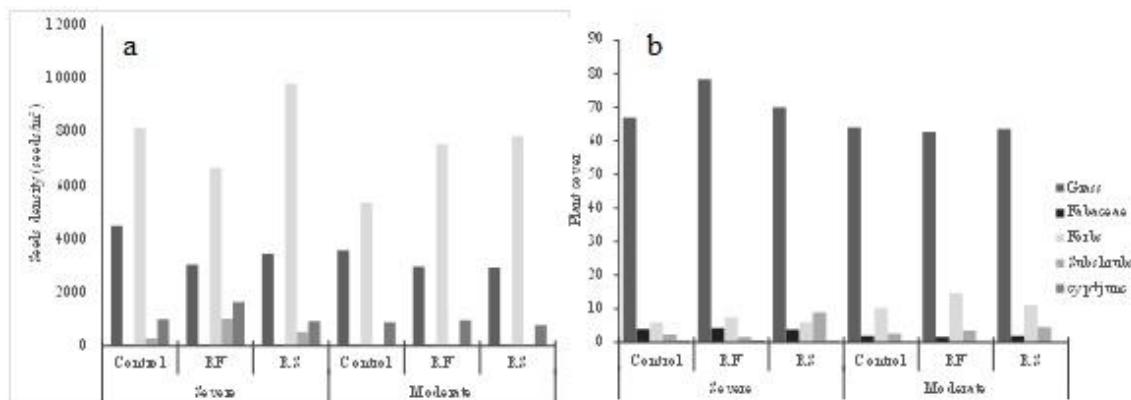


Figure 4. Species biological types from the soil seed bank (a, density – seeds/m<sup>2</sup>) and percentage of plant cover in established vegetation (%), b).

### Dynamics of grass taxonomy and functional groups

From 50 grass species identified in established vegetation (Appendix 1), only 16 were found in the SSB (Figure 5). *Andropogon lateralis* and *Paspalum notatum* were grasses with greater coverage (nearly 30%) respectively in moderate and severe intensity grazing (5b). *Piptochaetium montevidense*, however, showed greater contribution in SSB for both grazing intensities, with a further top contribution under moderate grazing (5a).

Regarding to life cycle, the perennial grasses had higher abundance in both established vegetation and SSB (figure 6). Annual grasses, however, that actively contributed in the SSB, showed low coverage in the established vegetation.

The NMDS ordination plot from established vegetation evidenced a clear separation of the grass species groups (Figure 7a). Two main groups were correlated with axis 1: WPEL ( $r^2=0.90$ ), and WPPG ( $r^2=-0.86$ ), that were linked to the both grazing intensities of our study, moderate and severe, respectively. The first group comprises perennial grasses like *Andropogon lateralis* and *Aristida spp.*, both less tolerant to high grazing intensities and with more conservative strategies for resources use (Cruz et al., 2010), while another group was mainly formed by prostrate grass species like *Paspalum notatum*, *Paspalum paucifolium* and *Axonopus affinis* (WPPG group) that are typical resource acquisitive and tolerant to grazing.

We performed a second ordination using only the data from the overgrazed pasture (Figure 7b) in order to verify specific changes due grazing exclusions. This analysis shows association between the plots under continuous stocking with the species

groups WPPG and CPEG ( $R^2$  axis1=0.54 and 0.24, respectively), formed by typical species of overgrazed grassland. However, the plots under grazing exclusions were also linked to WPEG and WPEL (axis 1=-0.60 and -0.41; axis 2= 0.41 and -0.64, respectively) (Table 1).

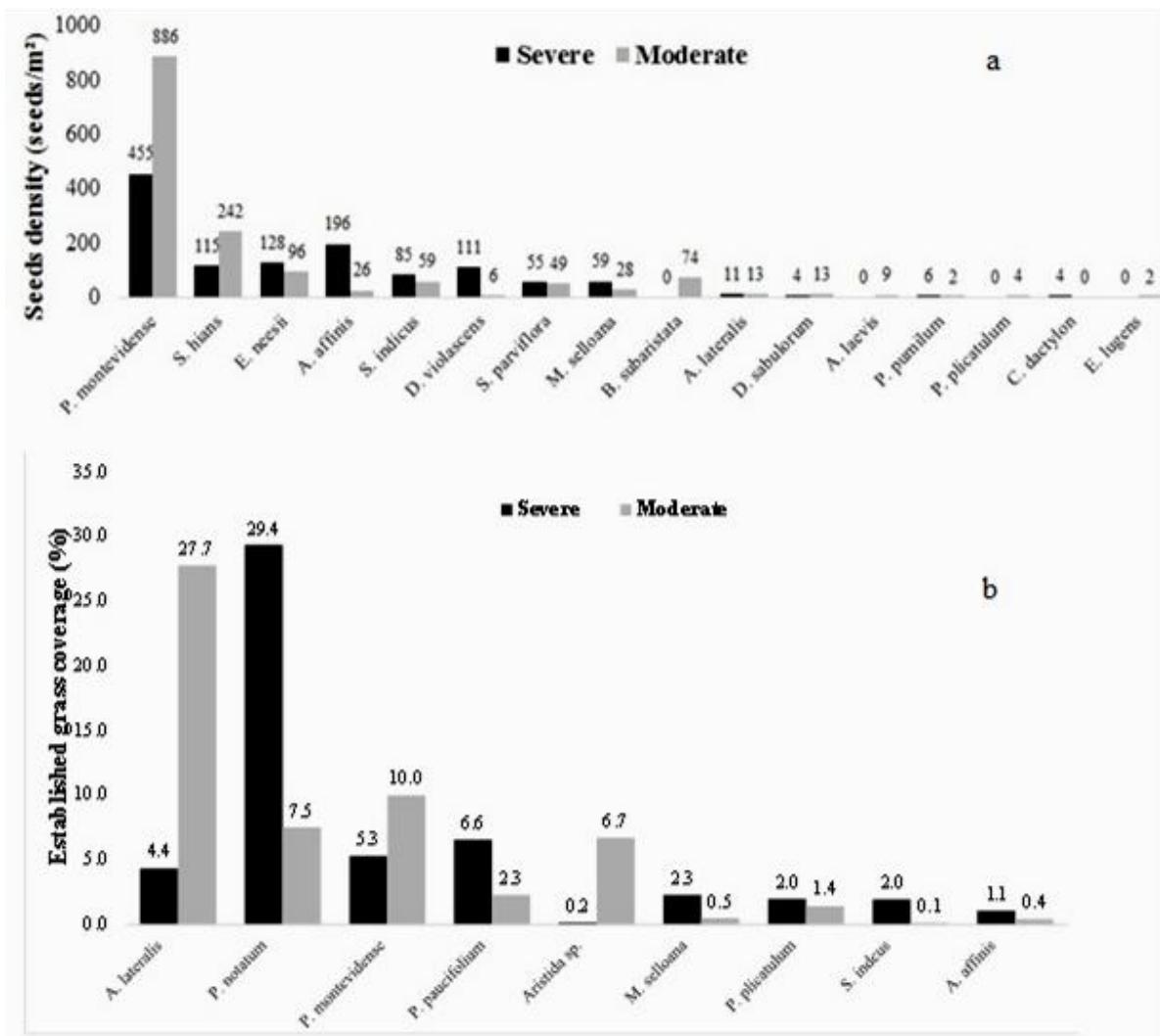


Figure 5. Seed density (seeds/m<sup>2</sup>) of grass species in SSB (a) and cover of the most abundant grass species in vegetation (%) (b), under severe and moderate grazing intensity.

The contrasting grazing intensities (figure 8a) also showed significant differences of the grass species groups from the soil seed bank. The WPEG group (comprised by *Steinchisma hians*, *Setaria parviflora*, *Mnesitea selloana*, and *Paspalum plicatulum*) and the CPEG group (represented by *Piptochaetium montevidense*) were associated with moderate grazing intensity. On the other hand, the specie group with highest correlation with severe grazing intensity was WPPG (r<sup>2</sup> = -0.52 NMDS1), formed by the prostrate grasses *Axonopus affinis*, *Paspalum pumilum* and *Dichantelium sabulorum*.

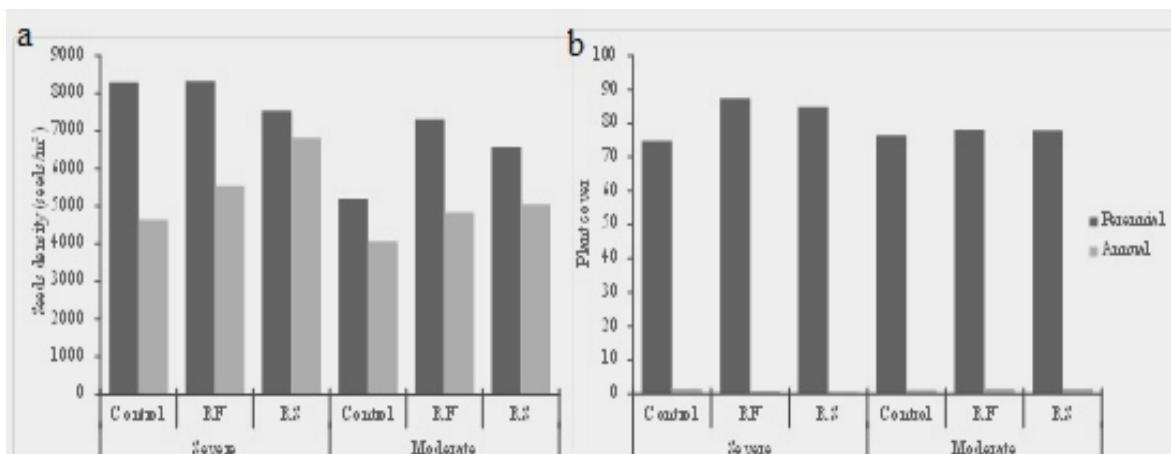


Figure 6. Seed density in the soil seed bank (a, seeds/m<sup>2</sup>) and plant cover (b, %) related to life cycle (perennial or annual) of the grass species.

Grass species groups from SSB also changed due to spring grazing exclusion under severe grazing intensity (P<0.05) and were mainly associated with WPEG group (r<sup>2</sup> NMDS1=-0.68), which was also a characteristic seeds species group from the moderate grazing. Fall grazing exclusion, however, remained in intermediate class (Figure 8b).

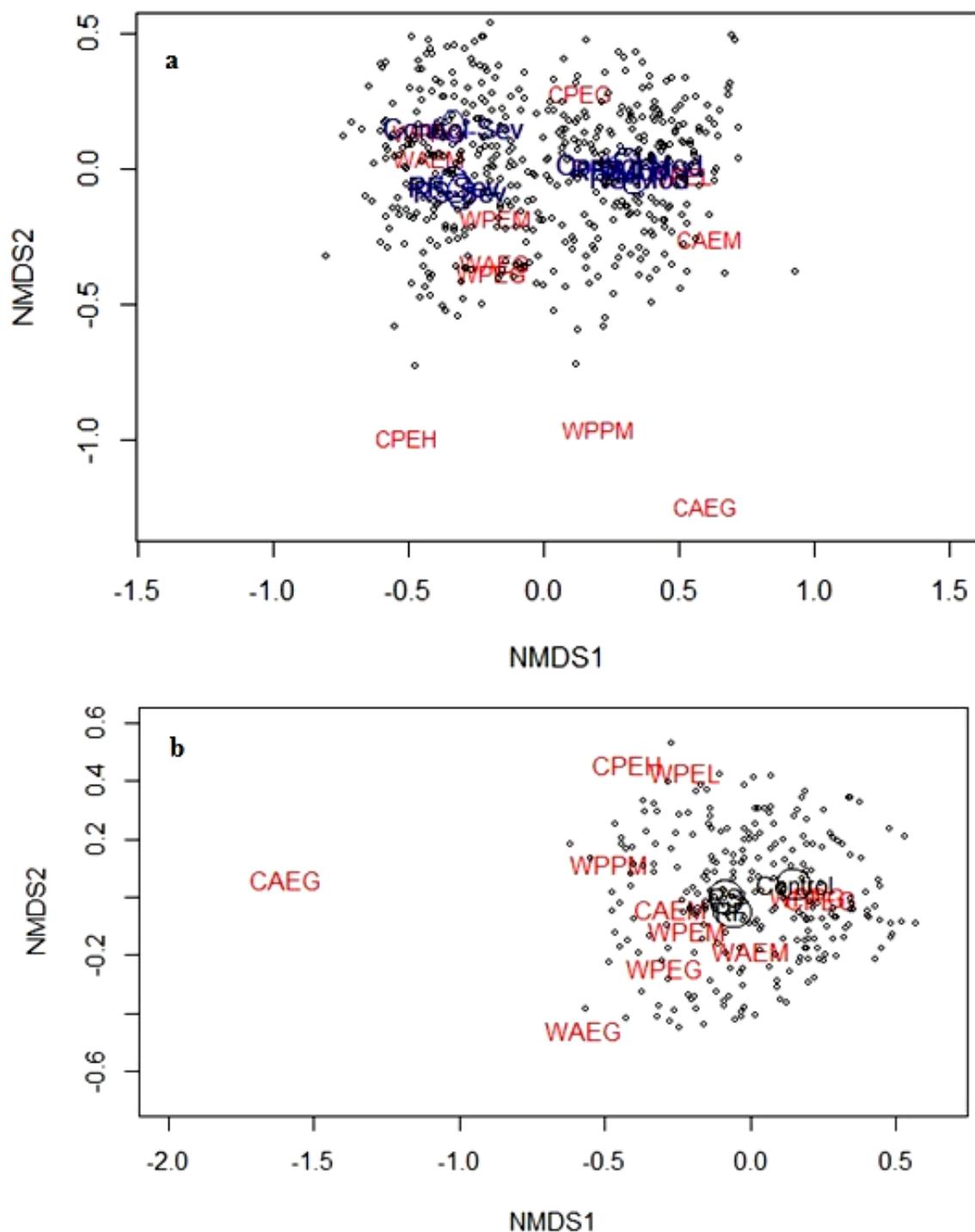


Figure 7. NMDS ordination diagrams of the first 2 dimensions based on Bray-Curtis dissimilarities for grass species traits from established vegetation. Ordinations are from moderate and severe grazing intensities (a) and from only severe grazing intensity (b). Sample units were represented by black points, and to the treatments associated to

them were calculated 95% confidence intervals obtained by ordiellipse command of Vegan Package. First letters of the grass species traits were described in red, and species associated to them were showed in Appendix 1. Grass species groups abbreviations are: CAEG (cool, annual, erect and good forage value), CAEM (cool, annual, erect and moderate forage value), CPEG (cool, perennial, erect and good forage value), CPEH (cool, perennial, erect and high forage value), WAEG (warm, annual, erect and good forage value), WPEL (warm, perennial, erect and low forage value), WPEM (warm, perennial, erect and moderate forage value), WPPG (warm, perennial, prostrate and good forage value), WPPM (warm, perennial, prostrate and moderate forage value), WPEG (warm, perennial, erect and good forage value), WAEM (warm, annual, erect and moderate forage value).

Table 1. Squared correlation coefficients of established vegetation based on species groups with first two NMDS ordination axes in severe and in both forage allowances.

Species groups	4%		4% and 12%	
	NMDS1	NMDS2	NMDS1	NMDS2
WPPG	<b>0.54</b>	0.09	<b>-0.86</b>	0.17
WPPM	-0.05	-0.02	0.02	-0.10
WAEG	-0.26	0.22	0.01	-0.15
WAEM	-0.09	0.11	-0.14	-0.07
WPEG	<b>-0.60</b>	<b>0.41</b>	-0.25	<b>-0.66</b>
WPEM	-0.37	0.10	-0.13	-0.25
WPEL	<b>-0.52</b>	<b>-0.64</b>	<b>0.90</b>	-0.11
CAEG	-0.11	-0.01	0.07	-0.17
CAEM	-0.13	-0.03	0.21	-0.21
CPEG	<b>0.24</b>	0.01	<b>0.44</b>	<b>0.50</b>
CPEH	-0.03	-0.04	-0.05	-0.05

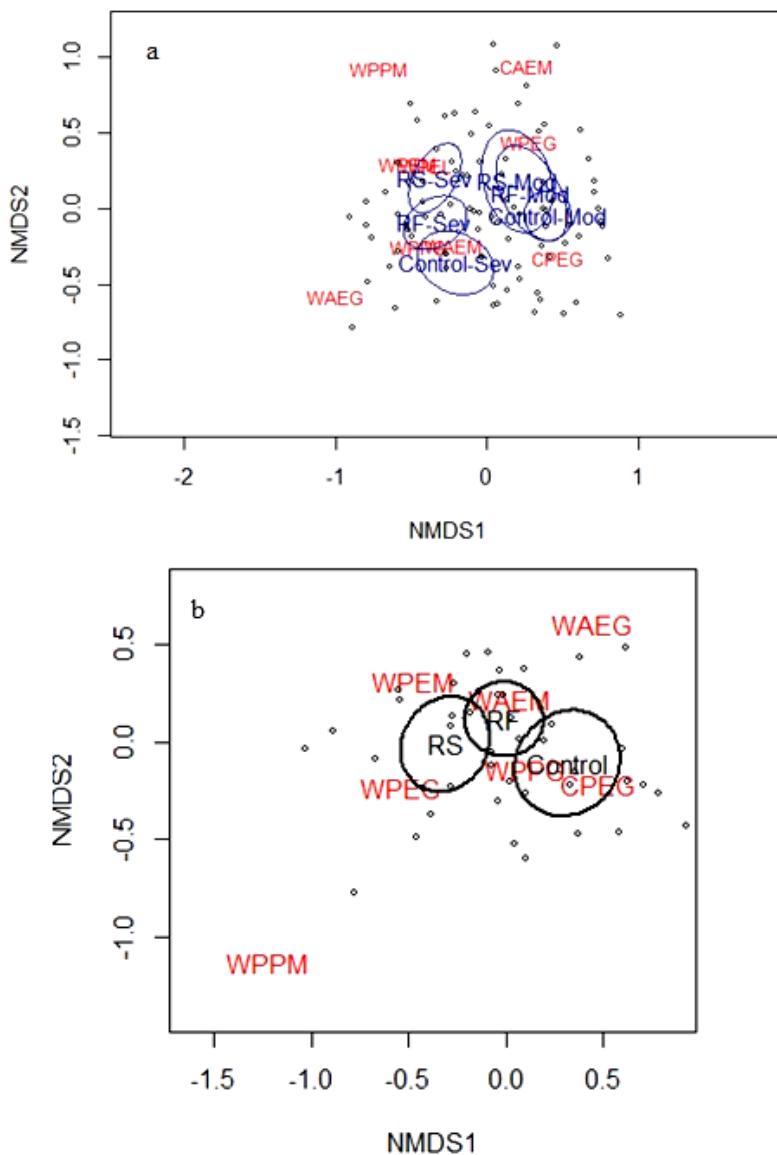


Figure 8. NMDS ordination diagrams of the first 2 dimensions based on Bray-Curtis dissimilarities for grass species traits from SSB. Ordinations are from moderate and severe grazing intensities (a) and from only severe grazing intensity (b). Sample units were represented by black points, and to the treatments associated to them were calculated 95% confidence intervals obtained by ordiellipse command of Vegan Package. First letters of the grass species traits were described in red, and species associated to them were showed in Appendix 1. Grass species groups abbreviations are: CAEM (Cool, annual, erect and moderate forage value), CPEG (Cool, perennial, erect

and good forage value), WAEG (Warm, annual, erect and good forage value), WPEL (Warm, perennial, erect and low forage value), WPEM (Warm, perennial, erect and moderate forage value), WPPG (Warm, perennial, prostrate and good forage value), WPPM (Warm, perennial, prostrate and moderate forage value), WPEG (warm, perennial, erect and good forage value), WAEM (warm, annual, erect and moderate forage value).

Table 2. Squared correlation coefficients of soil seed bank species based on species groups with first two NMDS ordination axes in severe and in both forage allowances.

Species groups	4%		4% and 12%	
	NMDS1	NMDS2	NMDS1	NMDS2
WPPG	<b>0</b>	0.22	<b>-0.52</b>	0.07
WPPM	-0.30	-0.36	-0.10	0.21
WAEG	0.18	-0.40	<b>-0.44</b>	-0.12
WAEM	-0.07	-0.31	-0.32	0.02
WPEG	<b>-0.68</b>	<b>0.37</b>	0.28	<b>0.64</b>
WPEM	-0.36	-0.37	-0.29	0.30
CAEM	na	na	0.32	<b>0.55</b>
CPEG	<b>0.65</b>	0.44	<b>0.49</b>	<b>-0.33</b>
WPEL	-0.17	0.41	ns	ns

[

### Vegetation structure

There were significant effect ( $P<0.05$ ) of grazing intensities and removals of grazing on each of the three sward structure features. Severe grazing showed lower values for PAR intercepted, sward height and forage mass (Figure 9); however, it showed positive increments in response to spring grazing exclusion. On the other hand, grazing exclusions did not change the sward structure on moderate grazing intensity.

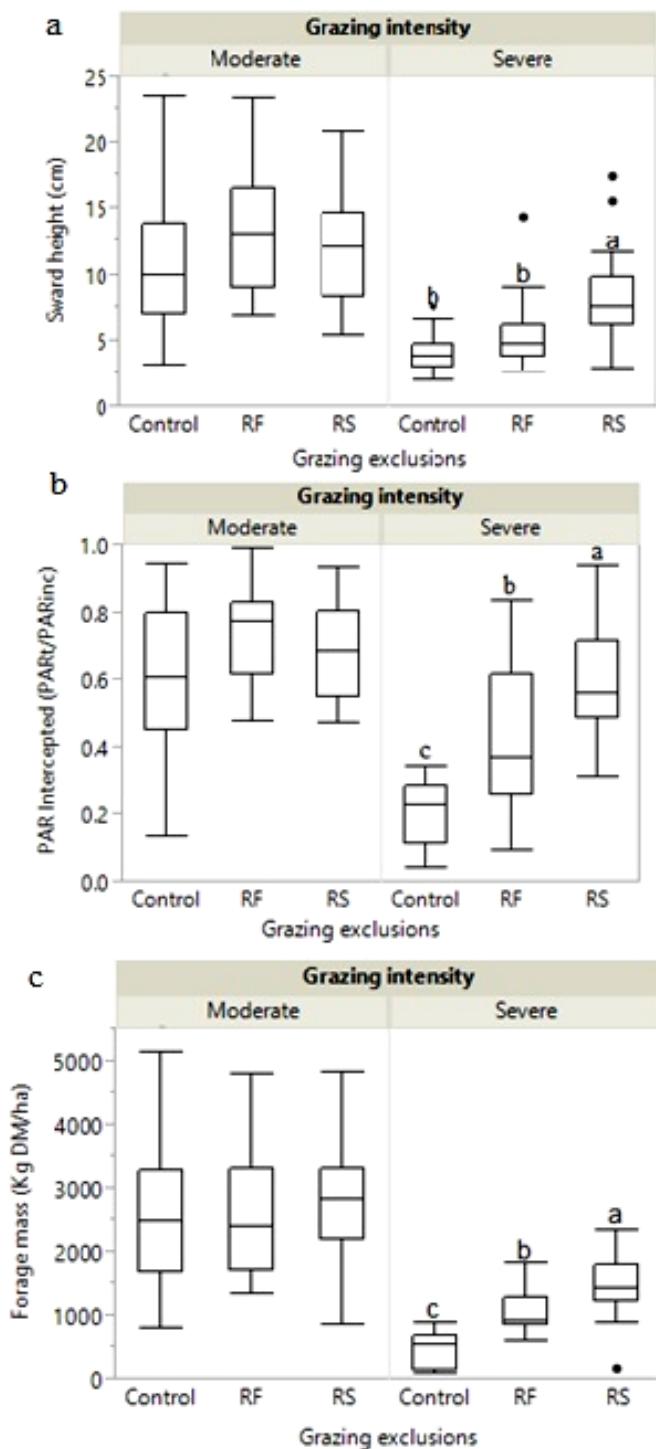


Figure 9. Average values of sward height (a), light interception (b) and forage biomass (c) of all the experimental period. Different letters means significant differences between grazing exclusions within each grazing intensity ( $P<0.05$ ). The box-plots present the median, 25% – interquartiles, and maximum and minimum values.

## DISCUSSION

### **Established vegetation**

The present study reveals significant changes on species composition and functional plant groups under contrasting grazing intensities and grazing exclusions both for established vegetation and SSB (Figure 2). The established vegetation from overgrazed pasture was associated to species with prostrate growth habit (mainly *Paspalum notatum*, *Axonopus affinis* and *Paspalum paucifolium*), a morphological adaptive strategy that allows concentrating the leaf area near the soil surface (Sinoquet et al. 1990). These plants are not able to invest in durable and strong leaves, but they have a quick regrowth after grazing events (Díaz et al. 1992). The pasture under moderate grazing intensity, however, showed high proportion of tall species (mainly *Andropogon lateralis* and *Aristida spp.*), a growth form that enhance the competitiveness for light, but make them more vulnerable to severe grazing (Díaz et al. 2007, Cruz et al. 2010). The plots with this grazing intensity has also a low-strate comprising characteristic species from overgrazed pasture, but with structural paramenters in better conditions (Soares et al 2005, Mezzalira et al 2012, Da Trindade et al 2012) to livestock performance (Gonçalves et al. 2009a, Gonçalves et al. 2009b)

We verified that spring grazing exclusion promoted a grass directional change of the established overgrazed vegetation towards the well-managed grassland (Fig. 7). The negative influence of severe grazing to tall species and favoring prostrate plants is well known in the literature (Diaz et al 2007). However, there are few works aiming grassland restoration based on species functional groups and not only based on the forage productivity. In order to check these assumptions, we verified that spring grazing exclusion promoted a grass directional change of the established overgrazed vegetation

towards the well-managed grassland.

Other studies also suggest that natural grasslands in South America can have a fast restoration capacity by using temporary grazing exclusions. Loydi et al. (2012) verified that montane grasslands at Southern Pampas in Argentina may recover fast from overgrazing by large herbivores without application of specific restoration techniques. The authors verified a 3-fold increase of above-ground biomass after 12 months of grazing exclusion, in addition to important changes in botanical composition, mainly due an increase of perennial and tall grasses. Our study, on the other hand, verified recovery of the most important grasses after only two periods of 90 days of temporary grazing exclusions, showing considerable resilience of this environment.

### **Soil seed bank**

Regarding to the soil seed bank, the total seed density and richness of grass seeds in the overgrazed pasture was higher than in moderate grazing intensity. This increase could be explained by two reasons. Firstly, some studies have shown that the bare soil, situation frequently originated by overgrazing, is a gateway for seeds accumulation in the soil from adjacent vegetation areas by wind or animals (Zhao et al 2005). Secondly, we verified in this grazing intensity greater seed density of forbs species, and most of them are typical ruderal species, which is in agreement with other studies which demonstrated that high disturbance levels maintain higher ruderal seed density in grasslands (Vieira et al. 2013). The grassland degradation process can increase the number of seeds in the soil due to the increase of short-lived species in established vegetation, which depends on high and prolific seed production as a survival strategy (Snymam, 2004).

In addition to the lower amount of ruderal species, the SSB from moderate

grazing intensity was associated with WPEG group (Figure 8a and Table 2), comprised by warm, perennial, erect grasses with good forage value. The importance of the species from this group (*Mnesitea selloana*, *Paspalum plicatulum*, *Steinchisma hians* and *Setaria parviflora*,) for provision of important ecosystem services like soil cover and forage production is outstanding (Rosengurtt 1979, Olmos et al 2013, Scheffer-Basso & Gallo 2008); furthermore their high capacity to produce seeds plays important role for vegetation stability. CPEG grass group (comprised only by *Piptochaetium montevidense* in SSB) were also associated with moderate grazing intensity. The spring grazing exclusion in the overgrazed plot showed positive response to WPEG (Figure 8b and Table 2), suggesting a fast seed bank recovery after long term intensive grazing. A work carried out within the same experiment (Azambuja Filho 2013) verified improvement in grasses inflorescences due to short term grazing exclusions in overgrazed pastures, providing abundant seeds sources for further restoration and succession. This result could be explained because grazing exclusion promotes a massive improvement of seed production either by higher allocation of plants resources for reproduction due stoppage of defoliation or by stopping direct removal of flowers and seeds (Sternberg et al. 2003).

### **Vegetation structure**

The evaluation of the pasture structural parameters is usually included in recovery projects of degraded areas, assuming that the re-establishment of these characteristics is associated with several ecosystem processes. These processes includes, for example, the pasture production recovery, soil conservation due increments in plant cover, and the restoration of habitats for wildlife (Young, 2000). About this aspect, some studies (Tilghman 1987, George & Zack 2001) showed a strong and positive correlation

between the re-establishment of vegetation structure (e.g., sward height and basal area) with the appearance of birds in natural pasture, stating that recovery these parameters are important for several purposes. In our experimental conditions, we observed significant improvements in the structural conditions in the overgrazed pasture (Figure 9). Treatments without grazing exclusion in this grazing intensity showed forage mass less than 500 kg DM/ha, PAR Intercepted only 20% and sward height lower than 4cm. Even though this overgrazing condition have been continuously applied for 25 years, we found an impressive resilience of these areas. The sward canopy reached 60% of PAR intercepted with spring grazing exclusion, which was linked to higher forage mass (over than 1500 kg/ha) and sward height (10 cm). Fall grazing exclusion also showed significant responses compared to the control, but with lower magnitude in relation to spring grazing exclusion. This response probably occurred because spring is the period with more suitable climatic conditions for development of grasses with C4 photosynthetic metabolism, main plant group of the study area which has his growing season concentrated in spring and summer.

A fast recovery in aboveground biomass may also reflect a fast recovery in grassland functionality, such as productivity and nutrient cycling (Tilman et al. 1996). As our results are short-term, so we do not intend to discuss in greater detail the provision of these ecosystem services, and is therefore crucial monitoring for a longer period.

## IMPLICATIONS

Temporary grazing exclusion is a tool for restoration of natural grasslands degraded by overgrazing. It favors productive characteristics (forage mass, sward height and light interception) and enables changes in grasses functional types, from both established

vegetation and soil seed bank, towards natural grasslands managed according their carrying capacity. Although spring and fall grazing exclusion periods shows important responses to the restoration process of these grasslands, faster and consistent results were observed for the spring grazing exclusion, probably because it is a season with suitable climatic condicions for the growth of C4 grasses, specie group with greater vegetation cover of the study area.

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## Appendix

Appendix 1. List of species found in all surveys in the experimental units and the Poacea's plant functional groups.

<b>Family</b>	<b>Specie</b>	<b>Author</b>	<b>Poacea's plant functional groups*</b>
Acanthaceae	<i>Justicia axillaris</i>	Lindau	
Acanthaceae	<i>Ruellia hypericoides</i>	(Nees) Lindau	
Acanthaceae	<i>Ruellia morongii</i>	Britton	
Alliaceae	<i>Nothoscordum minarum</i>	Beauverd	
Amaranthaceae	<i>Pfaffia tuberosa</i>	(Spreng.) Hicken	
Apiaceae	<i>Apium leptophyllum</i>	F. Muell. ex Benth	
Apiaceae	<i>Centella asiatica</i>	(L.) Urb.	
Apiaceae	<i>Eryngium ciliatum</i>	Cham. & Schltdl.	
Apiaceae	<i>Eryngium horridum</i>	Malme	
Apiaceae	<i>Eryngium sanguisorba</i>	Cham. Et Schlecht.	
Apocynaceae	<i>Macrosiphonia pinifolia</i>	(A. St.-Hil.) Malme	
Araliaceae	<i>Hydrocotyle exigua</i>	Malme	
Aristolochiaceae	<i>Aristolochia sessilifolia</i>	(Klotzsch) Duch.	
Asparagaceae	<i>Clara Ophiogonoides</i>	Kunth	
Asteraceae	<i>Aspilia montevidensis</i>	(Spreng.) Kuntze	
Asteraceae	<i>Baccharis articulata</i>	(Lam.) Pers.	
Asteraceae	<i>Baccharis dracunculifolia</i>	DC.	
Asteraceae	<i>Baccharis riograndensis</i>	I.L.Teodoro & J.Vidal	
Asteraceae	<i>Baccharis trimera</i>	(Less.) DC.	
Asteraceae	<i>Chaptalia exscapa</i>	(Pers.) Baker	
Asteraceae	<i>Chaptalis integerrima</i>	(Vell.) Burk	
Asteraceae	<i>Chaptalia mandoni</i>	(Sch. Bip.) Burkart	
Asteraceae	<i>Chaptalia piloselloides</i>	(Vahl) Baker	
Asteraceae	<i>Chaptalia runcinata</i>	Kunth	
Asteraceae	<i>Chaptalia sinuata</i>	(Less.) Baker	
Asteraceae	<i>Chevreulia acuminata</i>	Less.	
Asteraceae	<i>Chevreulia sarmentosa</i>	(Pers.) Blake	

Asteraceae	<i>Conyzia bonariensis</i>	(L.) Cronquist	
Asteraceae	<i>Conyzia primulifolia</i>	(Lam.) Cuatrec. & Lourteig	
Asteraceae	<i>Elephantopus mollis</i>	Kunth	
Asteraceae	<i>Eupatorium ascendens</i>	Sch. Bip. ex Baker	
Asteraceae	<i>Facelis retusa</i>	(Lam.) Sch. Bip.	
Asteraceae	<i>Gamochaeta americana</i>	(Mill.) Wedd.	
Asteraceae	<i>Hypochaeris megapotamica</i>	Cabr.	
Asteraceae	<i>Hypochaeris radicata</i>	L.	
Asteraceae	<i>Lucilia acutifolia</i>	(Poir.) Cass.	
Asteraceae	<i>Micropsis spathulata</i>	(Pers.) Cabrera	
Asteraceae	<i>Orthopappus angustifolius</i>	Gleason	
Asteraceae	<i>Pteurocaulon alopecuroides</i>	(Lam.) DC.	
Asteraceae	<i>Pterocaulon angustifolium</i>	DC.	
Asteraceae	<i>Senecio brasiliensis</i>	(Spreng.) Less.	
Asteraceae	<i>Senecio leptolobus</i>	DC.	
Asteraceae	<i>Senecio madagascariensis</i>	Poir.	
Asteraceae	<i>Senecio selloi</i>	(Spreng.) DC.	
Asteraceae	<i>Soliva pterosperma</i>	Ruiz et Pavón	
Asteraceae	<i>Stenachaenium campestre</i>	Baker	
Asteraceae	<i>Vernonia flexuosa</i>	Sims	
Asteraceae	<i>Vernonia megapotamica</i>	Spreng.	
Asteraceae	<i>Vernonia nudiflora</i>	Less.	
Asteraceae	<i>Vernonia selowii</i>	Less.	
Campanulaceae	<i>Pratia hederacea</i>	(Cham.) G. Don	
Campanulaceae	<i>Wahlebergia linariooides</i>	(Lam.) A.DC.	
Caryophyllaceae	<i>Cerastium glomeratum</i>	Thuill	
Caryophyllaceae	<i>Spergularia grandis</i>	(Pers.) Cambess.	
Cistaceae	<i>Helianthemum brasiliense</i>	(Lam.) Pers.	
Convolvulaceae	<i>Dichondra macrocalyx</i>	Meisn.	
Convolvulaceae	<i>Dichondra sericea</i>	Sw.	
Convolvulaceae	<i>Evolvulus sericeus</i>	Sw.	
Cyperaceae	<i>Abildgaardia ovata</i>	(L.) Vahl	
Cyperaceae	<i>Bulbostylis capillaris</i>	(L.) C.B. Clarke	
Cyperaceae	<i>Carex phalaroides</i>	Kunth	
Cyperaceae	<i>Carex sororia</i>	Kunth	
Cyperaceae	<i>Cyperus aggregatus</i>	(Willd.) Endl.	
Cyperaceae	<i>Cyperus reflexus</i>	Vahl	
Cyperaceae	<i>Cyperus rigidus</i>	J. Presl & C. Presl	
Cyperaceae	<i>Eleocharis viridans</i>	Kük. ex Osten	
Cyperaceae	<i>Fimbristylis autumnalis</i>	(L.) Roem. & Schult.	
Cyperaceae	<i>Fimbristylis dichotoma</i>	(Retz.) Vahl	
Cyperaceae	<i>Kyllinga brevifolia</i>	Rottb.	
Cyperaceae	<i>Kyllinga odorata</i>	Vahl	

Cyperaceae	<i>Kyllinga vaginara</i>	Lam.	
Cyperaceae	<i>Rhynchospora barrosiana</i>	Guagl.	
Cyperaceae	<i>Rhynchospora megapotamica</i>	(A. Spreng.) H. Pfeiff.	
Cyperaceae	<i>Rhynchospora rugosa</i>	(Vahl) Gale	
Cyperaceae	<i>Rhynchospora setigera</i>	(Kunth) Boeck.	
Euphorbiaceae	<i>Euphorbia selloi</i>	(Klotzsch & Garske) Boiss.	
Euphorbiaceae	<i>Tragia bahiensis</i>	Müll. Arg.	
Fabaceae	<i>Aeschynomene falcata</i>	(Poir.) DC.	
Fabaceae	<i>Chamaecrista repens</i>	(Vogel) H.S. Irwin & Barneby	
Fabaceae	<i>Clitoria nana</i>	Benth.	
Fabaceae	<i>Crotalaria tweediana</i>	Benth.	
Fabaceae	<i>Desmanthus tatuhyensis</i>	Hoehne	
Fabaceae	<i>Desmanthus virgatus</i>	(L.) Willd.	
Fabaceae	<i>Desmodium adscendens</i>	(Sw.) DC.	
Fabaceae	<i>Desmodium incanum</i>	DC.	
Fabaceae	<i>Galactis gracilima</i>	Benth.	
Fabaceae	<i>Galactia marginalis</i>	Benth. ex Benth. & Hook. f.	
Fabaceae	<i>Macroptilium prostratum</i>	(Benth.) Urb.	
Fabaceae	<i>Pomaria pilosa</i>	(Vogel) B.B.Simpson & G.P.Lewis	
Fabaceae	<i>Stylosanthes leiocarpa</i>	Vogel	
Fabaceae	<i>Stylosanthes montevidensis</i>	Vogel	
Fabaceae	<i>Trifolium polymorphum</i>	Poir.	
Fabaceae	<i>Vigna peduncularis</i>	(Kunth) Fawc. & Rendle	
Fabaceae	<i>Zornia cryptantha</i>	Arechav.	
Hypoxidaceae	<i>Hypoxis decumbens</i>	L.	
Iridaceae	<i>Herbertia pulchella</i>	Sweet	
Iridaceae	<i>Sisyrinchium macrocephalum</i>	Graham	
Iridaceae	<i>Sisyrinchium micranthum</i>	Cav.	
Iridaceae	<i>Sisyrinchium ostenianum</i>	Beauverd	
Iridaceae	<i>Sisyrinchium sellowianum</i>	Klatt	
Iridaceae	<i>Sisyrinchium striatum</i>	Sm.	
Juncaceae	<i>Juncus capillaceus</i>	Lam.	
Juncaceae	<i>Juncus imbricatus</i>	Laharpe	
Juncaceae	<i>Juncus tenuis</i>	Willd.	
Lamiaceae	<i>Peltodon longipes</i>	Kunth. ex Benth.	
Lamiaceae	<i>Scutellaria racemosa</i>	Pers.	
Linaceae	<i>Cliococca selaginoides</i>	(Lam.) C. M. Rogers & Mild	
Lythraceae	<i>Cuphea carthagrenensis</i>	(Jacq.) J. F. Macbr.	
Lythraceae	<i>Cuphea glutinosa</i>	Cham. & Schltdl.	
Malvaceae	<i>Krapovickasia flavescentia</i>	(Cav.) Fryxell	
Malvaceae	<i>Krapovickasia urticifolia</i>	(Cav.) Fryxell	
Malvaceae	<i>Sida rhombifolia</i>	L.	
Malvaceae	<i>Wissadula glechomifolium</i>	(A. St.-Hil.) R.E. Fr.	

Melastomataceae	<i>Tibouchina gracilis</i>	(Bonpl.) Cogn.	
Moraceae	<i>Dorstenia brasiliensis</i>	Lam.	
Myrtaceae	<i>Campomanesia aurea</i>	O.Berg	
Myrtaceae	<i>Psidium luridum</i>	(Cambess.) Landrum	
Myrtaceae	<i>Psidium salutarum</i>	(Cambess.) Landrum	
Orobanchaceae	<i>Agalinis comunis</i>	Cham. & Schlecht.	
Orobanchaceae	<i>Buchnera integrifolia</i>	Larrañaga	
Oxalidaceae	<i>Oxalis brasiliensis</i>	Lodd.	
Oxalidaceae	<i>Oxalis conorrhiza</i>	Jacq.	
Oxalidaceae	<i>Oxalis eriocarpa</i>	DC.	
Oxalidaceae	<i>Oxalis lasiopetala</i>	Zuccarini	
Oxalidaceae	<i>Oxalis perdicaria</i>	(Molina) Bertero	
Oxalidaceae	<i>Oxalis tenerima</i>	Knuth	
Passifloraceae	<i>Piriqueta selloi</i>	Urb.	
Passifloraceae	<i>Turnera sidoides</i>	L.	
Plantaginaceae	<i>Mecardonia tenella</i>	(Cham. & Schltl.) Pennell	
Plantaginaceae	<i>Plantago myosuros</i>	Lam.	
Plantaginaceae	<i>Plantago tomentosa</i>	Lam.	
Poaceae	<i>Agrostis montevidensis</i>	Spreng. ex Nees	WPEG
Poaceae	<i>Andropogon lateralis</i>	Nees	WPEL
Poaceae	<i>Andropogon selloanus</i>	Hack.	WPSEM
Poaceae	<i>Andropogon ternatus</i>	(Spreng.) Nees	WPEG
Poaceae	<i>Aristida circinalis</i>	Lindm.	WPEL
Poaceae	<i>Aristida filifolia</i>	(Arechav.) Herter	WPEL
Poaceae	<i>Aristida flaccida</i>	Trin. & Rupr.	WPEL
Poaceae	<i>Aristida jubata</i>	(Arechav.) Herter	WPEL
Poaceae	<i>Aristida laevis</i>	(Nees) Kunth	WPEL
Poaceae	<i>Aristida spegazini</i>	Arechav.	WPEL
Poaceae	<i>Aristida venustula</i>	Arechav.	WPSEM
Poaceae	<i>Axonopus affinis</i>	Chase	WPPG
Poaceae	<i>Axonopus argentinus</i>	Parodi	WPPG
Poaceae	<i>Axonopus suffultus</i>	(Mikan ex Trin.) Parodi	WPEG
Poaceae	<i>Ayra caryophyllea</i>	(L.) Nash	CAEM
Poaceae	<i>Chascolytrum subaristata</i>	Lam.	CAEM
Poaceae	<i>Chascolytrum uniolae</i>	(Nees) Steud.	CAEG
Poaceae	<i>Cynodon dactylon</i>	L.	WPPM
Poaceae	<i>Danthonia cirrata</i>	Hack. & Arechav.	CPEG
Poaceae	<i>Dichanthelium sabulorum</i>	(Lam.) Gould & C.A. Clark	WPPG
Poaceae	<i>Digitaria violascens</i>	(L.) Link	WAEG
Poaceae	<i>Eleusine tristachya</i>	(Lam.) Lam.	WPPM
Poaceae	<i>Elyonurus candidus</i>	(Trin.) Hack.	WPEL
Poaceae	<i>Eragrostis bahiensis</i>	Schrad. ex Schult.	WPSEM
Poaceae	<i>Eragrostis lugens</i>	Nees	WPSEM

Poaceae	<i>Eragrostis neesii</i>	Trin.	WAEM
Poaceae	<i>Eragrostis plana</i>	Nees	WPEL
Poaceae	<i>Eragrostis polytricha</i>	Nees	WPSEM
Poaceae	<i>Eustachys uliginosa</i>	(Hack.) Herter	WPEG
Poaceae	<i>Mnesitea selloana</i>	(Hack.) Henr.	WPEG
Poaceae	<i>Panicum bergii</i>	Arechav.	WPSEM
Poaceae	<i>Paspalum maculosum</i>	Trin.	WPEG
Poaceae	<i>Paspalum leptum</i>	Schult.	WPPG
Poaceae	<i>Paspalum notatum</i>	Fluegge	WPPG
Poaceae	<i>Paspalum paucifolium</i>	Swallen	WPPG
Poaceae	<i>Paspalum plicatulum</i>	Michx.	WPEG
Poaceae	<i>Paspalum pumilum</i>	Nees	WPPG
Poaceae	<i>Piptochaetium montevidense</i>	(Spreng.) Parodi	CPEG
Poaceae	<i>Piptochaetium lasianthum</i>	Griseb.	CPEG
Poaceae	<i>Piptochaetium stipoides</i>	(Trin. & Rupr.) Hack.	CPEG
Poaceae	<i>Saccharum angustifolium</i>	(Nees) Trin.	WPEL
Poaceae	<i>Schizachyrium microstachyum</i>	(Desv. ex Ham.) Roseng.	WPEL
Poaceae	<i>Schizachyrium tenerum</i>	Nees	WPEL
Poaceae	<i>Setaria parviflora</i>	(Poir.) Kerguélen	WPEG
Poaceae	<i>Setaria vaginata</i>	Spreng.	WPEG
Poaceae	<i>Sporobolus indicus</i>	(L.) R.Br.	WPSEM
Poaceae	<i>Steinchisma hians</i>	(Elliott) Nash.	WPEG
Poaceae	<i>Nasella nutans</i>	Hack.	CPEG
Poaceae	<i>Nasella setigera</i>	J.Presl	CPEH
Polygalaceae	<i>Polygala australis</i>	A. W. Benn.	
Primulaceae	<i>Centunculus mimus</i>	L.	
Rubiaceae	<i>Borreria capitata</i>	(Ruiz & Pav.) DC.	
Rubiaceae	<i>Borreria eryngioides</i>	Cham. & Schlecht.	
Rubiaceae	<i>Borreria verticillata</i>	(L.) G.Mey	
Rubiaceae	<i>Galianthe fastigiata</i>	Griseb.	
Rubiaceae	<i>Galium hirtum</i>	Lam.	
Rubiaceae	<i>Galium richardianum</i>	(Gillies ex Hook. & Arn.) Endl. ex Walp.	
Rubiaceae	<i>Richardia brasiliensis</i>	Gomes	
Rubiaceae	<i>Richardia grandiflora</i>	(Cham. & Schlecht.) Steud.	
Rubiaceae	<i>Richardia humistrata</i>	(Cham. et Schlecht.) Steud.	
Rubiaceae	<i>Richardia stellaris</i>	(Cham. & Schlecht.) Steud.	
Verbenaceae	<i>Glandularia marrubiooides</i>	(Cham.) Tronc.	
Verbenaceae	<i>Glandularia peruviana</i>	(L.) Small	
Verbenaceae	<i>Verbena montevidensis</i>	Spreng.	

\*Poacea's plant functional groups were performed according to the plant growth season (cool or warm), lifespan (perennial or annual), growth habit (erect or prostrate) and forage value (high, good, moderate and low), based on the species classifications by Rosengurtt (1979). The first letter of each parameter was used to codify the species groups.

## CAPÍTULO III

### **Improving native grasslands biodiversity by temporary grazing exclusion<sup>1</sup>**

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Artigo elaborado conforme as normas do periódico *Journal of Applied Ecology* (Apêndice 2).

## Improving native grasslands biodiversity by temporary grazing exclusion

### SUMMARY

1. Grazing management is an important strategy interferes in several ecosystem processes in grasslands. Moderate grazing is considered the basic requirement to enhance functional composition, species diversity and pasture productivity.
2. We investigated the impact of two seasons of temporary grazing exclusions in a natural grassland managed with two long term grazing intensities: severe and moderate. We studied vegetation assemblages patterns, species richness and functional diversity during two years.
3. The overgrazed pasture showed homogeneous structure that lead to lower values of species functional diversity and richness, regardless the grazing exclusions periods. Alternatively, we verified a rapid recovery of both functional and taxonomic diversity in response to grazing exclusions in this grazing intensity.
4. Grassland with moderate grazing intensity showed a balance between tussocks and low-strata grasses, which provided a bi-modal spatial structure to this environment, as a result of an improvement in species richness and diversity. However, we verified a negative effect of grazing exclusions for these parameters when pasture is long term maintained at moderate grazing intensity.
5. ***Synthesis and applications:*** Our results supports the hypothesis that natural grasslands from Southern Brazil can quickly restore its functional and taxonomic diversity by temporary grazing exclusions, mainly by spring

grazing exclusion.

**Key Words:** forage allowance, functional diversity, spatial structure, species richness

## Introduction

The great diversity of forms and functions of plant species are fundamental to the composition and functioning of ecosystems, which are directly influenced by environmental conditions (Craine 2005). For grasslands ecosystems, grazing management is the main anthropogenic disturbance related with these changes, which also plays an important role to stimulate growth of some grazing-tolerant plant species, increases productivity and diversity, in addition to maintain the structure of landscapes (Marty 2005; Augustine & Frank 2001). However, the use of grazing intensity above the carrying capacity of the pasture for a long period may result in loss of key species, many of them essential for the provision of important ecosystem services.

Overgrazing is a global trend and the recovery process should involve the re-establishment of native ecological processes, restoring functionality productivity of the ecosystem, native plants and diversity (Zaloumis & Bond 2011; Dobson, Bradshaw & Baker 1997). A common first step to recovery overgrazed pastures is to implement optimal stocking regimes (Campbell *et al.* 2006). The grazing reduction or temporary exclusions of grazing are the starting point for the vegetation recovery, giving to the plants opportunity to recover leaf area, increase solar radiation capture and accumulate reserves (Nabinger *et al.* 2009). It can promote both grassland primary production and restore the

taxonomic and functional diversity, usually the main goals of restoration and vegetation improvement (Smith et al. 2000, Martin, Moloney & Wisley 2005).

Pastures with long history of evolution with herbivory have higher potential to recover the richness and diversity of native species after severe grazing events (Cingolani, Noy-Meir & Díaz 2005). Although there is no a scientific consensus on the intensity and duration of these disturbances in South America natural grasslands, a better understanding of their resilience capacity is crucial for the implementation of projects aiming to improve the functionality of this environment.

For several decades, large proportion of the Campos natural grasslands has been managed with severe grazing intensity. This biome comprises subtropical grasslands located in South Brazil, Uruguay, northeastern Argentina and part of Paraguay, that covers about 500.000km<sup>2</sup>. This biome presents high plant diversity, with 2500 species, among which approximately 450 grasses and 250 species of legumes (Boldrini 1997), which are the forage substrate for 65 million of domestic ruminants (Berreta, 2001). Rising economic pressures to make these lands more productive has put this ecosystem under threat as a result of a rate of replacement by grain crops (mainly soybeans) or cultivated forests (*Pinus* and *Eucalyptus*) that achieved 135,000 ha per year in the last two decades. Moreover, overgrazing is common in the remaining areas, which associated to landscape fragmentation causes biodiversity losses, soil erosion, susceptibility to biological invasion and, in consequence, loss of ecosystem services (Cruz et al., 2010).

Many advances have occurred in the last 25 years in understanding the

potential of these grasslands, and showed great benefits of moderate grazing intensity on both forage and animal productions (Mezzalira *et al.* 2012, Soares *et al.* 2005). However, no studies have been conducted in this region concerning recovery of grassland degraded by long time overgazing. Therefore, the functional recovery capacity of these grasslands after a long term severe disturbances is unknown. Aiming to understand these processes, the first proposal of our study is to understand the impacts of the overgrazing in the plant species spatial organization, and its possible effect on diversity and species richness. For this, we worked in an experiment maintained for 27 years under severe and moderate grazing intensity. This scenario, singular in its long term application of grazing intensity treatments, allowed the characterization of the pasture with livestock intensity compatible with the limits provided by the ecosystem (moderate grazing intensity) to be used as a target situation to recovery the overgrazed area.

In order a technique to recovery overgrazed areas, we studied the effect of removal of grazing in two different seasons (spring and fall), by using a reference system (Pasture managed for a long period under moderate grazing intensity). We hypothesized that the deferment provides a recovery time for the plants to grow regardless of management history, and could increase plant richness and functional diversity in degraded pastures by overgrazing. Also, we aimed to verify reasons of these changes by studying species spatial organization in response to the long term contrasting grazing intensities and the grazing exclusions.

## Methods

## SITE DESCRIPTION, TREATMENTS AND EXPERIMENTAL DESIGN

This work was conducted in the context of a long-term experiment with different grazing intensities at the Research Station of the Federal University of Rio Grande do Sul (lat 30°05'S, long 51°40"W, and 46 m a.s.l.), Brazil. The climate at the experimental site is humid tropical, with an annual average precipitation of 1440mm, evenly distributed throughout the year, and mean air temperature varies between 9 and 25°C (Bergamaschi *et al.* 2003). A soil water deficit above the climate normal tendency occurred during the first months of the experiment (Figure 1). The soils are classified as Rhodic Paleudult and Typic Plinthudult classes (USDA 1999).

Since 1986, the experimental area has been managed with continuous stocking (see Mezzalira *et al.* 2012 for details of the entire protocol). Treatments consisted of grazing intensities (GI) adjusted by contrasting daily forage allowances: 1) Severe (SGI): 4 kg of dry matter per 100 kg of animal's body weight per day throughout the year and 2) Moderate (MGI): 8 kg of dry matter per 100 kg of animal's body weight during spring and 12 during the remainder of the year. Stocking rates were adjusted every 28 days using the put and take technique (Mott and Lucas, 1952). The SGI treatment has resulted in an overgrazed pasture during the course of the experiment, while the MGI treatment represented the forage allowance with best aboveground net primary productivity and animal performance (Soares *et al.* 2005, Mezzalira *et al.* 2012). The historical results attested the degradation process of the grassland under severe grazing intensity: the forage and animal production in this grazing intensity was respectively 1190 and 70 kg/ha/year of forage dry matter and live

weight, in contrast to the moderate grazing intensity that produced 3867 and 260 Kg/ha/year, respectively (Soares et al. 2005, Mezzalira et al. 2012). Severe grazing also affected the soil physical and chemical properties (decreased soil water infiltration, porosity, aggregation and organic matter content, and increased soil bulk density) (Bertol et al. 1998, Conte et al. 2011), and diversity of botanical species (Carvalho et al. 2013).

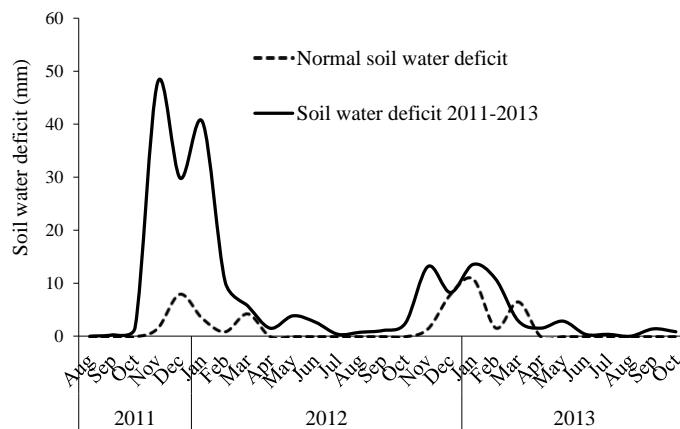


Figure 1. Soil water deficit during the experimental period (continuous line) and normal soil water deficit (dashed line) for the experimental unit.

In each of the two grazing intensities selected for this study, the following grazing exclusions treatments were applied: grazing exclusion during spring (RS), grazing exclusion during fall (RF) and control (continuous stocking) (CG). The experiment was performed from spring 2011 (November, 25) until end of fall 2013 (July, 14). Therefore two periods of grazing exclusion occurred for both RS and RF. Experimental units were plots of 8 x 15m with three replicates allocated in completely randomized design inside each main grazing intensity paddock.

#### ANALYSIS OF BOTANICAL COMPOSITION

Five permanent square of 1m<sup>2</sup> (sub-plots) were systematically fixed, nested within each plot. Vegetation sampling was conducted five times during the experiment period: a starting point (before the implementation of the treatments) and two annual assessments (after spring and after fall, during two years). All species were identified and their absolute coverage was estimated by using a decimal scale (Londo, 1976). Specimens that could not be identified in the field were collected outside the sample units and identified by consulting the specific taxonomic literature and specialists of the families in question.

Grass species were classified as proposed by Rosengurtt (1979), which is the most widely accepted guide in the management of natural grasslands in Uruguay and South Brazil. The taxonomic species were classified into functional groups according to growth season (cool or warm), lifespan (perennial or annual), growth habit (erect or prostrate) and forage value (high, good, moderate and low).

## DATA ANALYSIS

The spatial variation was analyzed using a matrix of dissimilarities among all sub-plots nested within each site and treatment. We used Bray Curtis as a measure of species composition dissimilarity and Euclidean distance as a measure of absolute spatial distance dissimilarity, both calculated using vegdist from Vegan R package. We used the Mantel test (references) to detect the dependence of each dissimilarity as function of distance. After that data were analyzed by classic ANOVA.

Species accumulation curves were performed in order to verify the number of species when increasing number of sample units. We used the

function specaccum of Vegan Package, and also performed the confidence limits intervals with 95% of significance.

## Results

### SPATIAL PATTERNS OF SPECIES COMPOSITION

The Mantel test detected significant spatial structure for species composition in moderate grazing intensity, both in plots under continuous grazing and grazing exclusions (Table 1). This positive correlation between the spatial dissimilarities (Euclidean) and the floristic dissimilarities (Bray-Curtis) shows that nearest locations had also more similar floristic composition, an indicative of species assemblages. At moderate grazing intensities, however, weak correlations were detected, indicating that species distributions are random over space.

Table 1. Mantel correlogram for the comparison between vegetation composition and spatial distance at contrasting grazing intensities (severe and moderate) and seasons of removals of grazing (spring, fall and control).

Grazing intensity	Mantel statistics	Removals of grazing		
		Spring	Fall	Control
Severe	Mantel r	0.09	0.09	0.11
	P value	0.016	0.055	0.009
Moderate	Mantel r	0.29	0.27	0.17
	P value	0.001	0.001	0.001

### LIFE FORMS COVERAGE

Species life forms with great plant coverage were: 1) Tussock species: *Aristida*, *Schizachyrium*, *Eryngium*, *Senecio* and *Elyonurus* genera; 2) Facultative species: *Andropogon* genera; 3) Low-strata species: *Paspalum*, *Axonopus*, *Piptochaetium*, *Mnesitea* and *Centella* genera. Both tussocks and

facultative species were higher in moderate grazing (Figure 2) and showed similar responses between fall grazing exclusion and control treatments in this grazing intensity ( $P>0.05$ ). Spring grazing exclusion, on the other hand, showed greater facultative and lower tussock species. Grazing exclusions in SGI increased tussock species coverage and did not affect the facultative species. Low-stratum species had higher coverage in severe grazing intensity and not showed differences due to grazing exclusions.

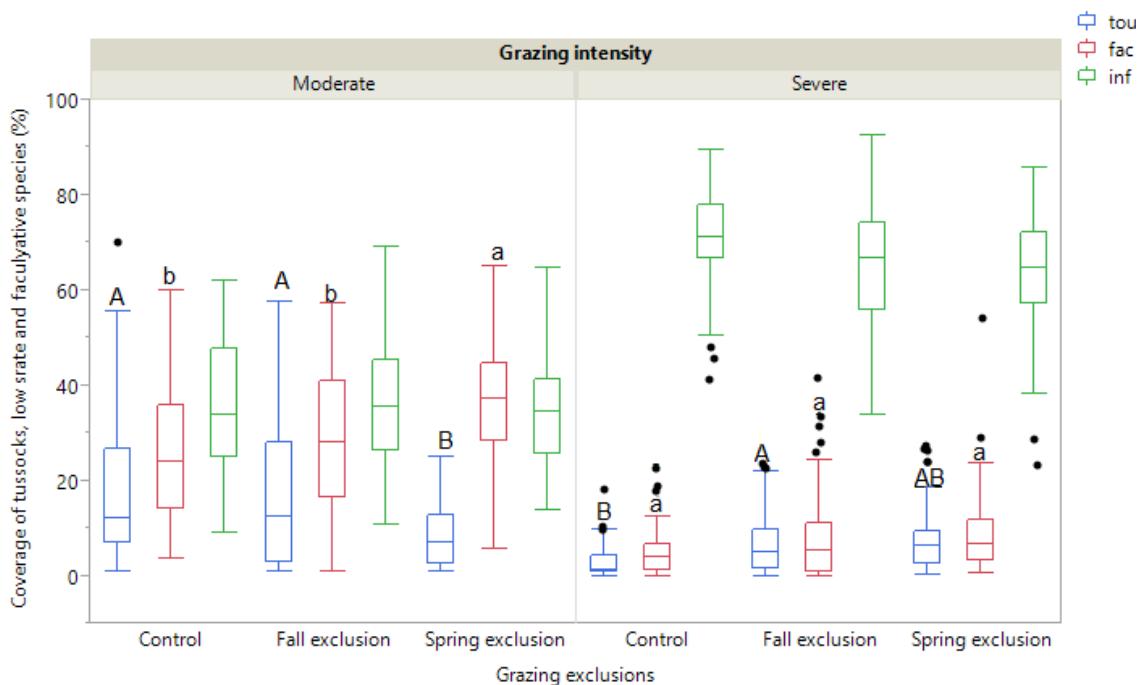


Figure 2. Coverage (%) of different species groups: tussocks (blue), facultative (red) and low-strata (green). Different letters in the same species group means significant differences between grazing exclusions within each grazing intensity ( $P<0.05$ ). The box-plots present the median, 25% – interquartiles, and maximum and minimum values.

#### SPECIES RICHNESS

A total of 198 species were found in the experimental area during the two years of study. The more common species were from Poaceae family,

which showed greater richness, 35 species for SGI and 49 for MGI (Figure 3a), and plant cover (Figure 3b). The other botanic families, although contributed together with only 27% of coverage, showed a substantial species richness, highlighting Asteraceae (35 and 40 species), Cyperaceae (15 and 13 species) and Fabaceae (18 and 14 species), respectively for severe and moderate grazing intensity.

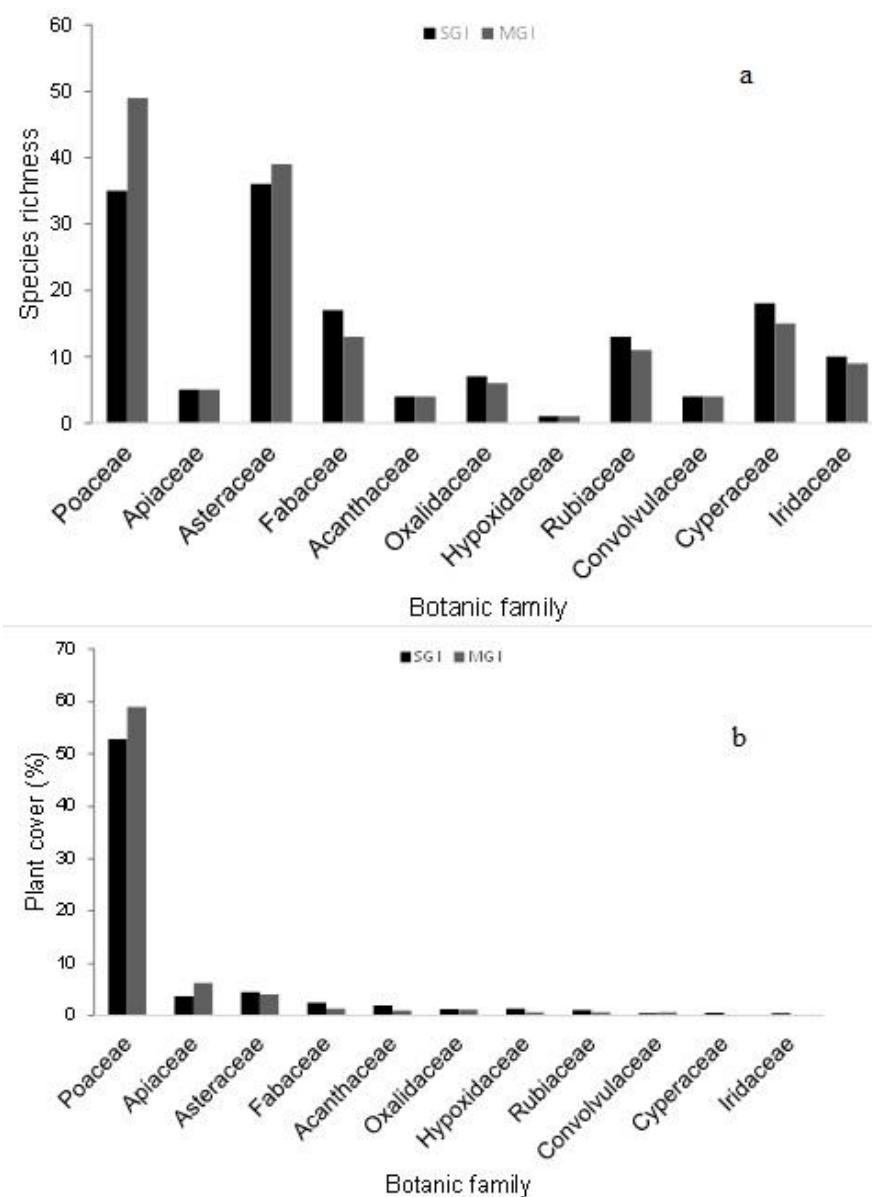


Figure 3. Botanic families with highest values of species richness (a) and plant coverage (b).

By analyzing the starting point of the accumulation curves, we verified similar amount of species in both grazing intensities when a limited number of sub-plots is evaluated (Figure 4). This result indicates that species richness was similar at patch scale. However, long term heavy grazing had lower number of species at site scale, being significantly lower than the pasture under moderate grazing intensity as increased the number of sample units. The species composition in SGI were therefore less similar to each other, thus increasing the probability of finding new species at every additional sample unit. The rarefaction curve obtained using data from both grazing intensities revealed higher richness than each one isolated, indicating that some species are specific to each environment.

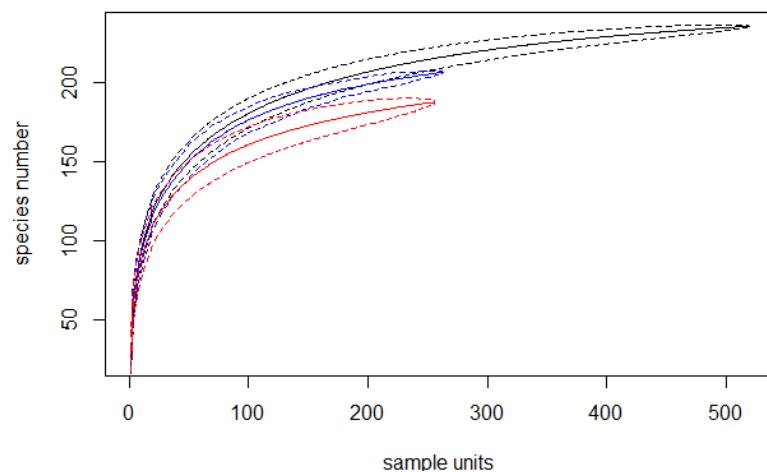


Figure 4. Sample-based rarefaction curves derived from moderate (blue) and low (red) forage allowances and their relationship with both data analyzed together (black).

While the removals of grazing did not change the trends in the rarefaction curves in SGI, we observed decrease in species richness in response to spring grazing exclusion in moderate grazing intensity (Figure 5d). This result was detected in the evaluations performed after the fall season,

acting as residual effect of the previous grazing exclusion period.

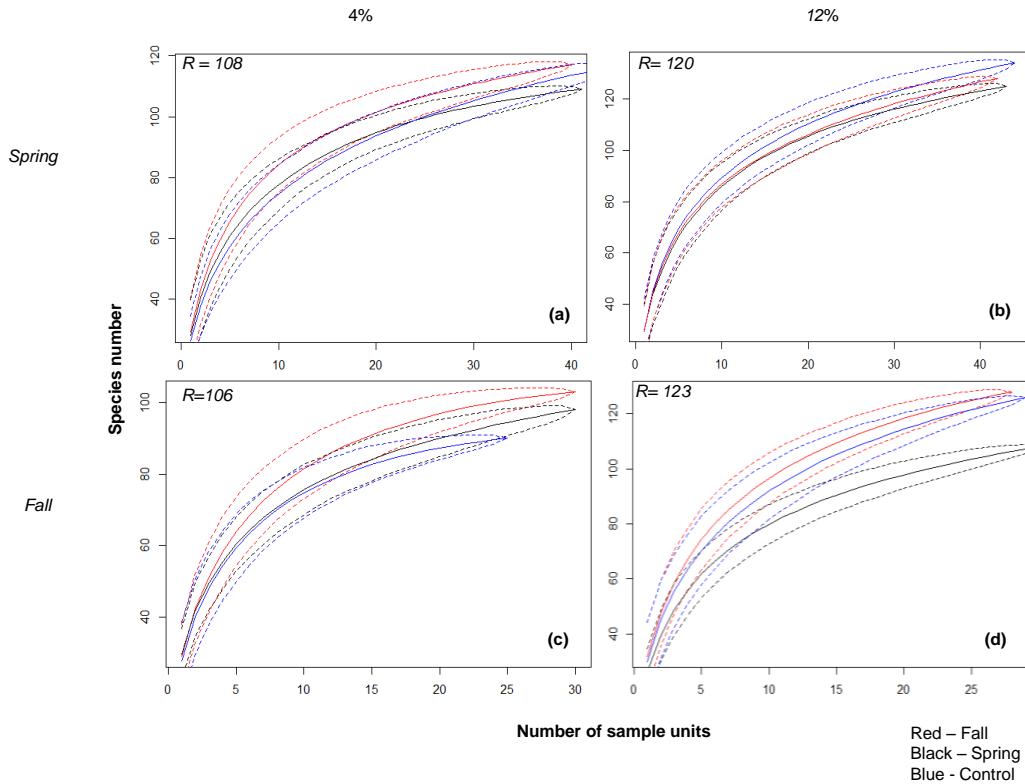


Figure 5. Sample-based rarefaction curves derived from removals of grazing in spring, fall and control, applied in moderate (12%) and low (4%) forage allowances. The analyzes were separated according to the measurement periods: after the spring (a and b) and fall (c and d) grazing exclusions.

#### TAXONOMIC AND FUNCTIONAL DIVERSITY

Species beta diversity (heterogeneity within the treatments) was significantly affected by treatment and grazing intensity (Table 2). The high grazing intensity had lower beta diversity compared with moderate grazing intensity. The removals of grazing improved values in SGI, mainly in the fall. For the moderate grazing intensity, however, we found negative beta diversity

values when the removals of grazing were applied, which was even lower in the spring grazing exclusion.

Table 2. Sum of squares from the species cover on a native pasture under two forage allowances (4 and 12%) and two removals of grazing seasons (Spring and Fall), as a measure of beta diversity. Means followed by different letters in the same column differ by Tukey test ( $P<0.05$ ).

Removals of grazing	Forage allowances	
	4%	12%
Spring	34,909b	32,966c
Fall	43,076a	49,503b
Control	30,130b	59,789a
Total	112,709	149,085

Figure 6 shows the evolution of the Shannon diversity index during the experimental period. On SGI, we verified the maintenance of a higher diversity at the end of the first period of spring grazing exclusion (2012Mar), compared to treatments under continuous stocking at that time (Fall grazing exclusion and continuous stocking). This situation allowed the maintenance of higher diversity values for this season of grazing exclusion during the entire trial period. The treatments under continuous stocking until March 2012 (Fall grazing exclusion and continuous grazing) showed decrease in this index from the first to the second period. This aspect could be related to the negative high soil water balance verified in this period (Figure 1). However, when the fall grazing exclusion was performed (starting in March 2012), we verified a diversity

recovery and its subsequent maintenance until the end of the experimental period. Treatment under continuous stocking, however, showed more instability during the course of the experiment. It was observed a new sharp drop in the assessment conducted in October 2012, again a period with soil water deficit.

Plots under moderate grazing intensity showed similar diversity results between grazing exclusions seasons and continuous grazing (Figure 6b). We verified a constant process of diversity evolution throughout the experimental period. The values of Shannon diversity in MGI, therefore, are lightly influenced by water deficiency determined by periods of negative soil water balance. Only in the last evaluation there was a positive effect of fall grazing exclusion in increasing species diversity.

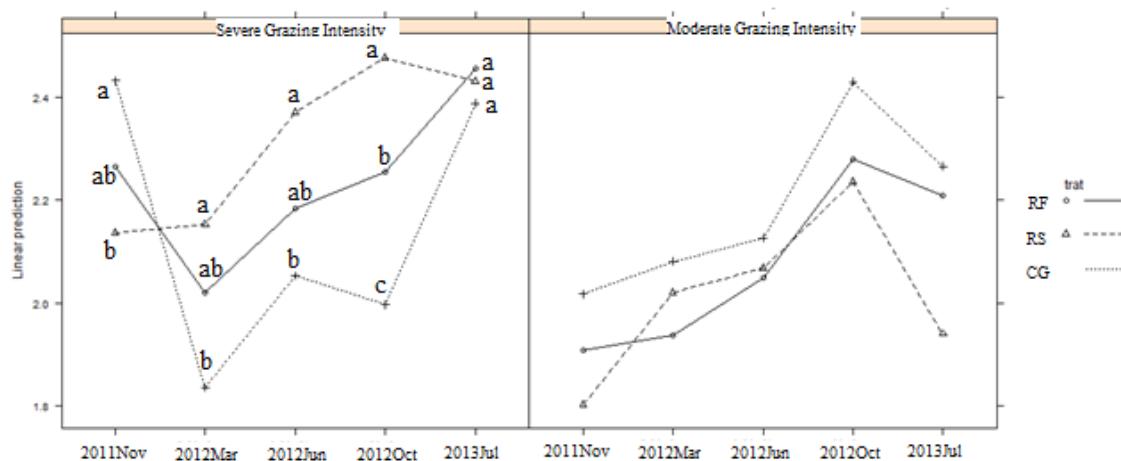


Figure 6. Evolution of species diversity (Shannon's index) of a native grassland under deferments and two levels of forage allowance during the experimental period. Different letters in the same period differ by Tukey test ( $P<0.05$ ).

The temporary grazing exclusion, both in spring and in autumn, improved the grass functional diversity in SGI (Figure 7). While the grazing exclusion during spring determined the maintainance of higher values of

functional diversity throughout the experimental period, the fall grazing exclusion increased functional diversity only after the second application of treatment, being statistically superior compared to continuous grazing. The MGI did not show significant variations with the grazing exclusion.

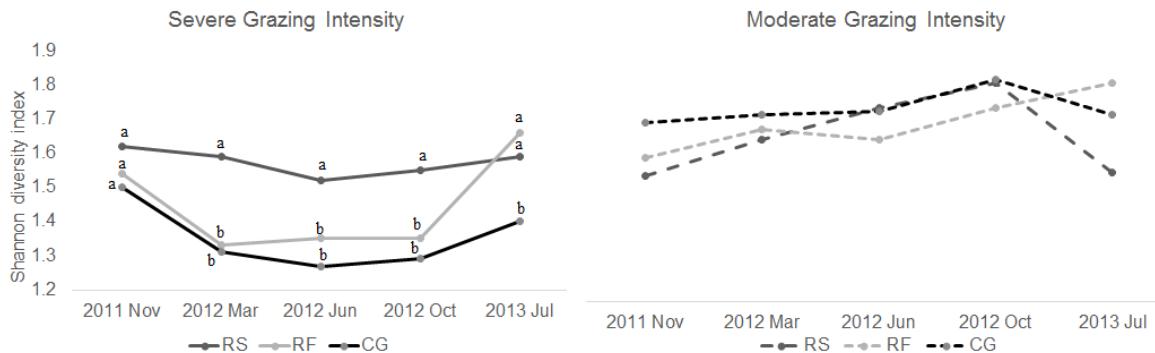


Figure 7. Functional diversity of grass species according to classifications from Rosegunrtt (1979). Different letters in the same period differ by Tukey test ( $P<0.05$ )

## Discussion

### SPATIAL PATTERNS

The spatial distribution of the vascular species varied across the contrasting grazing intensities applied for 27 years in this natural grassland. Spatial pattern had a greater tendency to be random when disturbance intensity was higher. On the other hand, moderate grazing showed spatial organization, a very common feature in many terrestrial ecosystems (Deblawé et al. 2008). According to Grime (1979), the intensity of disturbance is the main changing process of plants spatial patterns. The significative spatial pattern showed in our study (Table 1) is related to the development of double-stratum structure under moderate grazing intensity, which is composed by species assemblages in

tussocks and an inter-tussock stratum with more palatable species and lower size.

Studies from our research group shows that the area occupied by tussocks in moderate forage allowances, often seen as a problem for farmers due the loss of effectively grazed area, is offset by higher primary and secondary productivity of these pastures (Soares *et al.* 2005, Mezzalira *et al.* 2012). The species assemblages in patches or tussocks influences many processes of the community, such as the litter decomposition and resource acquisition efficiency, and can act as a positive feedback mechanisms associated with facilitating growth plants (Bertness & Callaway 1994).

Alternatively, species from the overgrazed pasture not showed spatial dependence, which characterizes the community as homogeneous and with random distribution. This stochastic species distribution leads to a limited species pools (Pacala & Tilman 1994). This lack of spatial dependence may be related to the grazing process that could also becomes random at high grazing intensities, due to the selectivity of impossibility in the diet.

Our results do not support the hypothesis that the grazing exclusion leads to higher spatial pattern of vegetation in SGI. It is known, however, that the exclusion of grazing for a longer period can lead to greater intra-specific aggregation states due to the dominance of tall and competitive species, similar to environments with lighter grazing. This tendency was verified by the improvement of tussock and facultative species in the SGI when submitted to grazing exclusions (Figure 2).

#### SPECIES RICHNESS

Species richness in individual quadrats were similar in the two grazing intensities, but when increased the number of quadrats evaluated we observed more frequently new species in moderate grazing intensity. It shows that although the richness at patch scale is the same, at the paddock scale more species composes the environment with moderate grazing intensity. The spatial structure of grassland with moderate grazing may have influenced these results, both for species richness and diversity, because the expansion of the sample area is crucial to detect the species living in organized patches, differently from those that are disperse randomly as in SGI.

The present study indicates also that the species dynamics can be altered when cattle are removed from natural grasslands. Although species richness did not changed significantly with the grazing exclusion in SGI, a decrease in the number of species was observed in early winter due to the previous spring grazing exclusion in MGI. Previous studies at the same experimental area support us to assign that tussocks/facultative botanical composition and its phenological stage may have influenced these results. Dominance of tussocks, mainly due to the facultative specie *Andropogon lateralis*, is common in this natural grassland, especially when forage allowance is moderate and high. In our protocol, *A. lateralis* represented more than 30% of the vegetation coverage on the paddocks in moderate grazing intensity (Azambuja Filho, 2013). This specie is induced to flowering from mid spring, and a more intense grazing during this period induces the elimination of reproductive meristems, allowing these plants remain in vegetative stage and more accessible to grazing during the remainder of the year (Soares *et al.*

2005). If the pasture is managed with light grazing intensity during spring is created a non desirable structure of the sward, both for pasture productivity and animal performance, due to the large physical barrier formed by these old and fibrous tillers. This spatial dominance condition, which in our case was generated by grazing exclusion in MGI, may have affected the development of some species and thus reducing the richness of the environment.

#### TAXONOMIC AND FUNCTIONAL DIVERSITY

In this study, we have shown that the beta diversity (the heterogeneity within treatments) is higher in the moderate grazing intensity. The spatial organization of the vegetation with light defoliation pattern, confirmed by Mantel test, results in increase of spatial heterogeneity due to the formation of mosaic-like structures. This pattern intensifies the beta diversity values of vegetation.

Grazing exclusion oppositely influenced the beta diversity in the two grazing intensities (Table 2). In SGI we observed increased species variability between plots due to changes in botanical composition, highlighting the increased presence of species with erect habit as *Andropogon lateralis* and *Mnesitea selloana*. On the other hand, the beta diversity decreased in MGI, indicating a tendency of structure homogenization due to the dominance of some species. These results support the idea that small changes in intensities of stocking management affect substantially species composition.

The Shannon's diversity index, which uses the coverage of botanical species from individual frames as a means of calculation, not showed important differences between grazing intensities (Figure 6). These values may have

followed the trend observed for the species richness values for individual frames discussed in the rarefaction curves, which showed a similar number of species at patch level in both grazing intensities. The removals of grazing, although it has not influenced the diversity of Shannon in MGI, improved the Shannon diversity both in spring as in the fall grazing exclusions. These two treatments allow the species diversity remain higher than CG throughout the experimental period. Especially in periods with higher soil water deficit, deferred areas allowed greater stabilization of species diversity compared with the significative decrease in the

In line with our expectations, plant functional diversity was greater in moderate grazing intensity. This response agrees with the intermediate disturbance hypothesis, proposed by Connell (1978). The grazing acts, therefore, as an environmental filter, in which the species tend to be more similar to each other due to environmental restrictions imposed by severe grazing, where only some plant functional groups have survival skill. In grasslands under moderate grazing, however, the competition can lead to niche differentiation of functional groups, which leads to a greater diversity (Keddy 1992).

Grazing exclusion seasons also positively affected the functional diversity on grassland under severe grazing. Currently, many authors concluded that the diversity impacts on ecosystem properties depends more on functional diversity than on species diversity (Tilman, 1997; Petchey, Hector & Gaston 2004; Duru, Theau & Cruz 2012). The hot spots of ecosystem services coincide both with species richness as functional diversity (Lavorel, 2011).

Resilience capacity of the South America natural grasslands after disturbances is a controversial topic. However, our results support the idea that vegetal community from the *Campos* have a fast recovery after a long-term overgrazing. The pastures under grazing exclusion, even during a short period, can recover its functional and taxonomic diversity. In addition, the diversity and richness responds differently to different grazing intensities. In both situations, we observed botanical changes towards tall and tussock species with longer leaf lifespan. This pattern enables to improve the diversity in the pasture under severe grazing (growth the new functional group) and may decrease under lower grazing intensity (dominance of tall species).

From a practical or management perspective, we verified important relationships between species biodiversity and spatial heterogeneity. Changes in spatial heterogeneity implies in changes in habitat diversity, which influence the diversity of consumers ranging from insects to birds and mammals.

Establishment of practices for conservation and recovery of this traditional and complex environment requires the use of strategies that take into account not only ecological issues, but also productive and economic aspects, due the necessity to be a productive system to the local people. In this kind of environment, the recovery of degraded state from overgrazing shown to be less dependent on inputs (introduction of new species, fertilization, irrigation, etc.) compared to other ecosystems around the world. The temporary grazing exclusion, mainly during spring, is a useful practice for cattle producers of this region, because it promotes both species diversity and richness, in addition to be easy to use and without installation costs.

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## **CAPÍTULO IV**

## CONSIDERAÇÕES FINAIS

Embora o conhecimento sobre as potencialidades das pastagens naturais do Sul do Brasil tenha avançado consideravelmente nas últimas décadas, ainda persistem lacunas na compreensão da adaptação ao pastejo e da resiliência desses ecossistemas frente a intensidades elevadas de distúrbio. Essa lacuna científica fortalece a ideia tradicional de que as técnicas de recuperação de pastagens degradadas devem sempre se apropriar de alto aporte de insumos. O presente trabalho mostrou, no entanto, o diferimento do pastejo pode ser uma ferramenta efetiva para a recuperação tanto produtiva quanto botânica das pastagens naturais.

Corroborando com a literatura internacional e com os trabalhos já desenvolvidos pelo Departamento de Plantas Forrageiras e Agrometeorologia da UFRGS, verificamos que o uso do pastejo moderado possibilita aliar diversidade de espécies e maior produtividade primária das pastagens. A sua utilização permanente durante o ano, com eventuais controles da estrutura em momentos específicos, destaca-se como um dos métodos mais eficientes de utilização das pastagens naturais para impedir a sua degradação. Essas medidas podem evitar o cruzamento de limites críticos que conduziriam a estados menos desejáveis e fortalecem a auto-organização e a capacidade de auto-regulação do sistema. Em áreas degradadas, no entanto, a exclusão temporária do pastejo apresentou excelentes resultados para a transição de grupos funcionais de gramíneas a estados desejáveis, favorecidos pelo regime climático privilegiado relativo a outras regiões do mundo e da capacidade de adaptação das plantas ao pastejo.

O banco de sementes do solo é um aspecto que deve ser levado em consideração em projetos de recuperação de pastagens degradadas devido a sua importante abundância nesses ambientes. No entanto, avançamos apenas no conhecimento das principais espécies presentes no banco de sementes e ainda são necessários maiores esclarecimentos sobre a sua real contribuição sucessão ecológica da comunidade.

O presente trabalho permitiu também a constatação da capacidade de resiliência dessas pastagens naturais após distúrbios de longa duração. A proposta não objetivou a definição de uma ferramenta de manejo específica, e sim compreender os padrões de resposta das pastagens naturais em diferentes situações de manejo para a aplicação de estratégias eficientes de uso do pasto em condições iniciais contrastantes. Reconhecemos, no entanto, que para a completa recuperação dessas áreas são necessárias ações de longo prazo, e que a isolada exclusão do pastejo por um curto período com a posterior retomada do manejo inadequado do pastejo torna pouco efetivos os benefícios da recuperação a estados alvo observados no presente estudo.

O conhecimento acerca do histórico de uso das áreas é essencial para o planejamento técnico de qualquer projeto de recuperação. Em situações onde a degradação atinge o solo, disponibilização de propágulos ou presença de invasoras em grandes proporções, seriam necessárias intervenções mais ativas para resultados satisfatórios. Um aspecto relevante para a conservação das pastagens naturais remanescentes é a manutenção de paisagens produtivas e com a utilização responsável das áreas que compõe os ambientes já fragmentados por outras formas de uso da terra. Certamente a fertilização e utilização de espécies hibernais nas pastagens naturais, e tecnologias como sistemas integrados de produção agropecuária são alternativas que podem proporcionar ao setor produtivo uma exploração mais sustentável, dentro das potencialidades do ambiente e ajudando a conservar boa parte das pastagens naturais da região.

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## APÊNDICES

**Apêndice 1:** Normas para preparação de trabalhos científicos para publicação no periódico *Rangeland Ecology & Management* (Normas utilizadas para escrever o Capítulo II).

### ***Rangeland Ecology & Management Style Manual***

Updated December 2012

**A manuscript must conform to the style manual before it begins the review process.**

#### ***Manuscript Categories***

**Research Papers** report original findings on all rangeland topics and must be based on a sound conceptual framework and a rigorous test of experimental hypotheses. The experimental design should be clearly described and analyzed with appropriate statistical procedures, and conclusions should be limited to the appropriate inference space. Papers that are descriptive (e.g., characterize landscape patterns or classify vegetative communities) or that are based on quantitative models are also appropriate.

#### ***Manuscript Organization***

**Page/Line Numbers and Spacing:** Page and line numbers must be included on all submitted manuscripts. Line numbers can be either sequential throughout the manuscript or repeated on each page. Text should be double spaced throughout.

#### ***Title page***

The title page is the first page, and includes these three components:

**Title:** Titles should be as brief as possible (15 word maximum) while conveying the broad contribution of the manuscript.

**Authors and affiliations:** One author should be designated as the corresponding author and his/her complete contact information should be provided, including business phone and email address.

**Support/Grant Information:** Include funding sources only; individuals who provided assistance with data collection or analyses and reviewers may be referenced in Acknowledgments. Use this format: "Research was funded by the Wyoming Abandoned Lands Program, University of Wyoming." or "A.L.H. was funded by Grant TA-MOU-94C13-149 from the US Agency for International Development."

If the information on the title page is missing or incomplete, the authors may be charged later for fixing it at the proof stage. See next page for formatting example.

[Note: this page serves as a formatting example for the title page. See appendix B for specific information.]

#### **Black-Tailed Prairie Dog Effects on Montana's Mixed-Grass Prairie**

*Carolyn M. Johnson-Nistler,<sup>1</sup> Bok F. Sowell,<sup>2</sup> Harrie W. Sherwood,<sup>3</sup> and Carl L. Wambolt<sup>4</sup>*

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Authors are <sup>1</sup>Associate Wildlife Specialist, <sup>2</sup>Associate Professor, <sup>3</sup>Research Associate, and

<sup>4</sup>Professor, Animal and Range Sciences Department, Montana State University, Bozeman, MT 59717, USA.

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Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA or the authors and does not imply its approval to the exclusion of the other products that also may be suitable.

At the time of research, Johnson-Nistler was a research assistant, Animal and Range Sciences Dept, Montana State University, Bozeman, MT 59717, USA.

**Apêndice 1 (cont.).** Normas utilizadas para escrever o Capítulo II.

Correspondence: Carolyn Johnson-Nistler, Animal and Range Sciences Dept, Montana State University, Bozeman, MT 59717, USA. Email: carolynjohnson@montana.edu

urrent address: Bok F. Sowell, Southern Plains Range Research Station, 2000 18th St, Woodward, OK 24615, USA.

## **Manuscript Elements or Sections**

### **Abstract**

The Abstract constitutes the second page and it is limited to a 300-word maximum. It includes a brief summary of the hypotheses, methods, conclusions, and management implications of the research. The Abstract must identify the relevance of the manuscript to the rangeland profession. It should include numerical data and a measure of variation, as well as both common and scientific names of organisms studied. The authority for scientific names should be listed. Citations to references, figures, and tables are not to be included in the Abstract.

### **Resumen**

Publication of Spanish abstracts has been suspended starting 2013.

### **Key Words**

Include four to six high-impact words for indexing and abstracting purposes; use words that are not already used in the title of the article. Key words should be alphabetical with comma separators, no period at the end.

### **Introduction**

The Introduction presents the rationale, justification, and hypotheses for the investigation. It should provide an appropriately detailed background for a broad readership to determine the potential contribution of the manuscript. This background information should be supported with peer-reviewed literature. It is the authors' responsibility to convey the importance of the work to the broadest potential audience. The Introduction provides the framework for the subsequent Discussion and Implications sections.

### **Methods**

This section should clearly delineate the study location, experimental design, and specific statistical analyses used. Sufficient detail must be provided to permit the reader to evaluate the proper application of the analyses and to repeat the experiments. Standard methods or techniques should be referenced and modifications of standard techniques should be clearly stated. Novel analytical methods should be clearly described and referenced. It is the authors' responsibility to describe the appropriateness and limitations of the experimental design and to acknowledge these constraints while drawing inferences.

## **Results**

The Results describe all of the relevant findings of the manuscript supported by critical tables and figures. The central tendencies of the data as well as the variability observed should be emphasized. Estimates of variability must accompany statistical analyses in data-based papers. Data comparisons to other published literature should not be included in this section.

## **Discussion**

The Discussion should place the research results in the broadest possible scientific or management context. It should highlight the important contributions of the work and relate these contributions to published knowledge. The Discussion should clearly state the importance of the work to rangeland ecology or management.

## **Implications**

All manuscripts should conclude with a brief section (maximum of two paragraphs) that highlights the broad implications of the research. The implications can be either scientific or managerial and reference any aspect of the rangeland profession.

## **Acknowledgments**

The Acknowledgments section immediately precedes Literature Cited and is used to acknowledge individuals who provided assistance with data collection, analyses, and reviews. Grant information is footnoted on the title page, rather than in this section.

## **Literature Cited**

List the citations of all published papers referenced in the text. The majority of citations should be from the peer-reviewed scientific literature. Citations from non-peer-reviewed sources should be limited to general databases (e.g., NOAA climate), manuals (e.g., SAS manuals) or to generic descriptions of study sites. It is the author's responsibility to ensure that all citations are correct and correctly cited in the text. Incorrect citations caught at the proof stage may result in extra charges for alterations.

## **Figures and Tables**

Figures must be uploaded separately from the manuscript text. However, figure captions should be listed on a separate page following the Literature Cited. Tables (in their entirety) should follow the figure captions list in the Word file, or they may be uploaded as separate files. See Appendix A for more information about figure files.

Figures or tables that are reproduced or adapted from another source must credit the original source with a statement such as "Reproduced with permission." Authors who use such material must obtain written permission from the copyright holder of the original material.

## **Supplemental Files**

Supplemental files offer additional information to the reader but are not vital to understanding the paper. These files may be tables, figures, appendices, etc., that are too lengthy to print, or non-traditional elements such as spreadsheet tools or audio or video files. Supplemental files are not reviewed, copyedited, or typeset, but posted as submitted directly onto the journal web site when the paper is published. The content of supplemental files is the responsibility of the author; therefore, please ensure supplemental files are ready to be published when they are submitted.

Online supplemental materials should be cited using a separate numbering system from regular tables and figures (i.e., Tables S1, S2; Figs. S1, S2; etc.). To refer readers to the online supplemental material, insert a callout when the material is referenced in the text. Example: ...Table S1 (available online at [insert URL here]) or ... (Table S1; available online at [insert URL here]). The exact URL to the supplemental material will be added during production. There is no additional cost to authors for posting supplemental material online.

## **Basic Formatting Rules (see Appendix B for specific information)**

### **Headings**

#### **FIRST ORDER HEADING (Head #1)**

All manuscripts should begin with the first order heading of Introduction. Heading should be all uppercase and centered. Insert a single line of space between Head #1 and text. Text following the heading is flush with the left margin and is not indented. Subsequent paragraphs in the section are indented.

#### **Second Order Heading (Head #2)**

Heading should be capitalized and bold, and should be flush with the left margin. The next line of text follows immediately and should be flush with the left margin.

**Third Order Heading (Head #3).** Heading should be capitalized and bold, but should be indented with a period at the end of the heading. Text begins on the same line.

**Fourth Order Heading (Head #4).** Heading should be indented and italicized with a period at the end of the heading. Text begins on the same line.

### **Internal and Technical Style**

See Appendix B for specific style instructions. Make sure that all abbreviations used in the text are defined, scientific names (including authorities) are provided for plant and animal species, and complete sources of materials are listed. If these items are missing at the proof stage authors may be charged for providing them.

### **In-Text Footnotes**

Material should be footnoted very rarely. Use superscript numerals.

### **Citations in Text**

Place citations in chronological order (oldest first), then alphabetical order with semicolon separators.

1. Use et al. with three or more authors.
2. EXAMPLES:

Johnson (2000), (Eliel 2003a, 2003b)

Johnson and Lewis (2001, 2002)

(Eliel 1999; Crews and Gartska 2000; Gardos et al. 2002a, 2002b)

3. Provide the date for personal communications. EXAMPLE: (J.T.C. Renner, personal communication, March 2001)
4. Avoid citing unpublished data.

### **Literature Cited**

Use #1 head style listed above: LITERATURE CITED.

1. Citations should be strictly alphabetical by author. Within multiple works by the same author(s), citations should be chronological with the oldest work cited first. If an agency-author's name has been abbreviated in citations in the text, list the abbreviation first in the Literature Cited: [WRCC] Western Regional Climate Center. 2007....
2. Use two-letter postal abbreviations for U.S. states and Canadian provinces when used with a city name. EXAMPLE: New York, NY, USA
3. Use city and country for countries outside the USA and Canada. EXAMPLE: Paris,

- France
4. Use the full name of journals; journal issue numbers are not necessary for journals that number pages continuously across each volume. Include information such as "Volume 1." and "2nd ed." with book titles.
  5. Except for proper names that occur in the titles of papers or books, **capitalize only** the first word in a title, and lowercase the first word after a colon or dash. The only exception is when the paper is published in a different language that typically capitalizes nouns.
  6. Author rules:
    - A. Schuman, G. E. (first/middle initials go after the last name for first authors only), T. Booth, and E. R. Roos
    - B. Schuman, G. E., III (1st author), G. E. Schuman III (other authors)
    - C. Engle, D. M., Jr. (1st author), D. M. Engle, Jr. (other authors)
    - D. NOTE: Please do not present author names in ALL CAPS; simply use upper- and lowercase letters as shown here; the proper font (SMALL CAPS) will be applied during production.

### **Citation Examples**

#### **Journal:**

Bates, J. D., R. F. Miller, and T. J. Svejcar. 2000. Understory dynamics in cut and uncut western juniper woodlands. *Journal of Range Management* 53:119–126.

Kurc, S. A., and E. E. Small. 2004. Dynamics of evapotranspiration in semiarid grassland and shrubland ecosystems during the summer monsoon season, central New Mexico. *Water Resources Research* 40:W09305. doi:10.1029/2004WR003068

#### **Book:**

Duncan, L., and J. K. Clark. 2005. Invasive plants of range and wildlands and their environmental, economic, and societal impacts. Lawrence, KS, USA: Weed Science Society of America. 222 p.

#### **Chapter in a book:**

West, N. E., and J. A. Young. 2000. Intermountain valleys and lower mountain slopes. *In: M.*

G. Barbour and W. D. Billing [eds.]. North American terrestrial vegetation. Cambridge, United Kingdom: Cambridge University Press. p. 255–284.

#### **Dissertation or Thesis:**

Johnson, T. 2005. Spatial dynamics of a bacterial pathogen sylvatic plague in black-tailed prairie dogs [thesis]. Manhattan, KS, USA: Kansas State University. 75 p.

#### **Software:**

SAS Institute. 2002. JMP statistics and graphics guide. Version 5. Cary, NC, USA: SAS Institute, Inc. 707 p.

[SPSS] Statistical Procedures for Social Science. 2005. SPSS guide to data analysis, release 14.0. Old Tappan, NJ, USA: SPSS. 652 p.

#### **URL:**

USDA-NRCS. 2007. The PLANTS database. Available at: <http://plants.usda.gov>. Accessed 25 July 2007.

#### **Proceedings paper (include dates and location of conference and place of publication if available):**

Bin fet, J., and D. W. Lutz. 2003. Deer and elk population status and harvest structure in western

North America: a summary of state and provincial status surveys. In: S. A. Tessmann [ed.]. Proceedings of the 5th Western States and Provinces Deer and Elk Workshop; 21–23 May 2003; Jackson, WY, USA. Jackson, WY, USA: Western States and Provinces Deer and Elk Workshop. p. 48–68.

**Report or Government Publication:**

McClaran, M. P. 2003. A century of vegetation change on the Santa Rita Experimental Range. In: M. P. McClaran, P. F. Ffolliott, and C. B. Edminster [tech. coords.]. Proceedings: Santa Rita Experimental Range: 100 years (1903–2003) of accomplishments and contributions. Ogden, UT, USA: US Department of Agriculture. Forest Service, RMRS-P-30. p. 16–33.

Walker, A. D. B., D. C. Heard, V. Michelfelder, and G. S. Watts. 2006. Moose density and composition around Prince George, British Columbia. Prince George, BC, Canada: British Columbia Ministry of Environment. Final Report for Forests for Tomorrow 2914000. 23 p.

**Foreign language:**

Koyumdjiski, H., J. Dan, S. Soriano, and S. Nissim. 1988. Selected profiles from Israeli soils. Bet Dagan, Israel: ARO, the Volcani Center. 244 p. (in Hebrew)

**In press (please update as much as possible before final submission; include DOI number if available):**

Campbell, E. S., C. A. Taylor, J. W. Walker, C. J. Lupton, D. F. Waldron, and S. Landau. 2007. Effects of protein supplementation on juniper intake by goats. *Rangeland Ecology & Management* 60:(in press). doi:10.2111/06-142R1.1

## Figures and Tables

**Figure and table references in text:**

1. All figures and tables must be referenced in the text in the order that they appear in the manuscript.
2. Figure and Table spelled out always in text. Use Fig. and Table in parentheses. If citing a figure or table from another work, use lowercase letters.
3. EXAMPLES:  
(Figs. 10A and 10B); (Figs. 4B–4D)

Figures 3–5; (Figs. 3–5)

Figures 1 and 2; (Figs. 1 and 2)

(Fig. 7; Tables 2 and 3)

(Johnson et al. 2007, fig. 1)

**Figure captions (see Appendix A for information about figure files):**

1. Figure captions should be listed on a separate page following the Literature Cited, since the figures will be uploaded separately from the manuscript text.
2. Caption style: **Figure 1.** Description that enables the reader to interpret the figure without referring to text. Refer to different panels in the figure as **A**, Text. **B**, More text. **C**, Final text.
3. Define all abbreviations used in the figure. Style for explanations: NS indicates not significant; ND, not done; and NA, not applicable.
4. When showing mean separations, either capital or lowercase letters are permitted, but should be consistent throughout the manuscript.

**Tables:**

1. Heading style: **Table 1.** Description that enables the reader to interpret the table without referring to the text. If needed: **Table 1. Continued.**

2. All footnotes are designated and use superscripted numerals. Place a period at end of each footnote. EXAMPLE: <sup>1</sup>TNC indicates total nonstructural carbohydrates; KNF, Kaibab National Forest.
3. Letter designation for statistical significance between values in the table should be lowercase, not superscript.
4. Redefine all abbreviations used in the table. Use the same style for explanations as in figure captions.
5. Abbreviate "number." EXAMPLE: No. of animals
6. All horizontal lines dividing the table should be solid, but lines designating the measurement units should be dashed.
7. Use an em dash (—) for empty data cells to let readers know the omission is intentional. Provide additional explanation with a footnote as needed.
8. A sample table appears below.

**Table 1.** Cow weights (SE), average daily gains (ADG), and body condition scores (BCS) at the beginning and end of spring and late summer grazing trials in Nephi, Utah.

			Weight		BCS <sup>2</sup>		
Yr	Season	Group	Begin	End	ADG <sup>1</sup>	Begin	End
			-----kg-----		kg · d <sup>-1</sup>		
2004	Spring	High BCS	565 (9)	552 (9)	-0.53 a	6.8	7.0
		Low BCS	447 (14)	435 (12)	-0.53 a	4.6	4.4
	Late summer	High BCS	504 (14)	469 (12)	-1.40 b	5.6	5.2
		Low BCS	359 (12)	360 (14)	0.06 a	3.4	3.4
2005	Spring	Supplement	507 (20)	545 (17)	1.53 a	5.7	— <sup>3</sup>
		No supp	525 (19)	546 (14)	0.85 b	5.8	— <sup>3</sup>
	Late summer	Supplement	569 (13)	582 (16)	0.29 a	6.5	6.3
		No supp	569 (12)	553 (12)	-0.35 b	6.5	6.3
2006	Spring		536 (14)	558 (15)	0.85	5.4	5.0
		Late summer	589 (14)	558 (15)	0.85	5.4	5.0

#### Appendix A: Figures

Figures must be uploaded as separate files from the text and must be of acceptable resolution to be published with the paper. Please label each figure as Figure 1, Figure 2, etc.

The Managing Editor will contact authors whose figures are of poor quality and ask for replacements. Following are some general tips for creating useable and effective figures.

#### Photos:

Must be submitted as .jpg, .tif, .eps, or .psd, and should be at least 300 dpi at FINAL SIZE. Figures intended to be printed one column wide must be 1050 pixels wide or greater; one and one half columns wide, 1650 pixels wide or greater; and two columns wide, 2175 pixels or greater.

<sup>1</sup> Average daily gains within seasons followed by different letters ( $P < 0.05$ ).

<sup>2</sup> Standard errors for BCS ranged from 0.1 to 0.2.

<sup>3</sup> —, data not collected.

Do not submit photos embedded in MS Word.

**Graphs, charts, or modified photos:**

*Font and type size:* Choose a readable and commonly used font that looks similar to the fonts used in the printed journal (e.g., Helvetica or Arial). Make sure that your axis or chart labels are large enough so that they can be reduced to a 1-column size. Avoid excessive white space around the figure. If all figures in a paper are reduced to 1-column width, the paper will be shorter—and page charges lower.

*File type:* There are many different programs that can be used to create acceptable figures. It is usually best to submit a figure in its original file type to prevent resolution problems. Unfortunately, this can also result in translation problems between versions of programs, especially with Microsoft programs (Word, Excel, PowerPoint), and certain file types are not useable at all (see below). For this reason, most figure software will allow you to save a figure as one of these file types: .pdf (preferred for Microsoft programs), .eps, and .tif. This will allow you to run the file through the VeriFig program (see below) to check for resolution. Always make sure, however, that the final image you submit is accurate and does not contain any typos or alignment problems: if you notice a mistake at the proof stage you will need to submit a new file.

**Usable and non-useable file types:**

*Usable and preferred:* .pdf, .tif, .eps, .psd

*Usable, but not preferred* (i.e., use only if you are unable to create a file type listed above at an acceptable resolution): .doc, .xls, .ppt

*Not usable:* .wps, .gif, .rtf, .pic

**About VeriFig:**

VeriFig is a tool available online (<http://verifig.allenpress.com>) that allows authors to check the resolution of certain types of image files: .jpg, .tif, .eps, .psd, or .pdf. Although a figure may appear high-quality on a computer screen this does not necessarily guarantee that it is acceptable quality for printing. Thus, it is recommended that authors run file types through VeriFig to check the resolution when submitting manuscript revisions. The size of the image must be checked prior to running it through VeriFig because a small image will lose a significant amount of quality if it must be enlarged. Make sure your figures are at least one column wide (about 3.5 inches). VeriFig will also identify potential font problems: if a font alert occurs, all fonts should be double-checked to make sure that they appear as intended.

To log in to VeriFig:

Email: [your email address]

Password: figcheck

**Color figures:**

In order to have a figure printed in color, a setup fee of \$450 per page must be paid before the article can enter production. Alternatively, the figure may be run in color online only, and printed in grayscale, for a fee of \$75. If an author has indicated on PeerTrack that he/she would like to print a figure in color (or online-only color), an invoice will be sent to the author after the manuscript is accepted. Please do not delay payment or the publication date of the paper may be delayed.

**Appendix B: Internal and Technical Style**

**Specific Instructions for Title Page**

Title:

1. Capitalize, bold, and centered
2. Capitalize after colon, hyphens, or dash
3. Italicize scientific name, without authority (*Genus species*)
4. Capitalize prepositions four or more letters long: From, With

Author:

1. Italic; centered; space between initials
2. Either full names or initials only (for first and middle names) are OK
3. Comma between authors
4. Indicate affiliation with superscripted numerals after the name
5. No separate affiliation designators are needed if all authors have same affiliation

Affiliation line:

1. Specify country always; use postal abbreviations for US states followed by "USA"
2. Use semicolon between affiliations; use "and" even if only two affiliations
3. Do not include street address, P.O boxes, etc.
4. Abbreviate "USDA" always. Abbreviate "USDA-ARS" and "USDA-NRCS." EXAMPLE: USDA-ARS Jornada Experimental Range

Footnotes (use this order):

1. Support/Grant Info:
  - Use complete sentences, no superscript designators
  - Dept rather than Department
  - Grants DK 41769 and 275859; omit No or # before grant numbers
  - Use initials (A.L.H.), not full names, for recipients
2. Disclaimer (if necessary):
  - Use complete sentences
3. At the time of research (if necessary):
  - Dept, St, Blvd, NE, SW (no periods)
  - Use postal codes: NC, CA, MT
  - Specify country always (use "USA")
  - Use wording and style in example
4. Correspondence
  - Use wording and style in example
  - No periods in abbreviations, use postal codes, specify country
5. Current address (if necessary)
  - Use wording and style in example
  - No periods in abbreviations, use postal codes, specify country

Internal Style

**General style:**

1. Lists given in the text should be styled as 1) more text, 2) still more text, and 3) last of text (use commas or semicolons between items for clarity).
2. The preferred order of brackets is: ([{}])
3. Use periods in the following abbreviations: i.e., e.g., etc., vs., et al.
4. Do not use periods in honorifics or degrees: Dr, Ms, Mr, PhD, MA

**Extracts and in-text quotations:**

1. All direct quotations must include the page number from the source of the quote.
2. Direct quotations of 40 or more words are set off from the text by indenting the left and

right margins; quotation marks should be omitted. The page reference for the quotation must be listed at the end of the quotation, after the ending punctuation. EXAMPLE: quoted text ends. (p. 276)

3. In-text quotations (those less than 40 words) leave the page number outside the quotation marks but before the ending punctuation. EXAMPLE: “in-text quoted material ends” (p. 11).

#### **Hyphenation rules:**

1. Retain hyphens for clarity if needed.
2. Use an en dash between two units of equal status: test–retest
3. In general, run these prefixes together with the word following: ante, anti, bi, co, contra, counter, de, extra, hyper, hypo, infra, inter, intra, micro, mid, multi, neo, non, over, poly, post, pre, pro, pseudo, re, semi, sub, super, supra, trans, tri, ultra, un, under
4. Do not permit double vowels or triple consonants with these prefixes; hyphenate these cases. EXAMPLE: bell-like; intra-abdominal, *but* defer to Webster’s 11th
5. Retain hyphen if word that follows prefix is capitalized, is an all-caps abbreviation, or is a numeral. EXAMPLE: pre-Columbian civilization, pre-USDA standards
6. Use regular grammatical rules for hyphenation of units of measure. EXAMPLE: a 3-cm-diameter pot; *but* a pot that was 3 cm in diameter, a 50 × 50 m plot.

#### **Abbreviations and acronyms:**

1. Keep acronyms to a minimum. Only use acronyms when they do not interfere with the legibility of the paper.
2. Define on first use; then abbreviate thereafter in each section: abstract, text, tables, and figures.
3. Do not include periods in abbreviations: Inc, Corp, Ltd, Co, St, Ave, Blvd, Dr, Ms, Mr, PhD
4. A sentence may begin with an acronym that has been defined previously.
5. Use the abbreviation “No.” to represent the word “number.” EXAMPLE: No. of plots

#### **Nomenclature:**

1. Use common names for plants and animals whenever possible.
2. Spell out *Genus species* upon first mention and provide taxonomic authority for plants (except in titles). Don’t use parentheses or brackets with just one authority name: *Genus species* Name. It is also advisable to cite the taxonomy reference used.
3. Thereafter, may use *G. species* (with period).
4. Spell out genus with each new species.
5. A sentence may begin with a genus abbreviation.
6. Place a period in nomenclature abbreviations: sp. (species, singular), spp. (species, plural), subsp. (subspecies)

#### **Geography:**

1. US (adj); United States (n); USA for affiliations and addresses only
2. UK (adj); United Kingdom (n)
3. Spell out states when used alone: Kansas; North Carolina; Illinois.
4. Spelled out state if city is mentioned in text: Denver, Colorado (state is abbreviated with postal codes in sources of materials)
5. Use postal codes with ZIP codes: DE, GA, IL, DC
6. St, Ave, Blvd, St, PO, NE, SW (no periods)

7. West Coast, Corn Belt, western California
8. lat 43°15'09"N, long 116°40'18"E (no spaces between numbers; use "lat" and "long")

**Sources of materials:**

(Model or amount; Sigma Chemical Company, St Louis, MO); subsequently, (Sigma Chemical)

**Time and dates:**

1. Units of time should be abbreviated when they are used as units: s, min, h, d, mo, wk, yr
2. Use numerals with periods of time. EXAMPLE: 7 d, 8 mo, 2 wk, 1 yr
3. Spell out all months in full 4. EXAMPLES of time:  
26 November 1996  
"from 11 July 1995 to 8 April 1996, we ..."  
November 2002  
1991–1992  
1940s
5. Use the 24-hour system. Example: 0830 hours, 1630 hours (NOTE: spell out "hours" in this case)

**Technical Style**

**Number style:**

1. Spell out numbers one through nine (and use numerals for 10 and up) unless a unit of measure is also given (e.g., 5 mm).
2. Spell out when quantity is not to be emphasized, EXAMPLE: "one problem after another"; "on the one hand"; "an example or two"; "in one recent case"; "two hypotheses"
3. Spell out numbers and accompanying units always when first words in sentence. EXAMPLE: "Twenty milligrams of..." 4. Use numerals for years to begin sentence.
5. Ordinals: spell out first through ninth, use numerals for 10th and above: third, seventh, 52nd, 328th.
6. Use a thin space as a thousands separator: 10, 100, 1 000, 10 000, 100 000.
7. 20–30%, 0–5°C, 40–50 kg; BUT 20% to 30%, 40 kg to 50 kg
8. 2-mm-thick segment; 50-km circumference 9.
9. Spell out fractions and use a hyphen: three-fourths.
10. Use leading zero in decimals: 0.34. 11. a 50 × 50 m plot (no hyphens); use a space around math operators.

**Units of measure:**

1. Abbreviate units of time: s, min, h, d, wk, mo, yr. Examples: 5 min.; 30 s; 44 mg·d<sup>-1</sup>.
2. Use standard SI units of measure: cm, g, ha, kg, km, kV, L, m, mg, mJ, mL, mm, µg.
3. Present units of measure with product dots, whether using two units or more. EXAMPLE: g · kg<sup>-1</sup> and kg · ha<sup>-1</sup> · yr<sup>-1</sup> (do not use kg/ha or kg/ha/yr).
4. Use a space before and after symbols. EXAMPLE: > 20, < 20, = 20, ± 20

**Statistical style:**

1. Statistical variables should be italic. EXAMPLE:  $r$ ,  $r^2$ ,  $R$ ,  $R^2$
2. Standard statistical abbreviations should be spelled out the first time they are used and abbreviated thereafter. The only exception is that abbreviations may be used parenthetically without explanation. EXAMPLE: (CI), (SD), (SE), (SEM) (no periods)
3. Define ANOVA at first use in running text as analysis of variance.
4. Use a space before and after symbols. EXAMPLE:  $n = 42$ ;  $P < 0.05$ ;  $< 0.01$
5. Student's  $t$  test
6.  $\chi^2$  test (use lower case Greek letter chi)
7. Fisher's Protected LSD test
8. Mean  $\pm$  SD, mean  $\pm$  SE, mean  $\pm$  SEM; example: 457 kg  $\pm$  87 SD
9. 1-way or 2-way ANOVA
10. df 1,38

**Math and equations:**

1. Equations that are presented apart from regular text should be numbered on the righthand margin using bolded brackets: [6]
2. Use a space between math operators:  $2 + 2 = 4$

## **Apêndice 2: Normas para preparação de trabalhos científicos para publicação no periódico *Journal of Applied Ecology*, utilizadas no Capítulo III.**

### **Author Guidelines**

Online submission and review of manuscripts is mandatory for all types of papers. Please prepare your manuscript following the instructions for authors given below before submitting it online at <http://mc.manuscriptcentral.com/jappl-besjournals>. If submission is completed successfully, a manuscript ID will appear on screen, and an e-mail acknowledgement will follow. All correspondence should be routed via the Assistant Editor, Alice Plane, at [admin@journalofappliedecology.org](mailto:admin@journalofappliedecology.org)

### **Editorial Policy**

Papers should convey important recommendations for environmental management and policy. There should be clear potential to make a substantial contribution both to ecological understanding and management issues. (See the recent Editorial 'Putting applied ecology into practice' published in Issue 1 of Volume 47).

Since the scope is large, contributions should be of the highest quality. In addition to standard research papers, we seek Reviews that offer timely syntheses, we encourage Forum articles that stimulate dialogue between ecologists and managers, and invite Policy Direction articles that offer discussion of policy-related topics. We also publish Practitioner's Perspective articles that provide a platform for individuals involved in hands-on management of ecological resources to present their personal views on the direction of applied ecological research.

The Journal sometimes draws together groups of papers in Special Profiles with a common theme of topical relevance in ecology. An editorial sets the context, highlights the key messages from the research included in the feature and shows how it contributes to the field of applied ecology as a whole. These articles provide an overview of the issue for our readers and demonstrate how themes in applied ecology develop within the pages of the Journal over time. We encourage authors to contact us with proposals for new Special Profiles. Initial enquiries should include a short summary of the rationale behind proposing a Special Profile on a particular topic. Special Profiles should consist of a well-rounded collection of papers, with a good international spread of authors who have tentatively agreed to supply a paper. This first enquiry will be discussed briefly by the Journal of Applied Ecology Editors to determine if there is interest in principle, before a full proposal is invited. Please send enquiries to [admin@journalofappliedecology.org](mailto:admin@journalofappliedecology.org)

### **Types of Paper Published**

**STANDARD PAPERS** - These are original articles reporting cutting-edge ecological research of international relevance that has clear implications for conservation or natural area policy or direct application to the management of natural systems. Given the need to balance a significant increase in submissions and our wish to publish as much top quality applied ecological science as we can, standard research papers should not exceed 7000 words. The word count is inclusive of all parts of the paper: summary, main text, acknowledgements, references, tables and figure legends (although excluding any online supporting information).

### **Welfare and Publication Ethics**

Researchers must have proper regard for conservation ethics and animal welfare. Any possible adverse consequences of the work for ecosystems, populations, individual organisms or local human communities must be weighed against the possible gains in knowledge and its practical applications. Attention is drawn to the 'Guidelines for the treatment of animals in behavioural research and teaching' published in the journal *Animal Behaviour*, 2006, 71, 245-253 and available at [http://www.elsevier.com/framework\\_products/promis\\_misc/ASAB2006.pdf](http://www.elsevier.com/framework_products/promis_misc/ASAB2006.pdf).

Social research should follow the highest standards of research ethics and we ask authors to ensure their research conforms to guidelines set by reputable sources such as the British Sociological Association <http://www.britsoc.co.uk/about/equality/statement-of-ethical-practice.aspx> and the Association of Social Anthropologists of the UK and Commonwealth <http://www.theasa.org/ethics.shtml>

Editors may seek advice from referees on ethical matters and the final decision will rest with the editors. The Journal is a member of and subscribes to the principles of the Committee on Publication Ethics.

### **Manuscript Structure**

**STANDARD PAPERS.** Original articles should not exceed 7000 words inclusive of all parts of the paper apart from online Supporting Information. Typescripts should be arranged as follows, with each section starting on a separate page.

Title page. This should contain:

A concise and informative title.

A list of author names, affiliation(s), and e-mail addresses.

The name, complete mailing address (including e-mail address, telephone and fax numbers) of the corresponding author.

A running title not exceeding 45 characters.

A word count of the entire paper broken down into summary, main text, acknowledgements, references, tables and figure legends.

The number of tables and figures.

The number of references.

**Summary.** This is called the Abstract on the web submission site. The Summary should outline the purpose of the paper and the main results, conclusions and recommendations, using clear, factual, numbered statements. Authors should follow a formula in which point 1 sets the context and need for the work; point 2 indicates the approach and methods used; the next 2-3 points outline the main results; and the last point identifies the wider implications and relevance to management or policy. The final summary point is the most important of all in maximising the impact of the paper. It should synthesise the paper's key messages and should be generic, seminal and accessible to non-specialists, and must carry one of the following subheadings:

'Synthesis and applications' for articles that identify recommendations for management practices.

'Policy implications' for articles that are less directly tied to on-the-ground management and include discussion on conservation implications or links to policy.

**Keywords.** A list in alphabetical order not exceeding ten words or short phrases, excluding words used in the title and chosen carefully to reflect the precise content of the paper.

**Introduction.** State the reason for the work, the context, background, aims and the hypotheses being tested. End the Introduction with a brief statement of what has been achieved.

**Materials and methods.** Include sufficient details for the work to be repeated. Where specific equipment and materials are named, the manufacturer's details (name, city and country) should be given so that readers can trace specifications by contacting the manufacturer. Where commercially available software has been used, details of the supplier should be given in brackets or the reference given in full in the reference list.

**Results.** State the results of experimental or modelling work, drawing attention to important details in tables and figures. The Results section should conform to the highest standards of rigour.

**Discussion.** Point out the importance of the results and place them in the context of previous studies and in relation to the application of the work (expanding on the Synthesis and applications section of the Summary). Include clear recommendations for management or policy.

**Acknowledgements.** Be brief. If authors refer to themselves as recipients of assistance or funding, they should do so by their initials separated by points (e.g. J.B.T.). Do not acknowledge Editors by name.

**Data Accessibility.** To enable readers to locate archived data from papers, we require that authors list the database and the respective accession numbers or DOIs for all data from the manuscript that has been made publicly available. An example of what this section should look like can be found in the Data Archiving Q&A.

**References** (see Manuscript Specifications below).

**Tables** (see Specifications). Each table should be on a separate page, numbered and accompanied by a legend at the top. These should be referred to in the text as Table 1, etc. Avoid duplication between figures and tables.

**Figures** (see Specifications). Figures and their legends should be grouped together at the end of the paper before Supporting Information (if present). If figures have been supplied as a list at the end of the text file (as recommended), they should appear above their respective legend. Figures should be referred to in the text as Fig. 1, Figs 1 & 2, etc. Photographic material should also be referred to as Figures. Do not include

high-resolution versions of figures at submission; reduce the size and resolution of graphics to a file size of less than 1 MB. If a manuscript is accepted, higher quality versions of figures can be submitted at a later stage.

**Supporting Information.** Essential supporting information can be published in the online version of the article. Instructions for the preparation of Supporting Information are given here and general guidance is available [here](#).

In order to promote the advancement of science through the process of documenting and making available the research information and supporting data behind published studies, the editors of this journal strongly encourage authors to make arrangements for archiving their underlying data.

**REVIEWS.** Reviews should not exceed 8000 words inclusive of all parts of the paper. The layout should follow the same format and specifications as for Standard Papers except that the organisation of the main text need not follow the division into Introduction, Materials and methods, Results and Discussion.

**FORUM ARTICLES and POLICY DIRECTIONS.** These articles should be short contributions up to 4000 words inclusive of all parts of the paper. Format and specifications are as for Standard Papers except that any Summary section should be short (no more than 150 words, but still formatted in numbered sections as for Standard Papers) and the layout of the main text can be flexible.

**PRACTITIONER'S PERSPECTIVES.** There is no prescribed structure to Practitioner's Perspectives but the prose style should be light and the article should be written with the minimum of technical language and jargon, so as to be understandable to a general audience. The article title should be brief (maximum 10 words), and the title page should provide author names and addresses, including an e-mail address for the corresponding author. Abstracts are not required and the title page should be followed by the body of the text (if headers are used within the text, keep them to a minimum), and the references (maximum 20), using the standard referencing system of the Journal, and finally a short biosketch (30–100 words for one author/150 words for the first three authors, respectively) describing the research interests of the author(s). At least one author should primarily be a practitioner, rather than an academic. The overall word count, inclusive of all of the above (i.e. main text, title line, author details, references, biosketch), should not exceed 4000 words. Should you wish to include a small figure or other illustration, this can be accommodated by a reduction in the number of words on a pro rata basis.

#### Manuscript Specifications

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## VITA

Jean Kássio Fedrigo nasceu em São Lourenço do Oeste – SC, aos quinze dias do mês de janeiro de 1985. Filho de Sérgio Fedrigo e Jecir Maria Fedrigo, iniciou seus estudos no ano de 1992 no Colégio Estadual Professor Zelindo Carbonera de Marema – SC. Em 2000, ingressou no Seminário Lateranense de Caxias do Sul, onde cursou o ensino médio até 2012 na escola de Ensino Médio do Seminário Paulino. Ingressou no curso de Zootecnia na Universidade do Estado de Santa Catarina (UDESC –Chapecó) em 2004, onde desenvolveu atividades de extensão universitária na área de forragicultura de 2005 a 2007. Recebeu o título de Bacharel em Zootecnia em julho de 2008. De março de 2008 a janeiro de 2009 foi bolsista de iniciação científica pela Embrapa Pecuária Sul, localizada em Bagé – RS. Em 2009 ingressou no curso de Mestrado junto ao Programa de Pós Graduação em Zootecnia da Universidade Federal do Rio Grande do Sul, na área de concentração em Plantas Forrageiras, com bolsa da Coordenação de Aperfeiçoamento Profissional de Nível Superior (Capes), recebendo o grau de Mestre em Zootecnia em Fevereiro de 2011. Em dezembro de 2010 foi aprovado no processo seletivo de Doutorado em Zootecnia/UFRGS na área de Plantas Forrageiras. Entre janeiro a julho de 2014 permaneceu em doutorado sanduíche na Universidade da Califórnia/Davis (UCDavis).