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# USO DO SENSORIAMENTO REMOTO NO MANEJO DO PASTO EM DIFERENTES INTENSIDADES DE PASTEJO EM UM SISTEMA INTEGRADO DE PRODUÇÃO AGROPECUÁRIA

Porto Alegre
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**Carolina dos Santos Cargnelutti**

# USO DO SENSORIAMENTO REMOTO NO MANEJO DO PASTO EM DIFERENTES INTENSIDADES DE PASTEJO EM UM SISTEMA INTEGRADO DE PRODUÇÃO AGROPECUÁRIA

Dissertação apresentada como requisito para obtenção do Grau de Mestre em Zootecnia, na Faculdade de Agronomia, da Universidade Federal do Rio Grande do Sul.

**Orientador:** Paulo César de Faccio Carvalho
**Coorientador:** Christian Bredemeier

**Porto Alegre**
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# Uso do sensoriamento remoto no manejo do pasto em diferentes intensidades de pastejo em um Sistema Integrado de Produção Agropecuária[1]

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Co-orientador: Christian Bredemeier

## RESUMO

Os Sistemas Integrados de Produção Agropecuária (SIPA) são uma alternativa para o aumento da produção de alimentos de forma sustentável. O manejo do pasto é um fator crucial para o sucesso desses sistemas, pois afeta diretamente a produção animal e a cultura sucessora. Apesar de sua importância, a gestão de pastagens continua sendo um desafio para as fazendas. O uso de ferramentas como índices de vegetação podem facilitar o manejo de pastagens, ao fornecer estimativas a partir de sensoriamento remoto baseado em imagens de satélite. Este estudo teve como objetivo estimar a altura e massa de forragem em quatro intensidades de pastejo por meio de índices de vegetação e determinar até qual fase do ciclo de pastejo pode-se estimar essas variáveis por sensoriamento remoto. A massa de forragem e altura real do pasto foram correlacionadas com índices de vegetação (NDVI e NDRE), obtidos através de imagens de satélite ao longo de um ciclo de pastejo de azevém em SIPA no sul do Brasil. As pastagens foram manejadas com quatro intensidades de pastejo: alta, moderada, moderada-leve e leve, além da área sem pastejo (G10, G20, G30, G40 e UG, respectivamente). A intensidade de pastejo moderada apresentou maior correlação entre NDRE e massa de forragem. Pastejos em intensidade leve apresentaram melhor correlação entre altura e índices de vegetação. Portanto, com o uso de índices de vegetação, é possível estimar a altura do pasto e a massa de forragem remotamente, com avaliação precisa em tempo real, desde que classificadas entre as diferentes intensidades de pastejo. O estágio do ciclo também deve ser considerado, já que a acuácia dos índices de vegetação descresce ao final do ciclo. Assim, o sensoriamento remoto apresenta-se como uma ferramenta importante para o futuro do manejo de pastagens.

**Palavras-chave:** índices de vegetação; pastagem; SIPA; imagens de satélite.

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[1] Dissertação de Mestrado em Zootecnia – Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil. 25 de Março de 2024.

# Use of remote sensing to manage pasture on different grazing intensities in an Integrated Crop-livestock System[2]

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## ABSTRACT

Integrated Crop-Livestock Systems (ICLS) are an alternative to increasing food production sustainably. Pasture management is a crucial factor for the success of these systems, as it directly affects animal production and the succeeding crop. However, assessing pasture management can be challenging and time-consuming at the farm level. Tools such as vegetation indices can facilitate pasture management by providing estimates from satellite-based remote sensing. This study aims to estimate herbage mass and sward height across contrasting grazing intensities using vegetation indices and to determine up to which phase of the grazing cycle the variables can be predicted through remote sensing. To validate, actual sward high and herbage mass measurements were correlated with vegetation indices (NDVI and NDRE) obtained through satellite images over a cycle of ryegrass on an ICLS in southern Brazil. The pasture was managed to maintain four different grazing intensities: intensive, moderate, moderate-light, and light, and an ungrazed treatment (G10, G20, G30, G40, UG). Moderate grazing intensity showed a higher correlation between herbage mass and NDRE. Light grazing intensities showed a better correlation with sward height and vegetation indices. These findings suggest that, with vegetation indices, it is possible to estimate sward height and herbage mass remotely with accurate real-time assessment, as long as they are classified among the different grazing intensities. The stage of the grazing cycle should also be considered, as the accuracy of vegetation indices decreases towards the end of the cycle. Thus, remote sensing emerges as an important tool for the future of pasture management.

**Keywords:** *vegetation index; forage; ICLS; satellite images.*

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[2] Master's dissertation in Animal Science, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. 24th March, 2024.

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## Capítulo II

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| | |
|---|---|
| NDVI | normalized difference vegetation index |
| NDRE | normalized difference red edge |
| ICLS | Integrated Crop-Livestock Systems |
| GPS | Global Positioning System |
| VI | vegetation index/ índice de vegetação |
| UG | Ungrazed/ não pastejado |
| G10 | Intensive grazing - 10 cm sward height (treatment)/ pastejo intensivo – 10 cm de altura de pasto (tratamento) |
| G20 | Moderate grazing/ 20 cm sward height (treatment) / pastejo moderado – 20 cm de altura de pasto (tratamento) |
| G30 | Moderate-light grazing/ 30 cm sward height (treatment)/ pastejo moderado-leve – 30 cm de altura de pasto(tratamento) |
| G40 | Light grazing/ 40 cm sward height (treatment) / pastejo leve – 40 cm de altura de pasto (tratamento) |
| UTM | Universal Transverse Mercator |
| Kg | Kilograms |
| Ha | Hectares |
| $M^2$ | Metros quadrados |
| NIR | Near infra-red |
| P1 | Period 1/ período 1 |
| P2 | Period 2/ período 2 |
| P3 | Period 3/ período 3 |
| P4 | Period 4/ período 4 |
| GEE | Gás de Efeito Estufa |

# CAPÍTULO I

# 1. INTRODUÇÃO

Segundo a (FAO, 2010), até 2050 a população mundial chegará a 9,8 bilhões de pessoas, o que provocará um aumento na demanda por alimentos, que deverá ser suprido 90% através da intensificação dos sistemas e apenas 10% decorrente da expansão das áreas agrícolas. A intensificação dos sistemas produtivos torna-se necessária para suprir as necessidades mundiais tanto do ponto de vista de suficiência de alimentos, quanto ambiental.

O desafio atual dos sistemas produtivos é viabilizar o aumento da produção mundial de alimentos sem causar degradação dos recursos naturais (Oliveira *et al.*, 2014). Nesse sentido, os Sistemas Integrados de Produção Agropecuária (SIPA) são uma importante alternativa para o aumento de produção de alimentos sem necessidade de expansão agrícola, uma necessidade frente à insegurança alimentar (FAO, 2023). Quando bem manejados, os SIPA são capazes de promover melhorias na qualidade de solo, ciclagem de nutrientes, aumentar performance econômica, adaptando-se à diversos agroecosistemas mundiais (Bell; Moore, 2012; De Moraes *et al.*, 2014; Carvalho *et al.*, 2018; Simili *et al.*, 2023).

Afim de promover a produção sustentável de alimentos através dos SIPA, é necessário um maior aporte de conhecimento, planejamento de uso da área, além do manejo (Moojen *et al.*, 2023). Nesse sentido, a intensidade de pastejo é um fator chave para o sucesso desses sistemas. A correta gestão da intensidade de pastejo desencadeia propriedades emergentes do sistema, promovendo maior estabilidade, otimizando resultados do sistema e aumentando sua resiliência (Nunes *et al.*, 2021b). Apesar dos benefícios do bom manejo dos sistemas, ainda existem barreiras para sua adoção. Uma delas é o manejo correto do pasto, que pode demandar tempo e mão de obra ao produtor. Nesse sentindo, o uso do sensoriamento remoto pode ser uma ferramenta promissora para melhor compreender e manejar a pastagem, que é fator chave para o sucesso dos sistemas integrados.

Através da obtenção de dados de massa de forragem e altura de pasto através do sensoriamento remoto, é possível compreender as limitações e potencialidades dos sistemas, direcionando manejos mais assertivos. Nesse sentido, o uso de índices de vegetação apresentam-se como uma alternativa eficiente para monitoramento da variabilidade espacial da produção de biomassa tanto para a fase de lavoura (Vian *et al.*, 2018) quanto pecuária (Michez *et al.*, 2019). O uso dessa tecnologia pode ser feito através de índices de vegetação obtidos a partir de imagens de satélite ou câmeras embarcadas em Veículos Aéreos Não Tripulados (VANTs). Em ambientes pastejados, onde há imposição de heterogeneidade, ainda há necessidade de maiores estudos para viabilizar sua aplicação. Especialmente no contexto de imagens de satélite, que proporcionam maior praticidade de obtenção, embora apresentem menor resolução espacial.

A aplicação da pecuária de precisão ao pastoreio tem o potencial de facilitar o manejo mais detalhado e dinâmico de pastagens. O uso dessas ferramentas são capazes de promover inovações desruptivas no manejo do pasto, baseados em processos de interação planta-animal (Bindelle *et al.*, 2021). Para bem manejar o pasto, é necessário compreender sua dinâmica ao longo do ciclo. Dessa forma, a utilização de agricultura de precisão em sistemas integrados apresenta-se como uma alternativa altamente viável para o melhor entendimento e posicionamento de manejos nesses sistemas complexos.

O documento será dividido em três capítulos. No primeiro, será apresentada a introdução geral da dissertação, seguida da revisão de literatura sobre os Sistemas Integrados de Produção Agropecuária e o uso de ferramentas de agricultura de precisão para o manejo desses sistemas. No segundo capítulo, os resultados serão apresentados em forma de artigo científico, entitulado "*Integrated Crop-livestock System managed through vegetation indices*". O terceiro capítulo apresenta as considerações finais gerais.

# 2. REVISÃO BIBLIOGRÁFICA

## *2.1 Sistemas Integrados de Produção Agropecuária (SIPA)*

O cultivo de plantas e criação de animais já se integravam de maneira diversa sob o manejo do homem na agricultura neolítica, sob o princípio básico dos ecossistemas naturais: ciclagem de nutrientes (Anghinoni *et al.*, 2013). A agricultura pós Revolução Verde, apresentou a narrativa de que a ciclagem de nutrientes a partir das fezes de animais em sistemas mistos poderia ser substituída por fertilizantes sintéticos, facilitando as práticas agrícolas (Liebig, 1840). O resultado disso foi a especialização dos sistemas junto a utilização descompromissada de recursos não renováveis, com grandes impactos ambientais como aumento da produção de GEE, contaminação de lençóis freáticos e perda de biodiversidade (Franzluebbers; Sulc; Russelle, 2011).

A redução na biodiversidade através da desconexão entre a produção de alimentos e a natureza começou com a ideia de que a variabilidade do ecossistema representava uma ameaça para a agricultura (Gordon *et al.*, 2017). O uso de cultivares altamente produtivas, aumento do aporte de insumos sintéticos e maquinários tecnológicos possibilitou a intensificação dos sistemas especializados de produção, maximizando a produção de alimentos, porém às custas de outros serviços ecossistêmicos fundamentais como a regulação climática. (Foley *et al.*, 2005; Kremen; Merenlender, 2018; Carvalho, *et al.*, 2021). Junto à diminuição da biodiversidade e de serviços ecossistêmicos, há também a diminuição da resiliência do sistema e aumento o risco de produção (Szymczak *et al.*, 2020).

A agricultura mundial está frente ao desafio de continuar a aumentar a produção de alimentos para uma população mundial em expansão, com área de terra cultivada limitada e em competição por recursos hídricos com outros setores (Lemaire et al., 2015). Nesse cenário, é imperativo restabelecer uma conexão entre agricultura e natureza para garantir a viabilidade duradoura dos sistemas de produção (Lemaire *et al.*, 2023). Nesse sentido, os Sistemas Integrados de Produção Agropecuária (SIPA) são uma alternativa para essa reconexão, capazes de aliar lucratividade e proteção do ambiente

(Franzluebbers; Martin, 2022).

Segundo a FAO (2010), Sistemas Integrados de Produção Agropecuária (SIPA) são sistemas de intensificação sustentáveis que envolvem a integração intencional entre componentes (lavoura, animais e/ou árvores), afim de explorar relações sinérgicas, promovendo melhorias no âmbito social, econômico e ambiental. Esses sistemas podem ser organizados em diferentes arranjos espaço-temporais (Carvalho *et al.*, 2021), promovendo diversos serviços ecossistêmicos e constituindo-se como componente fundamental para a economia global (Duru *et al.*, 2015). A resiliência na agricultura é um fator importante frente aos futuros desafios da produção, como o suprimento de alimentos em uma mesma área para uma população crescente, adversidades climáticas, escassez de matéria prima e instabilidade econômica (Lin, 2011; Altieri *et al.*, 2015; Fair; Bauch; Anand, 2017; Chaudhary; Gustafson; Mathys, 2018; Szymczak *et al.*, 2020). Portanto, desde que bem manejados, os SIPA apresentam-se como uma promissora alternativa em busca do desenvolvimento sustentável.

A fim de proporcionar uma padronização do uso dos termos no que diz respeito a esses sistemas produtivos e facilitar sua difusão, são encontrados na literatura termos técnicos e científicos sobre o tema. Sugere-se que na literatura técnica se use o termo Integração Lavoura-Pecuária e na literatura científica, o termo Sistema Integrado de Produção Agropecuária; os acrônimos em português são ILP e SIPA, respectivamente (Carvalho *et al.*, 2014). Essa uniformização de termos para a ciência se justifica em razão de tornar o tema mais abrangente, além de facilitar a busca em meios digitais através da sigla, que em inglês é ICLS (Integrated Crop-Livestock System).

De acordo com Moraes *et al.* (2014), as propriedades dos SIPA baseados em princípios da agricultura conservacionista, podem resultar em um sistema único e eficiente que resolva o dilema produção *versus* conservação. Para atingir tal meta, é necessário que sejam respeitados os limites produtivos do sistema, afim de otimizá-lo como um todo, sem haver preferência sobre uma fase ou outra. Os principais objetivos do uso da integração entre pastagens e agricultura são: rotação de culturas, aumento da produção de forragem, incremento de palhada para o Sistema de Plantio Direto (SPD), reestruturação do solo, ciclagem de nutrientes, aumento do teor de MO e redução de pragas, doenças e plantas daninhas (Balbino *et al.*, 2012; Kunrath *et al.*, 2020; Arnuti *et al.*, 2021).

Afim de explorar os benefícios dos SIPA, é importante compreendê-los e manejá-los adequadamente. A incorporação do componente animal em SIPA adiciona maior nível de complexidade ao sistema, especialmente em termos de manejo do pasto, essencial para desbloquear benefícios potenciais do sistema. Anghinoni *et al.* (2013) afirma que os possíveis riscos inerentes ao sistema de integração estão associados à maior complexidade em seu manejo e gerenciamento, sendo o preparo convencional totalmente desaconselhado. O mesmo autor frisa que o bom manejo da pastagem, representado por intensidades moderadas, causa efeitos positivos sobre o sistema, aumentando a biodiversidade do solo, condicionando a melhoria nos processos de ciclagem e mineralização de nutrientes. Considera-se então a necessidade de maior conhecimento técnico e científico sobre manejo e os fatores que o influenciam em um SIPA para promover melhores resultados.

A intensidade de pastejo utilizada é um fator de extrema importância a ser considerado no manejo de sistemas integrados. O ajuste de manejo da pastagem é capaz de promover diversas melhorias ao sistema, entre eles a menor emissão de GEE por kg de carne produzida. Estudos de Souza Filho *et al.* (2019), constataram que pastejos entre 23 a 30 cm em consórcio de aveia preta e azevém foram capazes de reduzir a emissão de metano ($CH_4$) através da melhoria na performance animal. Os mesmos autores tratam o manejo da pastagem como estratégia chave para a melhora da produção animal e redução de impacto ambiental da pecuária em SIPA. Savian *et al.* (2018), em experimento com azevém com ovinos, confirmaram redução de 35% de emissões de $CH_4$ por kg de ganho médio de peso vivo diário através do manejo correto da pastagem.

Da mesma forma que o bom manejo promove melhorias ao sistema, manejos inadequados são capazes de causar decréscimos em produtividade e reduzir sua eficiência e sustentabilidade. Pastejos intensivos podem causar problemas ao sistema, como a inviabilização da ressemeadura natural de pastagens como azevém (Nunes *et al.*, 2021a) e maior incidência de plantas invasoras (Schuster *et al.*, 2020). O produtor precisa estar atento à utilização de práticas de manejo que otimizem o uso de seus recursos, e a viabilização da ressemeadura natural de pastagens e redução de insumos para conter invasoras implica em redução de custos e aumento da eficiência do sistema. Nesse sentido, a simplificação não pode ser uma alternativa para o futuro da produção de alimentos (Franzluebbers; Martin, 2022). A reconexão entre lavoura e pecuária, através dos benefícios encontrados em sistemas mais complexos e bem manejados, é capaz de promover sistemas mais resilientes e sustentáveis.

### *2.2 Influência da intensidade de pastejo no sistema*

A intensidade de pastejo modifica de forma significativa a estrutura do dossel e o valor nutritivo da forragem (Paula *et al.*, 2012), tanto de forma positiva quanto negativa, dependendo do manejo. O efeito dos animais no ecossistema inclui alterações nas taxas de ciclagem e de disponibilidade de nutrientes, decorrentes da resposta das plantas ao pastejo (Silva *et al.*, 2020). Sendo que intensidades moderadas são capazes de melhorar a produtividade das espécies forrageiras (Kunrath *et al.*, 2020).

A altura do pasto e a relação folha-colmo são fatores determinantes para a massa de bocado, sendo que, pastagens com maior quantidade de folhas são mais palatáveis, o que possibilita ao animal a realização de bocados maiores (Galli *et al.*, 1996). Hodgson (1981), ressalta que variações de estrutura de pasto causam modificações na mecânica de pastejo, o que pode exercer importante influência sobre o consumo de animais em pastejo. Carvalho *et al.* (2016) explica que a ingestão de pasto pelo animal está fundamentalmente limitada pelo tempo de aquisição de forragem (tempo de pastejo), que é determinado pela oferta de forragem disponível no momento, que influencia no tempo em que o animal demanda para capturá-lo.

Quando se considera a produção animal, a massa de forragem, altamente relacionada com a altura do pasto, define o ganho de peso por animal e por área, uma vez que ela determina a ingestão e a seleção da forragem (Anghinoni *et al.*, 2013). O desempenho individual dos animais em pastejo é resultado do seu comportamento ingestivo frente à estrutura do pasto, que por sua vez, depende diretamente da intensidade de pastejo empregada sobre ele (Carvalho *et al.*, 2016). Além disso, a intensidade de pastejo apresenta-se como o fator que mais influencia no ambiente pastoril, pelo fato de afetar diretamente a massa de forragem, altura e taxa de acúmulo (Franzluebbers *et al.* 2013). Por consequência, a intensidade de pastejo influencia sobre a taxa de ingestão do animal submetido ao pastejo (Agreil, 2006), de forma que animais sob maior intensidade de pastejo terão menor ganho de peso ao final do ciclo, comparados a pastejos moderados.

Além do resultado da comercialização do animal, a pecuária inserida no sistema promove a produção de diversos serviços ecossistêmicos. Assim, a intensidade de pastejo apresenta-se como determinante para a efetividade dos benefícios oriundos dos sistemas integrados. O manejo de pastagens nos SIPA, que tem como ferramenta de controle a intensidade de pastejo, deve vislumbrar a condução de uma estrutura de vegetação capaz de otimizar a colheita de forragem por parte dos animais (Wesp *et al.*, 2016). Kunrath *et al.* (2020), em estudos de longa duração em um SIPA soja-pastagem de inverno concluíram que pastejos moderados, entre 20 e 30 cm, maximizam a produção animal e vegetal.

Para o sucesso da utilização dos SIPA, é necessário que o sistema seja planejado como um todo, sem que uma parte seja prejudicada em detrimento da outra. Assim, altas intensidades de pastejo podem ser prejudiciais ao sistema, pois implicam na menor produção total de matéria seca ao final do ciclo (Lunardi *et al.*, 2008). Além disso, em intensidades de pastejo muito altas, há outras perdas a nível de sistema, como maior incidência de plantas invasoras (Schuster *et al.*, 2016). Nessas situações há menor eficiência econômica em função da menor produção de forragem, além dos maiores custos para combater plantas invasoras (Schuster *et al.*, 2019).

O desafio para o sucesso do SIPA é manejar máquinas e animais no sentido de que não se comprometa a produtividade e sustentabilidade do sistema produtivo e do ambiente (Anghinoni *et al.*, 2013). Nesse sentindo, em experimento com SIPA de longa duração submetido a diferentes intensidades de pastejo, Conte *et al.* (2011) interpolou dados de resistência do solo à penetração. Os resultados mostraram que a presença de animais em pastejo provoca aumento da resistência do solo à penetração na camada de 0-10 cm imediatamente após o ciclo de pastejo, porém não constatou alterações significativas na densidade e porosidade de solo. Flores *et al.* (2007) analisaram as alterações em atributos físicos de solo em diferentes intensidades de pastejo comparadas a áreas sem pastejo, concluindo que as alterações ocasionadas não exerceram influência sobre o estabelecimento e rendimento de grãos de soja em um SIPA.

Outro desafio para a adoção dos SIPA é a resistência de produtores, motivada pelo receio acerca da compactação do solo causada pelos animais em pastejo, que pode prejudicar a cultura sucessora. Kunrath *et al.* (2015) estudaram a interferência da intensidade de pastejo na produtividade de grãos em SIPA e observaram que não há efeito negativo da pastagem sobre a colheita de grãos na fase de lavoura, desde que não haja pastejo intensivo – pastagens de azevém manejadas acima de 10 cm. Franzluebbers *et al.* (2014) demonstraram resultados positivos em lavouras após pastagens, favorecendo solos agrícolas com a sucessão de gramíneas e leguminosas através da resiliência, maior capacidade de infiltração de água, aumento de matéria orgânica e reconexão dos sistemas integrados de forma sinérgica. Além disso, pastejos moderados em SIPA favorecem a estabilidade da cultura de grãos a longo prazo (Nunes *et al.*, 2021b).

Considerando a relevância dos Sistemas Integrados de Produção Agropecuária no futuro da produção de alimentos de forma sustentável e resiliente, é necessário o contínuo aporte de pesquisas sobre sua dinâmica. Nesse contexto, a intensidade de pastejo é fator-chave para o sucesso do sistema como um todo. Assim, é importante desenvolver ferramentas que facilitem o manejo dessas áreas, afim de que se possa manter as intensidades de pastejo indicadas.

### *2.3 Agricultura de precisão nos Sistemas Integrados de Produção Agropecuária*

A agricultura de precisão teve maior impulso mundial a partir do surgimento do GPS, que com a existência do GLONASS (Rússia), além do Galileo (União Europeia) e Compass (China), dão origem a sigla GNSS – Sistemas de Navegação Global por Satélites, em português (Molin, 2013). Também chamada de Agricultura 4.0, é capaz de promover melhorias aos sistemas, através de ferramentas que permitem otimizar o uso de recursos de forma sustentável, integrar métodos para compreender condições complexas de sistemas integrados entre animais e plantas (Debauche *et al.*, 2021).

O sensoriamento remoto é a técnica de aquisição de informações sobre um objeto localizado sobre a superfície da terra sem que haja contato físico (Meneses, 2001), facilitando a aquisição de dados no tempo e espaço. Imagens aéreas e sensores de escaneamento tem sido adotados para detectar variabilidade espacial de áreas agrícolas e pecuárias, auxiliando na gestão de decisões de manejo (Canata *et al.*, 2022). Mostrando-se uma promissora alternativa para o futuro dos sistemas integrados, aumentando a assertividade de operações e assim otimizando o uso dos recursos.

Os avanços em ferramentas de agricultura e pecuária de precisão são uma importante alternativa na realização de avaliações mais precisas, especialmente quando se trata de comportamento e interferência animal (Chebli *et al.*, 2022). É preciso seguir avançando em estudos sobre sistemas integrados de produção precisos, em razão da sua complexidade e necessidade de maior conhecimento técnico e globalizado do sistema. Assim, é possível através da agricultura de precisão, compreender mais detalhadamente as interações entre solo-planta-animal-atmosfera e seus benefícios.

### *2.4 Sensoriamento remoto: uso de índices de vegetação no manejo de SIPA*

Os últimos cinquenta anos foram marcados pelo surgimento do sensoriamento remoto para o monitoramento dos ecossistemas terrestres (Sparrow *et al.*, 2020). O sensoriamento remoto baseado em satélites promoveu maior facilidade na obtenção de dados, como valores obtidos a partir de índices de vegetação. Além disso, o uso de índices de vegetação apresentam-se como uma alternativa eficiente no monitoramento de biomassa tanto para lavoura (Vian *et al.*, 2018), quanto na pecuária (Junges *et al.*, 2016; Michez *et al.*, 2019). Assim, o uso de índices pode auxiliar no monitoramento de crescimento e desenvolvimento de plantas, com alto detalhamento de informações e praticidade.

Rouse *et al.* (1973) propôs a utilização do NDVI (*Normalized Difference*

*Vegetation Index*) para fins de quantificação da vegetação através de reflectâncias no infravermelho próximo (NIR) e vermelho (RED) – Equação 1. Seus valores variam entre -1 a +1, onde quanto maior o valor de NDVI, maior o vigor de crescimento da cultura (LIU, 2006). NDRE (*Normalized Difference Red Edge*) é um índice relacionado ao conteúdo de nitrogênio e clorofila na planta. Utiliza valores de NIR e Red Edge – Equação 2.

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)} \qquad (1)$$

$$NDRE = \frac{(NIR-RED\ EDGE)}{(NIR+RED\ EDGE)} \qquad (2)$$

Técnicas como sensoriamento remoto baseado em satélite (Schellberg, J; Verbruggen, 2014) e utilização de câmeras 2D e 3D para campo , tem sido utilizadas para medir a atividade fotossintética e atributos de forragem (Andriamandroso *et al.*, 2017), além da identificação de plantas daninhas. Fontana *et al.* (2018) caracterizaram a dinâmica temporal e heterogeneidade espacial do crescimento vegetativo em espécies do bioma pampa usando índices de vegetação obtidos por meio de sensores orbitais. Tan *et al.* (2020) observaram alto grau de significância entre NDVI e índice de área foliar, o que permitiu constatar a possibilidade de monitoramento da cultura de trigo com essa ferramenta.

A utilização de imagens de satélite para obtenção de valores de NDVI podem ser utilizados para estimar produtividade de grãos e biomassa (Bernardi *et al.*, 2017). Em estudo realizado em um SIPA, os mesmos autores constataram que a geoestatística e o GIS são ferramentas efetivas para coleta de dados em relação a variabilidade espacial de solo e estimativas de produtividade, sendo alternativas para definir estratégias de manejos em propriedades rurais. Bredemeier *et al.* (2013), em experimento com trigo, constatou efetividade no uso de NDVI para direcionar aplicação de nitrogênio em trigo com taxa variável, visando realizar maiores aplicações em área com maior potencial produtivo, afim de explorar o máximo potencial da área. Já Junges *et al.* (2016), estudaram a relação entre NDVI e EVI (Índice de Vegetação Melhorada) com a dinâmica temporal da vegetação em um protocolo de longa duração com mais de 30 anos em campo nativo do bioma Pampa, e também encontraram respostas que sugerem sua eficiência.

Tendo em vista a importância do manejo correto do pasto para o sucesso dos sistemas, é importante que se desenvolvam ferramentas que facilitem o manejo de forma assertiva. Assim, o uso de índices de vegetação baseados em imagens de satélite podem ser uma alternativa para facilitar o manejo da fase pastagem de um SIPA.

## 3. HIPÓTESES

(1) A estimativa de massa e altura de forragem através do sensoriamento remoto é melhor quando se classificam as diferentes intensidades de pastejo.

(2) A acurácia da estimativa da massa e altura de forragem via sensoriamento remoto diminui com o avanço do ciclo de pastejo.

# 4. OBJETIVOS

(1) Avaliar a acurácia de índices de vegetação na estimativa de altura e massa de forragem em quatro diferentes intensidades de pastejo e área não pastejada em azevém anual;

(2) Determinar se as mudanças estruturais induzidas pelo avanço do ciclo vegetativo afetam a sensibilidade das estimativas.

# CAPÍTULO II

Artigo escrito no formato das normas da revista Grass and Forage Science (Apêndice A)

# Integrated Crop-livestock System managed through vegetation indices

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## Abstract

Pasture management is crucial for optimizing animal performance and the food production efficiency of integrated crop-livestock systems. However, assessing data for pasture management can be challenging and time-consuming at the farm level. This study aimed to assess the precision of the vegetation indices in estimating herbage mass and sward height across contrasting grazing intensities and determine up to which phase of the grazing cycle the pasture can be managed through remote sensing. To achieve this, the study correlated actual sward height and herbage mass measurements with NDVI

(Normalized Difference Vegetation Index) and NDRE (Normalized Difference Red-Edge) indices obtained from *PlanetScope* satellite imagery collected throughout an annual ryegrass (*Lolium multiflorum* Lam.) growth cycle in southern Brazil. The pasture was managed to maintain four different average sward heights: 10, 20, 30, and 40 cm, along with an ungrazed control (G10, G20, G30, G40, and UG, respectively). The results indicate that ryegrass on treatments G10, G20, and G30 showed higher accuracy in herbage mass estimation when correlated with the vegetation indices. Conversely, the best correlation between sward height and vegetation indices was observed at G40 and UG treatments. These findings indicate that remote sensing-derived vegetation indices can effectively estimate sward height and herbage mass, offering producers precise, real-time data that can be a breakeven point for producers' management decisions.

**Keywords:** *satellite images; heterogeneous environment; normalized difference vegetation index; normalized difference red-edge;*

## 1. INTRODUCTION

Integrated Crop-Livestock Systems (ICLS) are recognized by the Food and Agriculture Organization (FAO, 2010) as an alternative for sustainable intensification as they are planned systems for exploring synergies among their components. When well-managed, these systems have the potential to improve soil quality, promote nutrient cycling, and enhance the economic performance of grain and livestock production, adapting to diverse agroecosystems in different regions of the world (Bell; Moore, 2012; De Moraes *et al.*, 2014; Carvalho, *et al.*, 2018; Simili *et al.*, 2023). Moreover, ICLS emerged as a viable solution for increasing food production without expanding agricultural areas, a necessity in the face of food insecurity, as reported by FAO (2023).

In order to promote sustainable food production via ICLS, there is no simple pathway, as these systems are more complex and require multiple knowledge inputs, customized design, and proper management (Moojen *et al.*, 2023). Incorporating grazing animals into ICLS adds another layer of complexity, particularly in terms of proper pasture management, which is essential to unlocking the potential benefits of these systems. The spatial heterogeneity imposed by animals when grazing is often seen as one of the challenges to ICLS adoption. Grazing intensity affects the spatial heterogeneity of vegetation (Nunes *et al.*, 2019), and it is the factor that most influences the pasture environment, as it directly affects forage mass, sward height, and accumulation rate (Franzluebbers *et al.*, 2013). Thus, understanding and managing grazing intensity correctly is crucial to successfully implementing ICLS.

In the past fifty years, remote sensing solutions have been created to monitor the Earth's ecosystems (Sparrow *et al.*, 2020). Regarding grassland science, most satellite-based remote sensing studies aimed to map areas with few types of species (Thornley *et al.*, 2023). In this context, vegetation indices emerge as an efficient alternative for monitoring herbage mass on crops (Vian *et al.*, 2018; Tan *et al.*, 2020) and pasture-based livestock systems (Junges *et al.*, 2016; Michez *et al.*, 2019). These indices can help monitor plant growth and development at a low cost with highly detailed information and practicality.

Different grazing intensities can modify plant structure, thereby affecting the efficiency of remote sensing in estimating herbage mass or sward height. Intensive grazing results in homogeneous overgrazed canopies with frequent bare soil patches (Nunes *et al.*, 2019), which can lead to confusion in indices designed to measure vegetation greenness. Similarly, areas with light grazing intensity and ungrazed areas may initiate flowering and plant senescence earlier (Rocha, 2004), further complicating the use of remote sensing data. Consequently, while remote sensing is a promising tool, its effectiveness for pasture monitoring may be reduced at the beginning of plant senescence because of the structural modifications that occur during that phase.

We hypothesized that estimating pasture herbage mass and sward height through remote sensing is enhanced when classifying the different grazing intensities, with moderate to moderate-light intensities being better estimated. Additionally, the accuracy of pasture herbage mass and sward height estimation via remote sensing may decrease towards the end of the grazing. We aim to i) assess the accuracy of vegetation indices to estimate sward height and herbage mass across four different grazing intensities in annual ryegrass pastures and an ungrazed canopy of the same grass species and ii) determine if structural changes induced by the advance of vegetation cycle affects the sensitivity of estimations.

## 2. MATERIALS AND METHODS

### *2.1 Study area and experimental design*

This study was part of a long-term ICLS protocol carried out at the Espinilho farm, in the municipality of São Miguel das Missões, Rio Grande do Sul state, Southern Brazil (28°56′14″ S, 54°20′52″ W, 465 m a.s.l.), and is running since 2001. The region's climate is classified as Cfa, Subtropical Humid, according to the Köppen classification (Alvares *et al.*, 2014). The average annual temperature is 20.5 °C, and the annual precipitation is 1989 mm (INMET, 2020). The soil is a clayey Oxisol (Rhodic Hapludox, Soil Survey Staff, 1999), deep and well-drained with clayey texture (540, 270 and 190 g kg$^{-1}$ of clay, silt, and sand, respectively).

The experiment’s framework consists of a crop-pasture rotation that encompasses the cultivation of soybeans (*Glycine max*) in the summer season (crop phase, from November to April) and annual ryegrass (*Lolium multiflorum* Lam.) in the winter season (pasture phase, from May to October) under increasing grazing intensities. The experimental area covers 22 hectares and has been managed under no-till since 1993 (for details of the experimental site’s history, see  Nunes *et al.*, 2021).

The experimental design was a randomized complete block. The treatment structure consisted of a factorial of five grazing treatments: 10 cm sward height—intensive grazing (G10), 20 cm sward height—moderate grazing (G20), 30 cm sward height—moderate-light grazing (G30), 40 cm sward height – light grazing (G40), and ungrazed annual ryegrass used as a cover crop (UG).

During the pasture phase, sward heights were measured every 15 days using a sward stick (Barthram, 1985) to keep the average sward heights as close as possible to the pre-established target heights. Three tester animals remained continuously in each paddock during the stocking period (Matches, 1974). A variable number of put-and-take animals were added or removed to the paddocks to adjust the sward heights upon demand. (Mott & Lucas, 1952).

The data presented in this study were obtained during the 2023 stocking period. Ryegrass was sown on May 9th of the same year at a 40 kg ha$^{-1}$ seeding after soybean harvest. The experimental animals were cross-bred Angus x Hereford x Nelore, with an average body weight of 217 ± 13kg and 12 months of age. Animals started grazing on July 17th, when the pasture reached the average sward height of 25 cm. The stocking period was finished on October 24th, totaling 100 grazing days.

## 2.2 *Experimental data collection*

### *2.2.1 Sward Height and Herbage Mass*

Herbage mass (kg dry matter (DM)/ha) was determined by collecting samples by clipping plants at the ground level within five randomly placed 0.25 m² quadrats per paddock before and during the stocking period (Kunrath *et al.*, 2014). Five sward height measurements were performed inside each quadrat using the sward stick. This process was then repeated at approximately 28-day intervals throughout the stocking period, ensuring a comprehensive monitoring of the forage dynamics.

To investigate the correlations between sward height and herbage mass with the vegetation indices (see next section), each sward height and herbage mass sample was georeferenced with a portable GPS device (Garmin e-Trex Vista HCx; Garmin International Inc., KS, USA) five times in each paddock. The portable GPS Garmin e-Trex Vista HCx has an accuracy of 3 meters. The georeferenced measurements were carried out in four periods in the pasture phase: August 16th (P1), September 9th (P2), October 3rd (P3), and October 24th (P4), represented on Figure 1.

The herbage samples were oven-dried at 55°C for 72 hours and were weighed using a precision scale. The total herbage mass for the stocking period was derived from the sum of all subperiods.

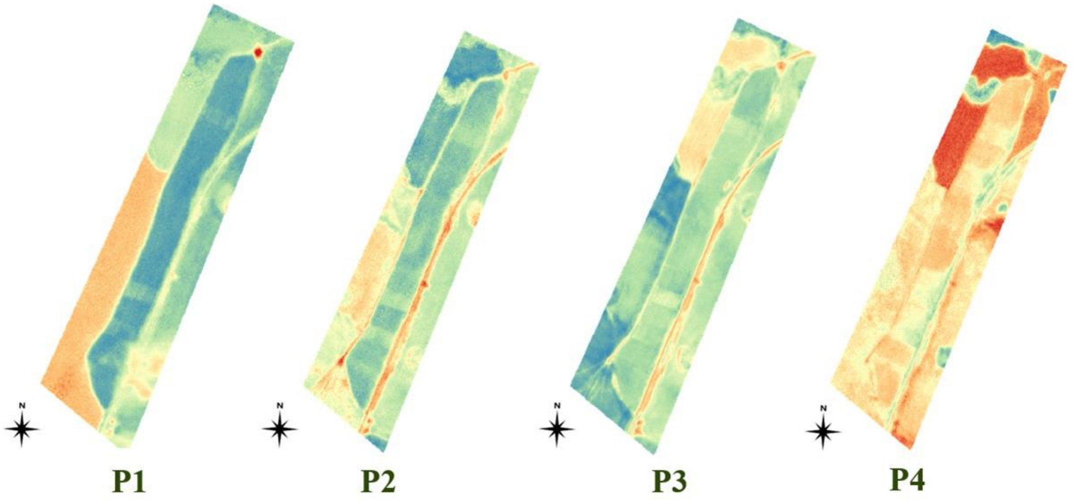

Figure 1. Periods of georeferenced sward height and herbage mass measurements during the pasture phase. P1: August 16th, P2: September 9th, P3: October 3rd, and P4: October 24th. Dark green represents higher NDRE and red lower.

### *2.2.2 Indices data collection and processing*

We used satellite-based imagery from *PlanetScope* (Planet Labs Inc., San Francisco, CA, USA) to obtain the values used for vegetation indices calculations. The *PlanetScope* images include 8 spectral bands (Coastal blue, Green I, Green, Yellow, Red, Red-edge, and NIR), with a spatial resolution of 3 meters and a revisit time of 1 or 2 days. The images and sample points are defined in the Universal Transverse Mercator (UTM) projection.

The vegetation indices used were the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Red Edge. The NDVI uses parameters of the photosynthetic activity and plant stress (Rouse *et al.*, 1973) and is calculated with Equation (1), using red (670nm) and NIR (near-infra-red – 790nm) light. Normalized Difference Red Edge (NDRE) captures chlorophyll and nitrogen content (Barnes *et al.*, 2000; Gitelson *et al.*, 2001). NDRE is calculated using Equation (2) and uses both red edge and NIR. The values range between -1 and +1, with higher values indicating greater vegetation attributes (Pettorelli *et al.*, 2005). The indexes are obtained by the equations:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \qquad (1)$$

$$NDRE = \frac{(NIR - RED\ EDGE)}{(NIR + RED\ EDGE)} \qquad (2)$$

*2.3 Statistical analysis*

We used NDVI and NDRE to correlate with sward height and herbage mass, which were obtained using geostatistical methods on QGIS Desktop 3.28.8. Sward height, herbage mass, NDVI, and NDRE were subjected to analysis of variance (ANOVA) at 5% significance level, with treatments and periods as fixed effects and block as a random effect. When significant differences were detected, means were compared using Tukey's test ($p < 0.05$). All analyses were performed using package "*lme4*" (Bates *et al.*, 2015) in R software (R Core Team, 2023).

To determine if sward height and herbage mass correlate with NDVI and NDRE, we performed the Pearson correlation test considering all the treatments together and separately. The magnitudes of correlation coefficients ($p<0.05$) were classified as follows: $r$= 0 was considered null; $r$= 0 to 0.30 was considered weak; $r$= 0.30 to 0.60 was considered moderate; $r$= 0.60 to 0.90 was considered strong and $r$= 0.90 to 1 (Asuero *et al.*, 2006; Silveira *et al.*, 2021).

## 3. RESULTS

Both NDVI and NDRE decreased across the periods because of the progress of the grazing cycle (Table 1). In the last period of pasture evaluation (P4), all the treatments presented lower results for NDVI and NDRE and herbage mass. The ungrazed and intensive treatments presented lower NDVI and NDRE in most of the periods. Moderate, moderate-light, and light grazing intensities presented the best results for most variables during the periods.

**Table 3**. Mean values and standard deviation for Sward Height, Herbage Mass, NDVI, and NDRE according to grazing intensities and periods for the pasture phase of an integrated crop-livestock system.

| | Periods | | | |
|---|---|---|---|---|
| Treatments | P1 | P2 | P3 | P4 |
| Sward Height | | | | |
| G10 | 19.94 ± 1.70 dA | 15.89 ± 1.70 d AB | 10.32 ± 1.99 dBC | 8.52 ± 1.70 bC |
| G20 | 30.52 ± 1.70 cA | 25.96 ± 1.70 cA | 18.10 ± 1.99 cB | 17.64 ± 1.70 aB |
| G30 | 31.09 ± 1.70 cA | 32.41 ± 1.70 bA | 31.80 ± 1.99 bA | 19.24 ± 1.70 aB |
| G40 | 37.77 ± 1.70 bA | 38.44 ± 1.70 aA | 35.78 ± 1.99 abA | 21.53 ± 1.70 aB |
| UG | 49.04 ± 2.44 aA | 39.97 ± 2.44 aAB | 42.51 ± 2.44 aB | 22.51 ± 2.44 aC |
| Herbage Mass | | | | |
| G10 | 1729 ± 215 cA | 1827 ± 215 dA | 1526 ± 269 cA | 361 ± 215 bB |
| G20 | 3057 ± 215 bA | 2992 ± 215 cA | 3347 ± 269 bA | 565 ± 215 bB |
| G30 | 3064 ± 215 bA | 3823 ± 215 cA | 3769 ± 269 bA | 999 ± 215 abA |
| G40 | 3222 ± 215 bB | 5067 ± 215 bA | 4186 ± 269 bA | 1462 ± 215 aC |
| UG | 4518 ± 345 aB | 6946 ± 345 aA | 6955 ± 345 aA | 1213 345 ± abC |
| NDVI | | | | |
| G10 | 0.843 ± 0.006 bA | 0.789 ± 0.006bB | 0.671 ± 0.008 cC | 0.598 ± 0.006 aD |
| G20 | 0.873 ± 0.006 aA | 0.828 ± 0.008 aB | 0.721 ± 0.008 abC | 0.552 ± 0.006 bD |
| G30 | 0.869 ± 0.006 aA | 0.833 ± 0.007 aB | 0.733 ± 0.008 abC | 0.460 ± 0.006 cD |
| G40 | 0.869 ± 0.006 aA | 0.848 ± 0.009 aB | 0.744 ± 0.008 aC | 0.460 ± 0.006 cD |
| UG | 0.877 0.01 aA | 0.813 ± 0.011 abB | 0.702 ± 0.010 bcC | 0.527 ± 0.010 bD |
| NDRE | | | | |
| G10 | 0.605 ± 0.005 bA | 0.540 ± 0.005 bB | 0.495 ± 0.006 cC | 0.381 ± 0.005 aD |
| G20 | 0.642 ± 0.005 aA | 0.580 ± 0.006 aB | 0.541 ± 0.006 abC | 0.359 ± 0.005 bD |
| G30 | 0.646 ± 0.005 aA | 0.590 ± 0.006 aB | 0.555 ± 0.006 abC | 0.304 ± 0.005 cdD |
| G40 | 0.647 ± 0.005 aA | 0.600 ± 0.008 aB | 0.562 ± 0.006 aC | 0.299 ± 0.005 dD |
| UG | 0.663 ± 0.008 aA | 0.575 ± 0.009 aB | 0.532 ± 0.008 bC | 0.330 ± 0.008 cD |

G10: intensive grazing; G20: moderate grazing; G30: moderate-light grazing; G40: light grazing; UG: ungrazed. Total grazing cycle was divided into four grazing herbage mass evaluation periods: P1, P2, P3 and P4, divided each other in 28 days between August to October. Uppercase letters for the period on the treatments. Lowercase letter treatments on the different periods. The means followed by the same letter, capitalized in the row and lowercase in the column, do not differ significantly from each other, according to the Tukey test, with a significance level of 5%.

When considering all treatments, herbage mass x NDVI (r=0.525, p<0.01) and herbage mass x NDRE (r=0.569, p<0.01) had a significant and moderate correlation (Figure 2). Similarly, significant correlations were observed between sward height x NDVI (r=0.484, p<0.01) and sward height x NDRE (r=0.533, p<0.01), with moderate correlation. The two Vegetation Indices (VI), NDVI and NDRE, had a strong correlation (r=0.98, p<0.001).

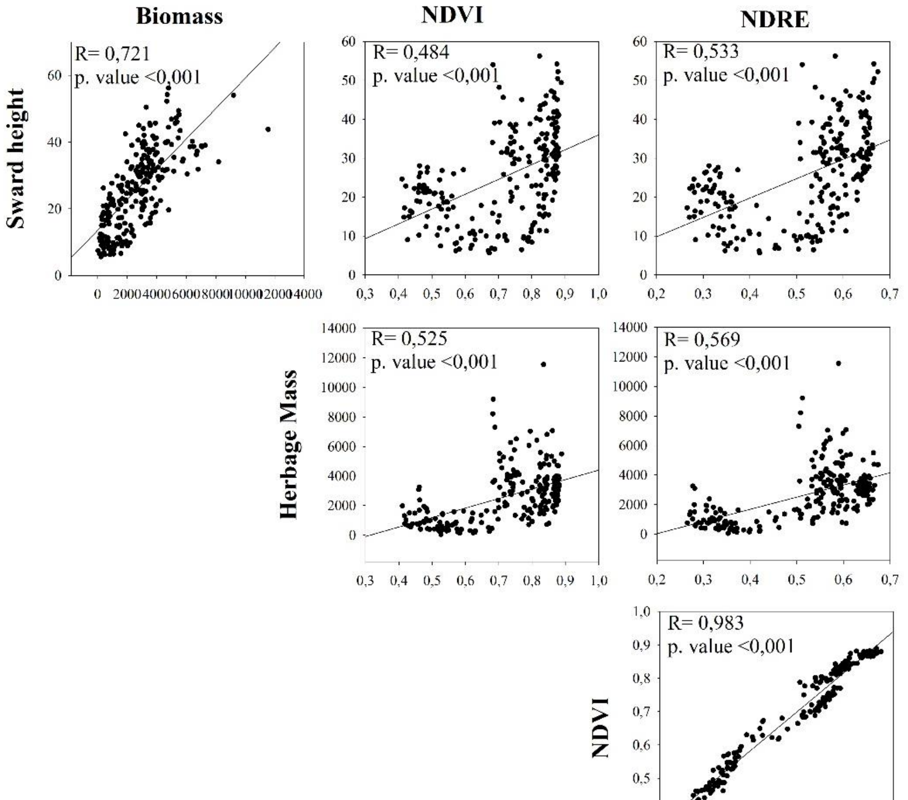

**Figure 2.** Pearson correlation between Sward height, Herbage Mass, Normalized Difference Vegetation Index (NDVI), and Normalized Difference Red Edge (NDRE) for ryegrass.

In order to determine the grazing intensity that could be best managed through remote sensing, correlation analyses were conducted throughout the grazing cycle, with treatments analyzed separately. Figure 3 illustrates the correlations for NDVI, NDRE, sward height, and herbage mass, considering the treatments separately. When considering treatments separately, the correlations demonstrate stronger associations and exhibit variations in correlation strength among them.

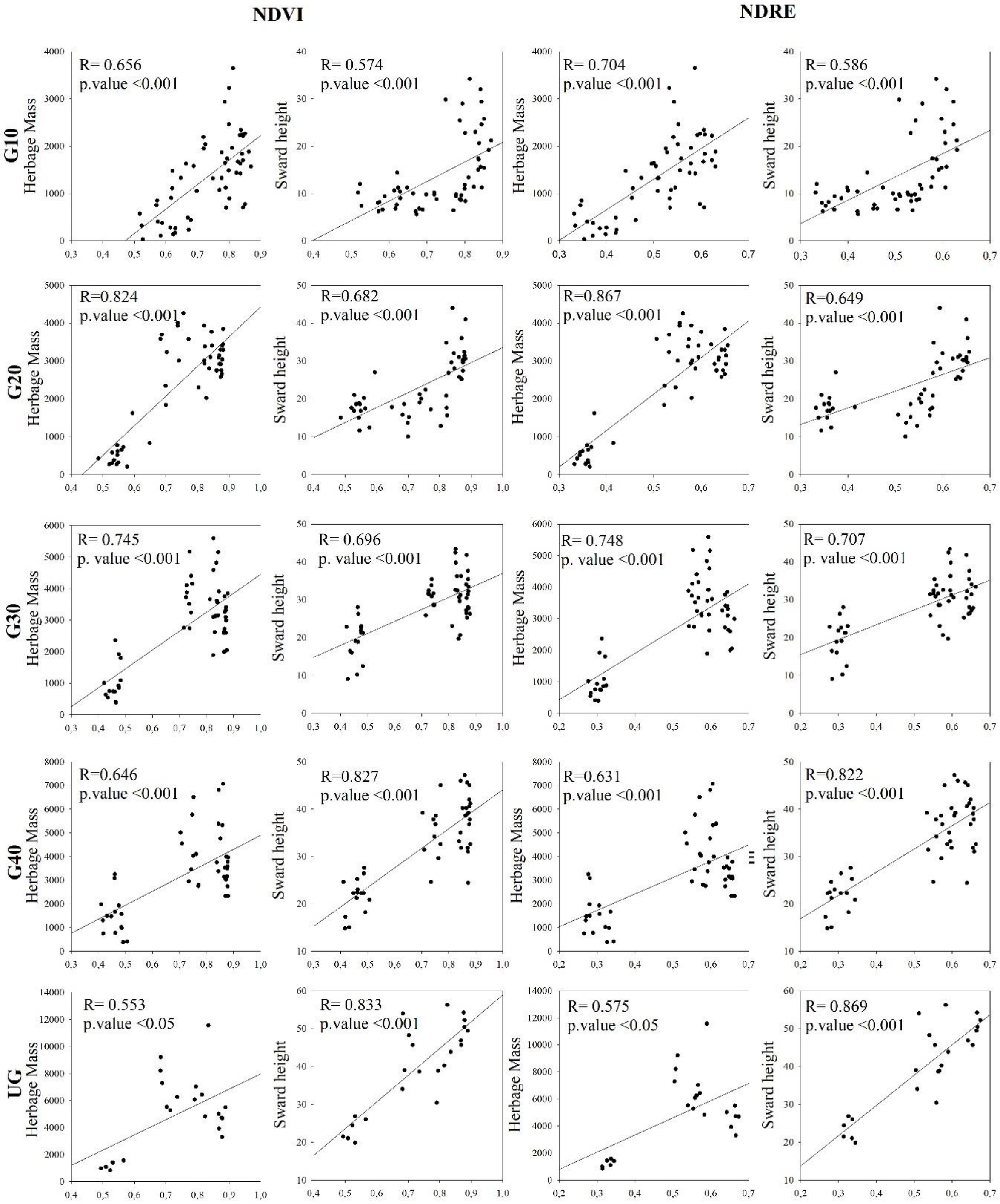

**Figure 3**. Pearson Correlation between Sward height, Herbage Mass, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Red Edge (NDRE) for ryegrass.

Observations were separated by grazing intensities: 10, 20, 30, 40 cm of ryegrass sward height and UG for ungrazed treatment.

Herbage Mass presented high correlation with NDVI and NDRE for all the treatments, especially for moderate ($r=0.82$, $p<0.001$ and $r=0.867$, $p<0.001$) and moderate-light ($R=0.745$ and $R=0.748$, $p<0.05$) grazing intensities. Sward height had better correlation with NDVI and NDRE when used in moderate-light ($r=0.696$, $p<0.01$ and $r=0.707$, $p<0.01$) and light grazing ($r=0.827$, $p<0.01$ and $r=0.822$, $p<0.01$) intensities. The ungrazed treatment also presented a strong correlation between sward height and NDVI ($r= 0.833$, $p<0.01$) and NDRE ($r=0.869$, $p<0.01$).

Similarly to the correlation analysis, linear regressions considering the different treatments demonstrated significance for all treatments, but no significance for ungrazed treatment (Table 2). Pastures with intensive grazing intensity (G10) presented significance for herbage mass considering both NDVI ($R^2= 0.430$, $p<0.001$) and NDRE ($R^2= 0.496$, $p<0.001$), the same was encountered for sward height with NDVI ($R^2=0.329$, $p<0.05$) and NDRE ($R^2= 0.343$, $p<0.05$). Moderate grazing intensity (G20) presented significance for herbage mass on both NDVI ($R^2= 0.680$, $p<0.001$) and NDRE ($R^2= 0751$, $p<0.001$). Moderate-light (G30) was significant for herbage mass on both NDVI (($R^2= 0.555$, $p<0.05$), NDRE ($R^2= 0.559$, $p<0.001$) and sward height for NDRE ($R^2= 0.50$, $p<0.05$). Light grazing intensity had significance for sward height with NDRE ($R^2= 0.676$, $p<0.05$).

**Table 4.** Linear regression considering the different treatments: P10, P20, P30, and P40 (grazing intensities: 10, 20, 30, and 40 cm for annual ryegrass).

| **10** | **20** | **30** | **40** |
|---|---|---|---|
| SH=-16.358+(41.338*NDVI) | SH=-6,142 + (39,723 * NDVI) | SH= 5,223 + (31,737 * NDVI) | SH=2,790+(41,328*NDVI) |
| $R^2=0.329$ | $R^2=0.465$ | $R^2=0.484$ | $R^2=0.684$ |
| $p<0.05$ | $p>0.05$ | $p>0.05$ | $p>0.05$ |
| SH=-11.057+(49.154*NDRE) | SH=-0,0444 + (44,186 * NDRE) | SH=7.612+(39.420*NDRE) | SH=6.990+(49.213*NDRE) |
| $R^2= 0.343$ | $R^2=0.421$ | $R^2=0.50$ | $R^2= 0.676$ |
| $p<0,05$ | $p>0.05$ | $p<0.05$ | $p<0.05$ |
| HM=-2434,610+(5177,203*NDVI) | HM=-3413,192+(7841,546*NDVI) | HM=-1545,729+(6000,346*NDVI) | HM=-1020,251+(5913,602*NDVI) |
| $R^2= 0.430$ | $R^2= 0.680$ | $R^2=0.555$ | $R^2=0.417$ |
| $p<0.001$ | $p<0.001$ | $p<0.05$ | $p>0.05$ |
| HM=-1932,521+(6475,620*NDRE) | HM=-2689,002+(9636,005*NDRE) | HM=-1045,715+(7358,892*NDRE) | HM= -357,200+(6919,819*NDRE) |
| $R^2= 0.496$ | $R^2=0.751$ | $R^2=0.559$ | $R^2=0.399$ |
| $p<0.001$ | $p<0.001$ | $p<0.001$ | $p>0.05$ |

SH= sward height; NDVI= Normalized Difference Vegetation Index; NDRE= Normalized Difference Red Edge; HB= Herbage Mass;

To better understand the accuracy of the indices during the grazing cycle, the four periods (P1, P2, P3 and P4) were analyzed separately (Figure 4). On intensive (G10), moderate (G20) and moderate-light (G30) grazing intensities, the vegetation indices demonstrated to be efficient on estimating herbage mass or sward height during P2 and P3. Light (G40) and ungrazed (UG) treatments could only be estimated in P2. These results suggest that the regressions presented on the Table 2 can have better results when these periods are considered.

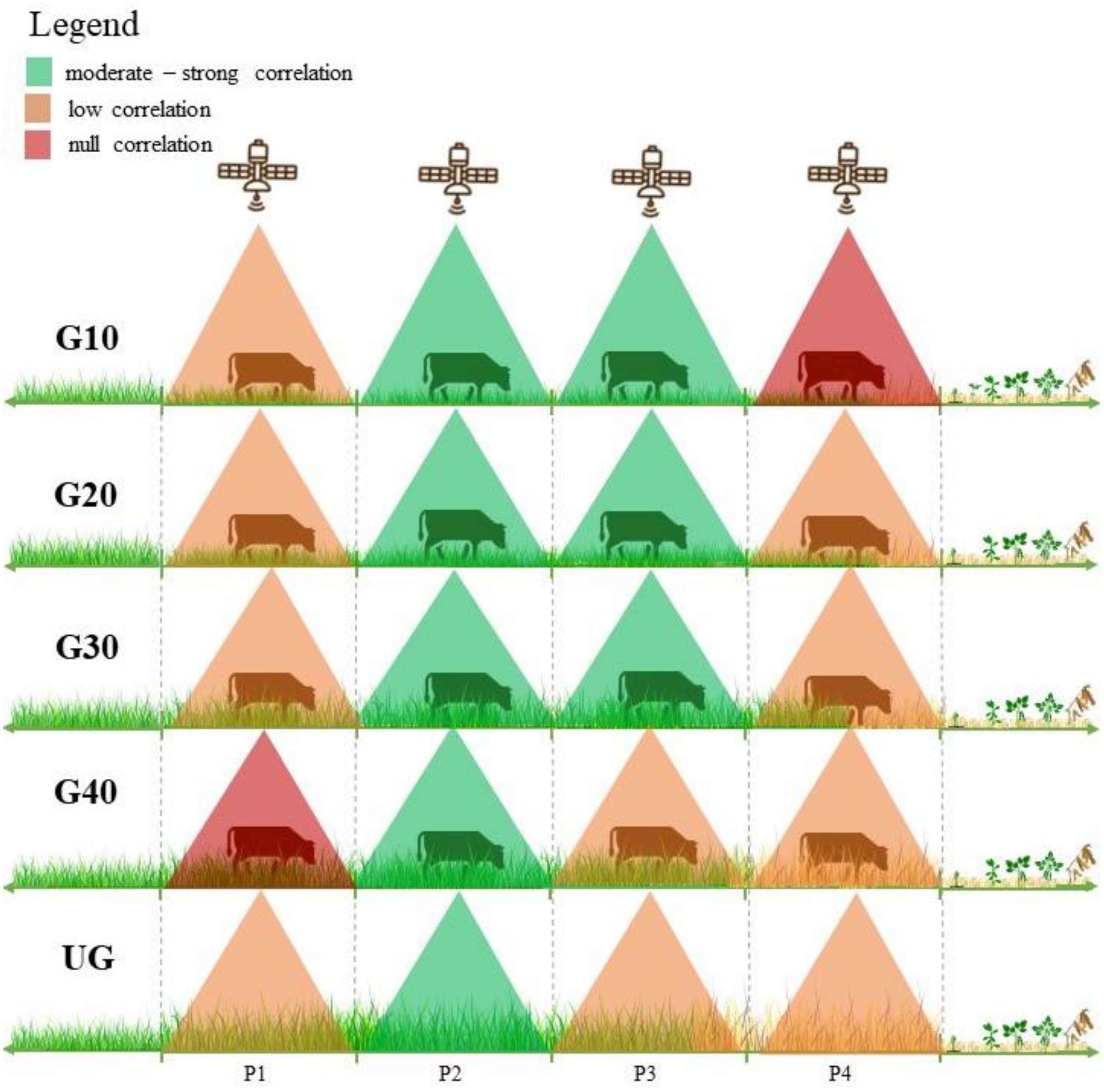

Figure 4. Accuracy of the indices during the grazing cycle on different grazing intensities. G10: intensive grazing; G20: moderate grazing; G30: moderate-light grazing; G40: light grazing; UG: ungrazed. The total grazing cycle was divided into four grazing herbage mass evaluation periods: P1, P2, P3, and P4, divided into 28 days between August and October.

## 4. DISCUSSION

The most significant result of this work is the evidence of the possibility of managing ryegrass pasture according to herbage mass or sward height using remote sensing. Our analysis revealed that vegetation indices obtained by remote sensing are more accurate in managing ryegrass by herbage mass from 10 to 30 cm of sward height – intensive to moderate-light grazing intensities. For pastures with 40 cm – light grazing intensity - or more, our results indicate that remote sensing is more accurate when predicting sward height.

The scenario that did not consider grazing intensities separately presented a low or moderate correlation between variables. Complementing a previous study that focused on correlating herbage mass with NDVI provided by satellite images (Gargiulo *et al.*, 2023), we focused on testing the accuracy of NDVI and NDRE to estimate herbage mass and sward height on different grazing intensities. With this study, by dividing the different grazing intensities, we demonstrate that managing the pasture phase with remote sensing is viable, facilitating pasture management and providing data for more assertive decisions.

Our findings exhibited increased accuracy when stratified by grazing intensities, demonstrating the importance of categorizing distinct grazing intensities prior to implementing remote sensing techniques for optimal outcomes. Moreover, using appropriate grazing intensities to increase production efficiency is essential for sustainable agricultural intensification in complex and resilient systems (Kirschenmann 2007; Nunes *et al.*, 2021).

Generally, the correlations were better for herbage mass among the treatments, especially at moderate (G20) and moderate light (G30) intensities. The better results for regression were found on moderate grazing for herbage mass using NDRE. Although, between herbage mass and sward height, the second is more directly linked to bite depth and has a greater influence on animal production (Laca *et al.*, 1992). Additionally, sward height serves a practical management tool in establishing goals for pasture structure and animal production (Carvalho *et al.*, 2010). However, with the strong association between sward height and pasture herbage mass, highlighted by Kunrath *et al.* (2020), it is possible to use one variable to predict the other.

The results presented in this paper showed that it is possible to manage pastures on moderate-light (G30) grazing intensity for herbage mass and sward height, with better responses when using NDRE. Light grazing intensity (G40) and ungrazed (UG) presented to be more related to sward height, suggesting that pastures with more than 40 cm effectively leverage the correlations between sward height and NDRE or NDVI. In the same sense, using satellite images combined with machine learning of tropical pastures, Bretas *et al.*, (2023) found important predictive capabilities for sward height of Mombaça guinea grass.

Grazing intensity defines the pasture structure and animal production, so it should be considered in good pasture management. Light grazing intensities promote more senescence flux (Cauduro *et al.,* 2007), while higher grazing intensities extend the vegetative stage of the pasture (Dumont *et al.*, 2012). Furthermore, because of shading in ungrazed and light grazing, the plants presents internodes elongation and early flowering, reducing their growth cycle (Rocha *et al.*, 2004). That explains the reduction in efficiency of indices occurring first at light grazing intensity and ungrazed areas. On the other hand, severe plant tissue removal and eventual tiller death at high grazing intensities result in slower pasture growth (Hodgson, 1990). So, the use of correct sward height is important to promote a good balance on these challenges of pasture management.

Very little or no defoliation promoted by light grazing intensities may ultimately reduce the potential for maximizing net primary production by shading out new plant growth. Plants undergo stoichiometric changes as they reallocate resources from vegetative growth (i.e., leaves and roots) to reproductive (i.e., seeds). As plants mature and approach senescence, their C: N ratios increase and their biomass contains proportionally more structural (i.e., lignin) than soluble (i.e., sugar) components (Stanley *et al.*, 2024). Because of the increase in stem size, the daily grazing time increases towards the end of the grazing cycle (Dumont *et al.*, 2020). So, the herbage mass structure change during the cycle, and with the advance of the grazing cycle, the stems increase in weight (Barth Neto et al., 2013) while the leaves decrease.

As demonstrated in our results, when the grazing season progresses, the grass starts the senescence period, and because of plant structure changes (e.g., inflorescences) in leaf color, the vegetation indices lose efficiency. So, our results suggest that remote sensing can be an effective tool for managing pastures until the beginning of the end of the cycle (e.g., flowering and senescence). Furthermore, heterogeneity is an inherent property of the pasture environment that we need to consider in management (Laca, 2008). More detailed studies need to be done to explore how heterogeneity behaves during the grazing cycle among the grazing intensities and estimate with more accuracy until where the management can be predicted by remote sensing.

The improvements in precision agriculture tools represent an important alternative to performing more accurate estimations (Chebli *et al.*, 2022), especially when considering animal behavior and their implications on pasture management. Due to present homogeneous environments, crop areas exhibit several studies with satisfactory results for the use of vegetation indices (e.g. NDVI and NDRE) in predicting crop biomass and productivity (Bredemeier *et al.*, 2013; Vian *et al.*, 2018; Trentin *et al.*, 2021). Despite significant advancements due to their heterogeneity, grazed areas still represent a challenge in management through vegetation indices obtained by satellite-based remote sensing. On the last years, techniques such as satellite-based remote sensing (Schellberg, J.; Verbruggen, 2014) and 2D or 3D cameras, have been used to measure the photosynthetic activity and pasture sward height (Andriamandroso *et al.*, 2017). Our results contribute to the advancement of satellite-based vegetation indices utilization, observing differences in accuracy considering the different grazing intensities.

On ICLS, it is necessary to plan all phases of the system without one being compromised at the expense of the other. Grazing intensity is an important role to consider for the success of the systems. Light grazing intensities can subtilize the pasture, and intensive grazing can hinder self-seeding (Barth Neto *et al.*, 2014) and promote more weed incidence (Schuster *et al.*, 2020). Furthermore, grazing intensity impacts the biomass residues for no-till. So, crop development is partially due to conditions created by grazing management (Carvalho *et al.*, 2010). Considering that moderate grazing intensities represent the option that can reconcile the maximization of both animal and plant production (Kunrath *et al.*, 2020). So, it is essential to develop methodologies and use tools that facilitate pasture management, especially considering intensities.

Integrating grazing into agricultural environments serves as an important role in creating more sustainable agricultural systems (Franzluebbers; Martin, 2022). Therefore, developing and utilizing tools that facilitate the proper management of both phases of these systems is necessary, considering their complexity. Our results are important to facilitate pasture management, which is both time-consuming and challenging to perform at a high level of spatial resolution (Bindelle *et al.*, 2021). Satellite imagery has the advantage of covering large areas instantaneously (Tattaris; Reynolds; Chapman, 2016), providing high temporal and spatial resolution (Roy *et al.*, 2021) at a low cost and fast way to obtain. *PlanetScope* satellite images have daily revisit frequency and good spatial resolution (Xu et al., 2022), so the growth and development of the pasture can be observed daily.

## 5. CONCLUSIONS

Satellite-based remote sensing can provide information to manage ryegrass in the ICLS pasture phase by assessing herbage mass or sward height. Moderate grazing intensity presented to be more accurate to predict herbage mass by vegetation indices. Vegetation indices can also predict pasture management of ryegrass by herbage mass from intensive to moderate-light. Pastures on light grazing intensity have a better correlation between NDRE and sward height, than with herbage mass. So, grazing intensity is paramount to consider which better parameters to manage pastures. Remote sensing demonstrates to be efficient until the beginning of senescence to manage ryegrass. The spatial heterogeneity in grazing intensities during the cycle should be accounted for in further investigations to improve the models that predict sward height and herbage mass for managing the pasture phase with satellite-based remote sensing.

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# REFERENCES

ADLER, P.B., Raff, D.A., Lauenroth, W.K., 2001. The effect of grazing on the spatial heterogeneity of vegetation. Oecologia 128, 465–479.

ALTIERI, M. A. *et al.* Agroecology and the design of climate change-resilient farming systems. **AGRONOMY FOR SUSTAINABLE DEVELOPMENT**, 22 RUE DE PALESTRO, PARIS, 75002, FRANCE, v. 35, n. 3, p. 869–890, 2015.

ALVARES, C. A. *et al.* Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, [*s. l.*], v. 22, n. 6, p. 711–728, 2013.

ANDRIAMANDROSO, A. L. H. *et al.* Differentiating pre- and post-grazing pasture heights using a 3D camera: A prospective approach. **Precision Livestock Farming 2017 - Papers Presented at the 8th European Conference on Precision Livestock Farming, ECPLF 2017**, [*s. l.*], p. 238–246, 2017.

ANGHINONI, I. *et al.* Abordagem sistêica do solo em Sistemas Integrados de Produção Agrícola e Pecuária no subtrópico brasileiro. **Tópicos em Ciência do Solo**, [*s. l.*], v. 8, n. 2, p. 325–380, 2013.

ARNUTI, F. *et al.* Erratum to: Arnuti, f., et al. sheep dung composition and phosphorus and potassium release affected by grazing intensity and pasture development stage in an integrated crop-livestock system. agronomy 2020, 10, 1162. **Agronomy**, [*s. l.*], v. 11, n. 1, p. 1–14, 2021.

ASUERO, A. G.; SAYAGO, A.; GONZÁLEZ, A. G. The correlation coefficient: An overview. **Critical Reviews in Analytical Chemistry**, [*s. l.*], v. 36, n. 1, p. 41–59, 2006.

BALBINO, L. C. *et al.* Sistemas de integração: o que são, suas vantagens e limitações. **Sistemas de integração lavoura pecuária floresta**, [*s. l.*], p. 12–18, 2012.

BARTH NETO, A. *et al.* Italian ryegrass establishment by self-seeding in integrated crop-livestock systems: Effects of grazing management and crop rotation strategies. **European Journal of Agronomy**, [*s. l.*], v. 57, p. 77–83, 2014.

BARTHRAM, G. T. Experimental techniques: the HFRO sward stick. *In*: HILL FARMING RES. ORGANIZATION/BIENNIAL REPORT. [*S. l.: s. n.*], 1985. p. 29-30.
BATES, D. *et al.* Fitting linear mixed-effects models using lme4. **Journal of Statistical Software**, [*s. l.*], v. 67, n. 1, 2015.

BELL, L. W.; MOORE, A. D. Integrated crop-livestock systems in Australian agriculture: Trends, drivers and implications. **Agricultural Systems**, [*s. l.*], v. 111, p. 1–12, 2012. Disponível em: http://dx.doi.org/10.1016/j.agsy.2012.04.003.

BERNARDI, A. C. d. C. *et al.* Spatial variability of vegetation index and soil properties in an integrated crop-livestock system. **Revista Brasileira de Engenharia Agricola e Ambiental**, [*s. l.*], v. 21, n. 8, p. 513–518, 2017.

BINDELLE, J. *et al.* Drone-based remote sensing of sward structure and biomass for precision grazing: state of the art and future challenges. [*s. l.*], v. 26, n. May, 2021.

BREDEMEIER, C. *et al.* Estimativa do potencial produtivo em trigo utilizando sensor óptico ativo para adubação nitrogenada em taxa variável. **Ciencia Rural**, [*s. l.*], v. 43, n. 7, p. 1147–1154, 2013.

BRETAS, I. L. *et al.* Canopy height and biomass prediction in Mombaça guinea grass pastures using satellite imagery and machine learning. **Precision Agriculture**, [*s. l.*], v. 24, n. 4, p. 1638–1662, 2023. Disponível em: https://doi.org/10.1007/s11119-023-10013-z.

CANATA, T. F. *et al.* 3D Data Processing to Characterize the Spatial Variability of Sugarcane Fields. **Sugar Tech**, [*s. l.*], v. 24, n. 2, p. 419–429, 2022.

CARVALHO, Paulo Cesar de Faccio *et al.* Animal production and soil characteristics from integrated crop-livestock systems: toward sustainable intensification. **JOURNAL OF ANIMAL SCIENCE**, [*s. l.*], v. 96, n. 8, p. 3513–3525, 2018.

CARVALHO, Paulo César de Faccio *et al.* Animal production and soil characteristics from integrated crop-livestock systems: Toward sustainable intensification. **Journal of Animal Science**, [*s. l.*], v. 96, n. 8, p. 3513–3525, 2018.

CARVALHO, P. C. de F. *et al.* Característica produtiva e estrutural de pastos mistos de aveia e azevém manejados em quatro alturas sob lotação contínua. **Revista Brasileira de Zootecnia**, [*s. l.*], v. 39, n. 9, p. 1857–1865, 2010.

CARVALHO, P. C. F. *et al.* Como a estrutura do pasto influencia o animal em pastejo? Exemplificando as interações planta-animal sob as bases e fundamentos do Pastoreio "Rotatínuo". **VIII Simpósio sobre manejo estratégico da pastagem**, [*s. l.*], n. October, p. 21, 2016.

CARVALHO, P. C. de F. *et al.* Definitions and terminologies for Integrated Crop-Livestock System. **Revista Ciência Agronômica**, [*s. l.*], v. 45, n. 5, p. 1040–1046, 2014.

CARVALHO, P. C. de F. *et al.* Managing grazing animals to achieve nutrient cycling and soil improvement in no-till integrated systems. **Nutrient Cycling in Agroecosystems**, [*s. l.*], v. 88, n. 2, p. 259–273, 2010.

CARVALHO, Paulo Cesar de Faccio *et al.* Reconnecting Grazing Livestock to Crop Landscapes: Reversing Specialization Trends to Restore Landscape Multifunctionality. **FRONTIERS IN SUSTAINABLE FOOD SYSTEMS**, [*s. l.*], v. 5, 2021.

CAUDURO, G. F. *et al.* Aerial biomass fluxes in an Italian ryegrass managed under two grazing intensities and two stocking methods. **Revista Brasileira de Zootecnia**, [*s. l.*], v. 36, n. 2, p. 282–290, 2007.

CHAUDHARY, A.; GUSTAFSON, D.; MATHYS, A. Multi-indicator sustainability assessment of global food systems. **NATURE COMMUNICATIONS**, [*s. l.*], v. 9, 2018.

CHEBLI, Y. *et al.* Using GPS Collars and Sensors to Investigate the Grazing Behavior and Energy Balance of Goats Browsing in a Mediterranean Forest Rangeland. **Sensors**, [*s. l.*], v. 22, n. 3, 2022.

CONTE, O. *et al.* Evolução de atributos físicos de solo em sistema de integração lavoura-pecuária. **Pesquisa Agropecuaria Brasileira**, [*s. l.*], v. 46, n. 10, p. 1301–1309, 2011.

DA SILVA, F. D. *et al.* Spatiotemporal distribution of cattle dung patches in a subtropical soybean-beef system under different grazing intensities in winter. **Agronomy**, [*s. l.*], v. 10, n. 9, 2020.

DE ALBUQUERQUE NUNES, P. A. *et al.* Intense winter grazing impairs subsequent Italian ryegrass re-establishment in soybean-pasture rotations. **Grass and Forage Science**, [*s. l.*], v. 76, n. 2, p. 258–269, 2021.

DE MORAES, A. *et al.* Integrated crop-livestock systems in the Brazilian subtropics. **European Journal of Agronomy**, [*s. l.*], v. 57, p. 4–9, 2014. Disponível em: http://dx.doi.org/10.1016/j.eja.2013.10.004.

DE OLIVEIRA, C. A. O. *et al.* Comparison of an integrated crop–livestock system with soybean only: Economic and production responses in southern Brazil. **Renewable Agriculture and Food Systems**, [*s. l.*], v. 29, n. 3, p. 230–238, 2014.

DE SOUZA FILHO, W. *et al.* Mitigation of enteric methane emissions through pasture management in integrated crop-livestock systems: Trade-offs between animal performance and environmental impacts. **Journal of Cleaner Production**, [*s. l.*], v. 213, p. 968–975, 2019.

DEBAUCHE, O. *et al.* Data management and internet of things: A methodological review in smart farming. **Internet of Things (Netherlands)**, [*s. l.*], v. 14, p. 100378, 2021. Disponível em: https://doi.org/10.1016/j.iot.2021.100378.

DUMONT, B. *et al.* How does pasture size alter plant–herbivore interactions among grazing cattle?. **Grass and Forage Science**, [*s. l.*], v. 75, n. 4, p. 438–446, 2020.

DUMONT, B. *et al.* When does grazing generate stable vegetation patterns in temperatepastures?. **AGRICULTURE ECOSYSTEMS & ENVIRONMENT**, [*s. l.*], v. 153, p. 50–56, 2012.

DURU, M. *et al.* How to implement biodiversity-based agriculture to enhance ecosystem services: a review. **Agronomy for Sustainable Development**, [*s. l.*], v. 35, n. 4, p. 1259–1281, 2015.

FAIR, K. R.; BAUCH, C. T.; ANAND, M. Dynamics of the Global Wheat Trade Network and Resilience to Shocks. **SCIENTIFIC REPORTS**, HEIDELBERGER PLATZ 3, BERLIN, 14197, GERMANY, v. 7, 2017.

FAO. An international consultation on integrated crop-livestock systems for development: the way forward for sustainable production intensification. **Integrated Crop Management**, [*s. l.*], v. 13, p. xii + 63 pp., 2010.

FAO. **Food security and nutrition in the world**. [*S. l.: s. n.*], 2023-. ISSN 22138595.v. 10

FLORES, J. P. C. *et al.* Atributos físicos do solo e rendimento de soja em sistema plantio direto em integração lavoura-pecuária com diferentes pressões de pastejo. **Revista Brasileira de Ciência do Solo**, [*s. l.*], v. 31, n. 4, p. 771–780, 2007.

FOLEY, J. A. *et al.* Global consequences of land use. **SCIENCE**, [*s. l.*], v. 309, n. 5734, p. 570–574, 2005.

FONTANA, D. C. *et al.* NDVI and meteorological data as indicators of the pampa biome natural grasslands growth. **Bragantia**, [*s. l.*], v. 77, n. 2, p. 404–414, 2018.

FRANZLUEBBERS, A. J.; MARTIN, G. Farming with forages can reconnect crop and livestock operations to enhance circularity and foster ecosystem services. **Grass and Forage Science**, [*s. l.*], v. 77, n. 4, p. 270–281, 2022.

FRANZLUEBBERS, A. J.; SAWCHIK, J.; TABOADA, M. A. Agronomic and environmental impacts of pasture-crop rotations in temperate North and South America. **Agriculture, Ecosystems and Environment**, [*s. l.*], v. 190, p. 18–26, 2014. Disponível em: http://dx.doi.org/10.1016/j.agee.2013.09.017.

FRANZLUEBBERS, A. J.; SEMAN, D. H.; STUEDEMANN, J. A. Forage dynamics in mixed tall fescue-bermudagrass pastures of the Southern Piedmont USA. **AGRICULTURE ECOSYSTEMS \& ENVIRONMENT**, RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS, v. 168, p. 37–45, 2013.

FRANZLUEBBERS, A. J.; SULC, R. M.; RUSSELLE, M. P. Opportunities and challenges for integrating North-American crop and livestock systems. *In*: LEMAIRE, G.; HODGSON, J.; CHABBI, A. (org.). **Grassland productivity and ecosystem services**. [*S. l.: s. n.*], 2011. p. 208–218.

GALLI, J. R.; CANGIANO, C. A.; FERNÁNDEZ, H. . Comportamiento Ingestivo Y Consumo De. **Revista Argentina de Producción Animal**, [*s. l.*], v. 16, n. 2, p. 1–10, 1996.

GARGIULO, J. I. *et al.* Comparison of Ground-Based, Unmanned Aerial Vehicles and Satellite Remote Sensing Technologies for Monitoring Pasture Biomass on Dairy Farms. **Remote Sensing**, [*s. l.*], v. 15, n. 11, 2023.

GORDON, I. J. *et al.* **Food Production and Nature Conservation: conflicts and solutions**. [*S. l.: s. n.*], 2017.

HODGSON, J. **Grazing Management: Science Into Practice**. [*S. l.*]: Longman Scientific \& Technical, 1990. (Lha Series). *E-book*. Disponível em: https://books.google.com.br/books?id=DdJ9QgAACAAJ.

HODGSON, J. Variations in the surface characteristics of the sward and the short-term rate of herbage intake by calves and lambs. **Grass and Forage Science**, [*s. l.*], v. 36, n. 1, p. 49–57, 1981.

JUNGES, A. H. *et al.* Temporal profiles of vegetation indices for characterizing grazing intensity on natural grasslands in Pampa biome. **Scientia Agricola**, [*s. l.*], v. 73, n. 4, p. 332–337, 2016.

KREMEN, C.; MERENLENDER, A. M. Landscapes that work for biodiversity and people. **SCIENCE**, [*s. l.*], v. 362, n. 6412, 2018.

KUNRATH, T. R. *et al.* Grazing management in an integrated crop-livestock system: soybean development and grain yield TT - Manejo do pastejo em sistemas integrados de produção agropecuária: desenvolvimento e rendimento de grãos de soja. **Revista Ciência Agronômica**, [*s. l.*], v. 46, n. 3, p. 645–653, 2015.

KUNRATH, T. R. *et al.* Management targets for continuously stocked mixed oat×annual ryegrass pasture in a no-till integrated crop-livestock system. **European Journal of Agronomy**, [*s. l.*], v. 57, p. 71–76, 2014. Disponível em: http://dx.doi.org/10.1016/j.eja.2013.09.013.

KUNRATH, T. R. *et al.* Sward height determines pasture production and animal performance in a long-term soybean-beef cattle integrated system. **Agricultural Systems**, [*s. l.*], v. 177, n. November 2019, p. 102716, 2020a. Disponível em: https://doi.org/10.1016/j.agsy.2019.102716.

LACA, E. A. Foraging in a heterogeneous environment. **Resource Ecology: Spatial and Temporal Dynamics of Foraging**, [*s. l.*], p. 81–100, 2008.

LEMAIRE, G. *et al.* Domestic Herbivores, the Crucial Trophic Level for Sustainable Agriculture: Avenues for Reconnecting Livestock to Cropping Systems. **Agronomy**, [*s. l.*], v. 13, n. 4, 2023.

LIEBIG, J. **Chemistry in its Application to Agriculture and Physiology**. [*S. l.: s. n.*], 1840. v. XXX

LIN, B. B. Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. **BIOSCIENCE**, GREAT CLARENDON ST, OXFORD OX2 6DP, ENGLAND, v. 61, n. 3, p. 183–193, 2011.

LUNARDI, R. *et al.* Rendimento de soja em sistema de integração lavoura-pecuária: Efeito de métodos e intensidades de pastejo. **Ciencia Rural**, [*s. l.*], v. 38, n. 3, p. 795–801, 2008.

MICHEZ, A. *et al.* Mapping and monitoring of biomass and grazing in pasture with an unmanned aerial system. **Remote Sensing**, [*s. l.*], v. 11, n. 5, p. 1–14, 2019.

MOLIN, J. P. **Agricultura de Precisão**. [*S. l.: s. n.*], 2013. *E-book*.

MOOJEN, F. G. **Estudo de longa guração em sistema integrado de produção**

**agropecuária: explorando relações planta-animal na fase pastagem**. 2017. [*s. l.*], 2017.

MOOJEN, F. G. *et al.* Farm advisors play a key role in integrating crop-livestock at the farm level: perceptions and experiences in Brazil and France. **Journal of Agricultural Education and Extension**, [*s. l.*], p. 1–25, 2023. Disponível em: https://doi.org/10.1080/1389224X.2023.2254308.

NUNES, P. A. de A. *et al.* Grazing intensity determines pasture spatial heterogeneity and productivity in an integrated crop-livestock system. **Grassland Science**, [*s. l.*], v. 65, n. 1, p. 49–59, 2019.

NUNES, P. A. de A. *et al.* Intense winter grazing impairs subsequent Italian ryegrass re-establishment in soybean-pasture rotations. **Grass and Forage Science**, [*s. l.*], v. 76, n. 2, p. 258–269, 2021.

NUNES, P. A. de A. *et al.* Livestock integration into soybean systems improves long-term system stability and profits without compromising crop yields. **Scientific Reports**, [*s. l.*], v. 11, n. 1, p. 1–15, 2021.

OLIVOTO, T.; LÚCIO, A. D. C. metan: An R package for multi-environment trial analysis. **Methods in Ecology and Evolution**, [*s. l.*], v. 11, n. 6, p. 783–789, 2020.

PAULA, C. C. L. *et al.* Estrutura do dossel, consumo e desempenho animal em pastos de capim-marandu sob lotação contínua X1  - Sward structure, herbage intake and animal performance on marandu palisadegrass pastures subjected to continuous stocking. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, [*s. l.*], v. 64, n. 1, p. 169–176, 2012.

PETTORELLI, N. *et al.* Using the satellite-derived NDVI to assess ecological responses to environmental change. **Trends in Ecology and Evolution**, [*s. l.*], v. 20, n. 9, p. 503–510, 2005.

ROCHA, M. G. da *et al.* Parâmetros produtivos de uma pastagem temperada submetida a alternativas de utilização. **Revista Brasileira de Zootecnia**, [*s. l.*], v. 33, n. 6, p. 1386–1395, 2004.

ROY, D. P. *et al.* A global analysis of the temporal availability of PlanetScope high spatial resolution multi-spectral imagery. **Remote Sensing of Environment**, [*s. l.*], v. 264, n. June, p. 112586, 2021. Disponível em: https://doi.org/10.1016/j.rse.2021.112586.

SAVIAN, J. V. *et al.* Rotatinuous stocking: A grazing management innovation that has high potential to mitigate methane emissions by sheep. **Journal of Cleaner Production**, [*s. l.*], v. 186, p. 602–608, 2018.

SCHELLBERG, J; VERBRUGGEN, E. Frontiers and perspectives on research strategies in grassland technology. **Crop and Pasture Science**, UNIPARK, BLDG 1, LEVEL 1, 195 WELLINGTON RD, LOCKED BAG 10, CLAYTON, VIC 3168, AUSTRALIA, v. 65, n. 6, p. 508, 2014.

SCHELLBERG, J.; VERBRUGGEN, E. Frontiers and perspectives on research strategies in grassland technology. **Crop and Pasture Science**, [*s. l.*], v. 65, n. 6, p. 508–523, 2014.

SCHUSTER, M. Z. *et al.* Grazing intensities affect weed seedling emergence and the seed bank in an integrated crop–livestock system. **Agriculture, Ecosystems and Environment**, [*s. l.*], v. 232, n. 2016, p. 232–239, 2016. Disponível em: http://dx.doi.org/10.1016/j.agee.2016.08.005.

SCHUSTER, M. Z. *et al.* Optimizing forage allowance for productivity and weed management in integrated crop-livestock systems. **Agronomy for Sustainable Development**, [*s. l.*], v. 39, n. 2, 2019.

SCHUSTER, M. Z. *et al.* Weed regulation by crop and grassland competition: critical biomass level and persistence rate. **European Journal of Agronomy**, Department of Crop Production and Protection, Federal University of Paraná, 1540 Rua dos Funcionários Road, Curitiba, PR 80035-060, Brazil, v. 113, 2020.

SILVEIRA, D. C. *et al.* Anatomical traits and structural components of peduncle associated with lodging in avena sativa l. **Agronomy Research**, [*s. l.*], v. 19, n. 1, p. 250–264, 2021.

SIMILI, F. F. *et al.* The economic value of sustainability of the integrated crop-livestock system in relation to conventional systems. **Revista Brasileira de Zootecnia**, [*s. l.*], v. 52, p. 1–14, 2023.

SPARROW, B. D. *et al.* Effective ecosystem monitoring requires a multi-scaled approach. **Biological Reviews**, [*s. l.*], v. 95, n. 6, p. 1706–1719, 2020.

STANLEY, P. L. *et al.* Ruminating on soil carbon : Applying current understanding to inform grazing management. [*s. l.*], n. February, p. 1–20, 2024.

SZYMCZAK, L. S. *et al.* System diversification and grazing management as resilience-enhancing agricultural practices: The case of crop-livestock integration. **Agricultural Systems**, [*s. l.*], v. 184, n. December 2019, p. 102904, 2020a. Disponível em: https://doi.org/10.1016/j.agsy.2020.102904.

TAN, C. W. *et al.* Quantitative monitoring of leaf area index in wheat of different plant types by integrating NDVI and Beer-Lambert law. **Scientific Reports**, [*s. l.*], v. 10, n. 1, p. 1–10, 2020.

TATTARIS, M.; REYNOLDS, M. P.; CHAPMAN, S. C. A direct comparison of remote sensing approaches for high-throughput phenotyping in plant breeding. **Frontiers in Plant Science**, [*s. l.*], v. 7, n. AUG2016, p. 1–9, 2016.

THORNLEY, R. H. *et al.* Prediction of Grassland Biodiversity Using Measures of Spectral Variance: A Meta-Analytical Review. **Remote Sensing**, [*s. l.*], v. 15, n. 3, 2023.

TILMAN, D. *et al.* Forecasting agriculturally driven global environmental change. **SCIENCE**, [*s. l.*], v. 292, n. 5515, p. 281–284, 2001.

TRENTIN, C. *et al.* Biomass production and wheat grain yield and its relationship with NDVI as a function of nitrogen availability. **Revista Brasileirade Ciencias Agrarias**, [*s. l.*], v. 16, n. 4, 2021.

VIAN, A. L. *et al.* Critical limits of ndvi for yield potential estimation in maize. [*s. l.*], n. April, 2018.

VIAN, A. L. *et al.* Nitrogen management in wheat based on the normalized difference vegetation index (NDVI). **Ciencia Rural**, [*s. l.*], v. 48, n. 9, 2018.

WESP, C. de L. *et al.* Steers production in integrated crop-livestock systems: Pasture management under different sward heights. **Revista Ciencia Agronomica**, [*s. l.*], v. 47, n. 1, p. 187–194, 2016.

# CAPÍTULO III

## CONSIDERAÇÕES FINAIS

O sensoriamento remoto baseado em satélites apresenta-se como uma importante ferramenta para o manejo de azevém em fase de pastagem de um Sistema Integrado de Produção Agropecuária, capaz de estimar massa de forragem ou altura de forma mais eficaz, a depender a intensidade de pastejo empregada. A intensidade moderada de pastejo obteve maior acurácia de estimativa por índices de vegetação para valores de massa de forragem. Intensidades moderada-leve e leve apresentaram resultados mais satisfatórios para estimativa de altura pelo uso da mesma ferramenta. Portanto, a intensidade de pastejo é primordial para considerar qual o melhor parâmetro a ser utilizado em cada situação. O uso de índices de vegetação deve considerar o ciclo da cultura, visto que ao final deste, com o florescimento e senescência do material vegetal, a acurácia é prejudicada. A heterogeneidade do pasto nas diferentes intensidades de pastejo durante o ciclo deve ser considerada em investigações posteriores para melhorar os modelos de estimativa de altura e massa de forragem via sensoriamento remoto baseado em satélite.

### Sugestões para pesquisas futuras

Ambientes pastoris são naturalmente heterogêneos, em razão da interferência animal, diferentemente de áreas de lavoura, que tendem a ser mais homogêneas devido ao seu crescimento livre. Além disso, diferentes intensidades de pastejo apresentam  distintos níveis de heterogeneidade de pasto, que variam em uma escala pequena. Afim de melhorar os modelos para estimar altura e massa de forragem via sensoriamento remoto baseado em satélites,é importante a obtenção de valores reais de altura de pasto georreferenciados em maior densidade ao longo do ciclo. Através desses valores, será possível comparar os valores estimados com valores reais medidos com maior detalhamento, melhorando os modelos estatísticos e aumentando a acurácia do uso dessa ferramenta. O aumento da eficiência do uso dessas ferramentas é capaz de facilitar a obtenção de dados e auxiliar na tomada de decisão em manejos de sistemas integrados. Isso se dá especialmente a nível de propriedade, já que o uso de imagens de satélite é uma alternativa prática para a obtenção de dados de áreas maiores, como fazendas de maior escala, por exemplo.

# REFERÊNCIAS

AGUINAGA, A. A. Q. *et al.* Componentes morfológicos e produção de forragem de pastagem de aveia e azevém manejada em diferentes alturas. **Revista Brasileira de Zootecnia**, Viçosa, MG, v. 37, p. 1523–1530, 2008.

ALTIERI, M. A. *et al.* Agroecology and the design of climate change-resilient farming systems. **Agronomy for Sustainable Development**, Paris, v. 35, n. 3, p. 869–890, 2015.

ANDRIAMANDROSO, A. L. H. *et al.* Differentiating pre- and post-grazing pasture heights using a 3D camera: a prospective approach. *In:* European Conference on Precision Livestock Farming, 8., 2017, Nantes. **Anais** […]. Nantes: [s.n.], 2017. p. 238–246.

ANGHINONI, I. *et al.* Abordagem sistêica do solo em Sistemas Integrados de Produção Agrícola e Pecuária no subtrópico brasileiro. **Tópicos em Ciência do Solo**, Viçosa, MG, v. 8, n. 2, p. 325-380, 2013.

ANGHINONI, I. *et al*. Ciclagem de nutrientes em integração lavoura-pecuária. **Synergismus scyentifica UTFPR**, Pato Branco, v. 6, n. 2, 2011.

ARNUTI, F. *et al.* Erratum to: Arnuti, f., et al. sheep dung composition and phosphorus and potassium release affected by grazing intensity and pasture development stage in an integrated crop-livestock system.. **Agronomy**, Basel, v. 11, n. 1, p. 1-14, 2021.

BAGGIO, C. *et al.* Padrões de deslocamento e captura de forragem por novilhos em pastagem de azevém-anual e aveia-preta manejada sob diferentes alturas em sistema de integração lavoura-pecuária. **Revista Brasileira de Zootecnia**, Viçosa, MG, v. 38, n. 2, p. 215-222, 2009.

BALBINO, L. C. *et al.* Sistemas de integração: o que são, suas vantagens e limitações. **Sistemas de integração lavoura pecuária floresta**. 2. ed. Brasília, DF: Embrapa, 2012. p. 12–18. Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/159845/1/Sistemas-de-integracao-o-que-sao-suas-vantagens-e-limitacoes.pdf. Acesso em: 10 dez. 2023.

BERNARDI, A. C. d. C. *et al.* Spatial variability of vegetation index and soil properties in an integrated crop-livestock system. **Revista Brasileira de Engenharia Agricola e Ambiental**, Campina Grande, v. 21, n. 8, p. 513–518, 2017.

BERTOL, F. D. Z. *et al.* Liming and grazing intensities effects on soil mineral nitrogen throughout the pasture cycle in a subtropical integrated crop-livestock system. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v. 46, n. 3, [art.] e0210042, 2022.

BONAUDO, T. *et al.* Agroecological principles for the redesign of integrated crop-livestock systems. **European Journal of Agronomy**, Amsterdam, v. 57, p.

43–51, 2014.

BREDEMEIER, C. *et al.* Estimativa do potencial produtivo em trigo utilizando sensor óptico ativo para adubação nitrogenada em taxa variável. **Ciência Rural**, Santa Maria, v. 43, n. 7, p. 1147–1154, 2013.

CANATA, T. F. *et al.* 3D Data Processing to Characterize the Spatial Variability of Sugarcane Fields. **Sugar Tech**, New Delhi, v. 24, n. 2, p. 419–429, 2022.

CARVALHO, P. C. de F. *et al.* Animal production and soil characteristics from integrated crop-livestock systems: toward sustainable intensification. **Journal of Animal Science**, Champaign, IL, v. 96, n. 8, p. 3513–3525, 2018.

CARVALHO, P. C. F. *et al.* Como a estrutura do pasto influencia o animal em pastejo? Exemplificando as interações planta-animal sob as bases e fundamentos do Pastoreio “Rotatínuo”. *In:* SIMPÓSIO SOBRE MANEJO ESTRATÉGICO DA PASTAGEM, 8., 2016, [S. l.]. **Anais** [...]. 2016. p. 21.

CARVALHO, P. C. de F. *et al.* Definitions and terminologies for Integrated Crop-Livestock System. **Revista Ciência Agronômica**, Fortaleza, v. 45, n. 5, p. 1040–1046, 2014.

CARVALHO, J. L. N. *et al.* Impact of pasture, agriculture and crop-livestock systems on soil C stocks in Brazil. **Soil and Tillage Research**, Amsterdam, v. 110, n. 1, p. 175–186, 2010.

CARVALHO, Paulo Cesar de Faccio *et al.* Reconnecting Grazing Livestock to Crop Landscapes: reversing specialization trends to restore landscape multifunctionality. **Frontiers in Sustainable Food Systems**, Lausanne, v. 5, [art.] 750765, 2021.

CHAUDHARY, A.; GUSTAFSON, D.; MATHYS, A. Multi-indicator sustainability assessment of global food systems. **Nature Communications**, London, v. 9, 2018.

CHEBLI, Y. *et al.* Estimation of Grazing Activity of Dairy Goats Using Accelerometers and Global Positioning System. **Sensors (Switzerland)**, Basel, v. 22, n. 15, 2022.

CONTE, O. *et al.* Evolução de atributos físicos de solo em sistema de integração lavoura-pecuária. **Pesquisa Agropecuaria Brasileira**, São Paulo, v. 46, n. 10, p. 1301–1309, 2011.

DEBAUCHE, O. *et al.* Data management and internet of things: A methodological review in smart farming. **Internet of Things (Netherlands)**, Amsterdam, v. 14, [art.] 100378, 2021. Disponível em: https://doi.org/10.1016/j.iot.2021.100378. Acesso em: 22 nov. 2023.

DURU, M. *et al.* How to implement biodiversity-based agriculture to enhance ecosystem services: a review. **Agronomy for Sustainable Development**, Paris, v. 35, n. 4, p. 1259–1281, 2015.

FAIR, K. R.; BAUCH, C. T.; ANAND, M. Dynamics of the global wheat trade network and resilience to shocks. **Scientific Reports**, Berlin, v. 7, n. 1, [art.] 7177, 2017.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS – FAO. **An international consultation on integrated crop-livestock systems for development**: the way forward for sustainable production intensification. Rome: FAO, 2010. (Integrated Crop Management, v. 13).

FLORES, J. P. C. *et al.* Atributos físicos do solo e rendimento de soja em sistema plantio direto em integração lavoura-pecuária com diferentes pressões de pastejo. **Revista Brasileira de Ciência do Solo**, Viçosa, MG, v. 31, n. 4, p. 771–780, 2007.

FOLEY, J. A. *et al.* Global consequences of land use. **Science**, Washington, DC, v. 309, n. 5734, p. 570–574, 2005.

FONSECA, L. *et al.* Effect of sward surface height and level of herbage depletion on bite features of cattle grazing Sorghum bicolor swards. **Journal of Animal Science**, Champaign, v. 91, n. 9, p. 4357–4365, 2013.

FONTANA, D. C. *et al.* NDVI and meteorological data as indicators of the pampa biome natural grasslands growth. **Bragantia**, Campinas, v. 77, n. 2, p. 404–414, 2018.

FRANZLUEBBERS, A. J.; MARTIN, G. Farming with forages can reconnect crop and livestock operations to enhance circularity and foster ecosystem services. **Grass and Forage Science**, Oxford, v. 77, n. 4, p. 270–281, 2022.

FRANZLUEBBERS, A. J.; SAWCHIK, J.; TABOADA, M. A. Agronomic and environmental impacts of pasture-crop rotations in temperate North and South America. **Agriculture, Ecosystems and Environment**, Amsterdam, v. 190, p. 18–26, 2014.

FRANZLUEBBERS, A. J.; SEMAN, D. H.; STUEDEMANN, J. A. Forage dynamics in mixed tall fescue-bermudagrass pastures of the Southern Piedmont USA. **Agriculture, Ecosystems and Environment**, Amsterdam, v. 168, p. 37–45, 2013.

FRANZLUEBBERS, A. J.; SULC, R. M.; RUSSELLE, M. P. Opportunities and challenges for integrating North-American crop and livestock systems. *In*: LEMAIRE, G.; HODGSON, J.; CHABBI, A. (org.). **Grassland productivity and ecosystem services**. Wallingford: CABI, 2011. p. 208–218.

GALLI, J. R.; CANGIANO, C. A.; FERNÁNDEZ, H. . Comportamiento Ingestivo Y Consumo De. **Revista Argentina de Producción Animal**, Buenos Aires, v. 16, n. 2, p. 1–10, 1996.

GORDON, I. J. *et al.* **Food Production and Nature Conservation**: conflicts and solutions. London: Routledge, 2017.

HENTZ, P. *et al.* Ciclagem De Nitrogênio Em Sistemas De Integração Lavoura-Pecuaria. **Ciência e Natura**, Santa Maria, v. 36, n. 2, p. 663–676, 2014.

HODGSON, J. Variations in the surface characteristics of the sward and the short-term rate of herbage intake by calves and lambs. **Grass and Forage Science**, Oxford, v. 36, n. 1, p. 49–57, 1981.

JAURENA, M. *et al.* Native Grasslands at the Core: A New Paradigm of Intensification for the Campos of Southern South America to Increase Economic and Environmental Sustainability. **Frontiers in Sustainable Food Systems**, Lausanne, v. 5, [art.] 547834, Mar. 2021.

JUNGES, A. H. *et al.* Temporal profiles of vegetation indices for characterizing grazing intensity on natural grasslands in Pampa biome. **Scientia Agricola**, Piracicaba, v. 73, n. 4, p. 332–337, 2016.

KREMEN, C.; MERENLENDER, A. M. Landscapes that work for biodiversity and people. **Science**, Washington, DC, v. 362, [art.] 6412, 2018.

KUNRATH, T. R. *et al.* Grazing management in an integrated crop-livestock system: soybean development and grain yield. **Revista Ciência Agronômica**, Fortaleza, v. 46, n. 3, p. 645–653, 2015.

KUNRATH, T. R. *et al.* Sward height determines pasture production and animal performance in a long-term soybean-beef cattle integrated system. **Agricultural Systems**, Barking, v. 177, [art.] 102716, Nov. 2020a.

LACA, E. A. Multi-Scape Interventions to Match Spatial Scales of Demand and Supply of Ecosystem Services. **Frontiers in Sustainable Food Systems**, Lausanne, v. 4, Jan., 2021.

LEBACQ, T.; BARET, P. V.; STILMANT, D. Role of input self-sufficiency in the economic and environmental sustainability of specialised dairy farms. **Animal**, London, v. 9, n. 3, p. 544–552, 2015.

LEMAIRE, G. *et al.* Domestic Herbivores, the Crucial Trophic Level for Sustainable Agriculture: Avenues for Reconnecting Livestock to Cropping Systems. **Agronomy**, Basel, v. 13, n. 4, 2023.

LIEBIG, J. **Chemistry in its Application to Agriculture and Physiology**. London: Taylor and Walton, 1840.

LIN, B. B. Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. **Bioscience**, Oxford, v. 61, n. 3, p. 183–193, 2011.

LUNARDI, R. *et al.* Rendimento de soja em sistema de integração lavoura-pecuária: Efeito de métodos e intensidades de pastejo. **Ciência Rural**, Santa Maria, v. 38, n. 3, p. 795–801, 2008.

MALDANER, L. F. *et al.* A statistical approach to static and dynamic tests for global navigation satellite systems receivers used in agricultural operations. **Scientia Agricola**, Piracicaba, v. 78, n. 5, p. 1–9, 2021.

MICHEZ, A. *et al.* Mapping and monitoring of biomass and grazing in pasture with an unmanned aerial system. **Remote Sensing**, Basel, v. 11, n. 5, p. 1–14, 2019.

MILLER, W.; SUPALLA, R. NF96-305 Precision Farming in Nebraska : a status report precision farming in nebraska: a status report. **NebFact**, Lincoln, p. 1–4, 1996.

MOLIN, J. P. **Agricultura de Precisão**. São Paulo: Oficina de Textos, 2013.

MOOJEN, F. G. **estudo de longa duração em sistema integrado de produção agropecuária**: explorando relações planta-animal na fase pastagem. Dissertação (Mestrado em Zootecnia) – Programa de Pós-Graduação em Zootecnia, Universidade Federal do Rio Grande Do Sul, Porto Alegre, 2017.

MORAES, A. *et al.* Integrated crop-livestock systems in the Brazilian subtropics. **European Journal of Agronomy**, Amsterdam, v. 57, p. 4–9, 2014.

NUNES, P. A. de A. *et al.* Grazing intensity determines pasture spatial heterogeneity and productivity in an integrated crop-livestock system. **Grassland Science**, Tochigi, v. 65, n. 1, p. 49–59, 2019.

NUNES, P. A. de Albuquerque *et al.* Intense winter grazing impairs subsequent Italian ryegrass re-establishment in soybean-pasture rotations. **Grass and Forage Science**, Oxford, v. 76, n. 2, p. 258–269, 2021a.

NUNES, P. A. de Albuquerque *et al.* Livestock integration into soybean systems improves long-term system stability and profits without compromising crop yields. **Scientific Reports**, London, v. 11, n. 1, p. 1–15, 2021b.

OLIVEIRA, C. A. O. *et al.* Comparison of an integrated crop–livestock system with soybean only: Economic and production responses in southern Brazil. **Renewable Agriculture and Food Systems**, Greenbelt, v. 29, n. 3, p. 230–238, 2014.

PAULA, C. C. L. *et al.* Estrutura do dossel, consumo e desempenho animal em pastos de capim-marandu sob lotação contínua X1 - Sward structure, herbage intake and animal performance on marandu palisadegrass pastures subjected to continuous stocking. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, Belo Horizonte, v. 64, n. 1, p. 169–176, 2012.

ROCHA, L. M. Da *et al.* Desempenho e características das carcaças de novilhos superprecoces em pastos hibernais submetidos a intensidades de pastejo. **Pesquisa Agropecuária Brasileira**, Brasília, DF, v. 46, n. 10, p. 1379–1384, 2011.

SAVIAN, J. V. *et al.* Rotatinuous stocking: A grazing management innovation that has high potential to mitigate methane emissions by sheep. **Journal of Cleaner Production**, Amsterdam, v. 186, p. 602–608, 2018.

SCHELLBERG, J.; VERBRUGGEN, E. Frontiers and perspectives on research strategies in grassland technology. **Crop and Pasture Science**, Collingwood, v. 65, n. 6, p. 508, 2014.

SCHUSTER, M. Z. *et al.* Grazing intensities affect weed seedling emergence and the seed bank in an integrated crop–livestock system. **Agriculture, Ecosystems and Environment**, Amsterdam, v. 232, p. 232–239, 2016.

SCHUSTER, M. Z. *et al.* Optimizing forage allowance for productivity and weed management in integrated crop-livestock systems. **Agronomy for Sustainable Development**, Paris, v. 39, n. 2, 2019.

SCHUSTER, M. Z. *et al.* Weed regulation by crop and grassland competition: critical biomass level and persistence rate. **European Journal of Agronomy**, Curitiba, v. 113, 2020.

SILVA, F. D. et al. Spatiotemporal distribution of cattle dung patches in a subtropical soybean-beef system under different grazing intensities in winter. **Agronomy**, Amsterdam, v. 10, n. 9, 2020.

SILVA, F. D. da *et al.* Pasture grazing intensity and presence or absence of cattle dung input and its relationships to soybean nutrition and yield in integrated crop-livestock systems under no-till. **European Journal of Agronomy**, Amsterdam, v. 57, n. SI, p. 84–91, 2014.

SOUZA FILHO, W. *et al.* Mitigation of enteric methane emissions through pasture management in integrated crop-livestock systems: Trade-offs between animal performance and environmental impacts. **Journal of Cleaner Production**, Amsterdam, v. 213, p. 968–975, 2019.

SPARROW, B. D. *et al.* Effective ecosystem monitoring requires a multi-scaled approach. **Biological Reviews**, London, v. 95, n. 6, p. 1706–1719, 2020.

STAVI, I.; BEL, G.; ZAADY, E. Soil functions and ecosystem services in conventional, conservation, and integrated agricultural systems. A review. **AGRONOMY FOR SUSTAINABLE DEVELOPMENT**, Paris, v. 36, n. 2, 2016.

SZYMCZAK, L. S. *et al.* System diversification and grazing management as resilience-enhancing agricultural practices: The case of crop-livestock integration. **Agricultural Systems**, Barking, v. 184, [art.] 102904, 2020a.

SZYMCZAK, L. S. *et al.* System diversification and grazing management as resilience-enhancing agricultural practices: The case of crop-livestock integration. **Agricultural systems**, Barking, v. 184, 2020b.

TAN, C. W. *et al.* Quantitative monitoring of leaf area index in wheat of different plant types by integrating NDVI and Beer-Lambert law. **Scientific Reports**, London, v. 10, n. 1, p. 1–10, 2020.

TILMAN, D. *et al.* Forecasting agriculturally driven global environmental change. **Science**, Washington, DC, v. 292, n. 5515, p. 281–284, 2001.

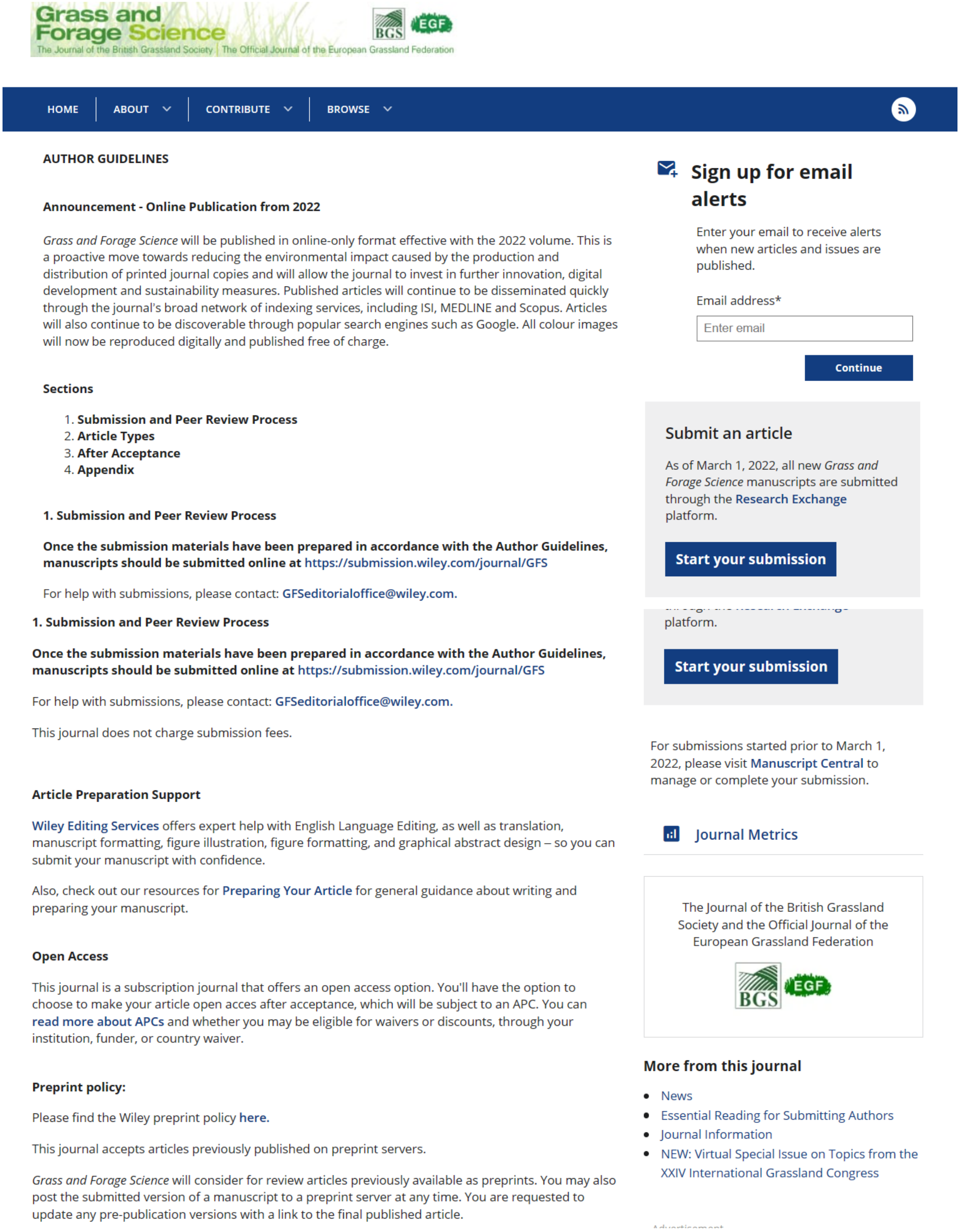
VIAN, A. L. *et al.* Critical limits of ndvi for yield potential estimation in maize. Revista Brasileira de milho e sorgo, Sete lagoas, MG, v. 17, n. 1, p. 91-100, 2018.

WESP, C. de L. *et al.* Steers production in integrated crop-livestock systems: pasture management under different sward heights. **Revista ciência agronômica**, Fortaleza, v. 47, n. 1, p. 187–194, 2016.

ZUBIETA, Á. S. *et al.* Does grazing management provide opportunities to mitigate methane emissions by ruminants in pastoral ecosystems?. **Science of the Total Environment**, Amsterdam, v. 754, p. 142029, 2021. Disponível em: https://doi.org/10.1016/j.scitotenv.2020.142029. Acesso em: 11 nov. 2023.

# APÊNDICES

## Apêndice 1. Normas para submissão de artigo científico para a Grass and Forage Science



**AUTHOR GUIDELINES**

**Announcement - Online Publication from 2022**

*Grass and Forage Science* will be published in online-only format effective with the 2022 volume. This is a proactive move towards reducing the environmental impact caused by the production and distribution of printed journal copies and will allow the journal to invest in further innovation, digital development and sustainability measures. Published articles will continue to be disseminated quickly through the journal's broad network of indexing services, including ISI, MEDLINE and Scopus. Articles will also continue to be discoverable through popular search engines such as Google. All colour images will now be reproduced digitally and published free of charge.

**Sections**

1. **Submission and Peer Review Process**
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**1. Submission and Peer Review Process**

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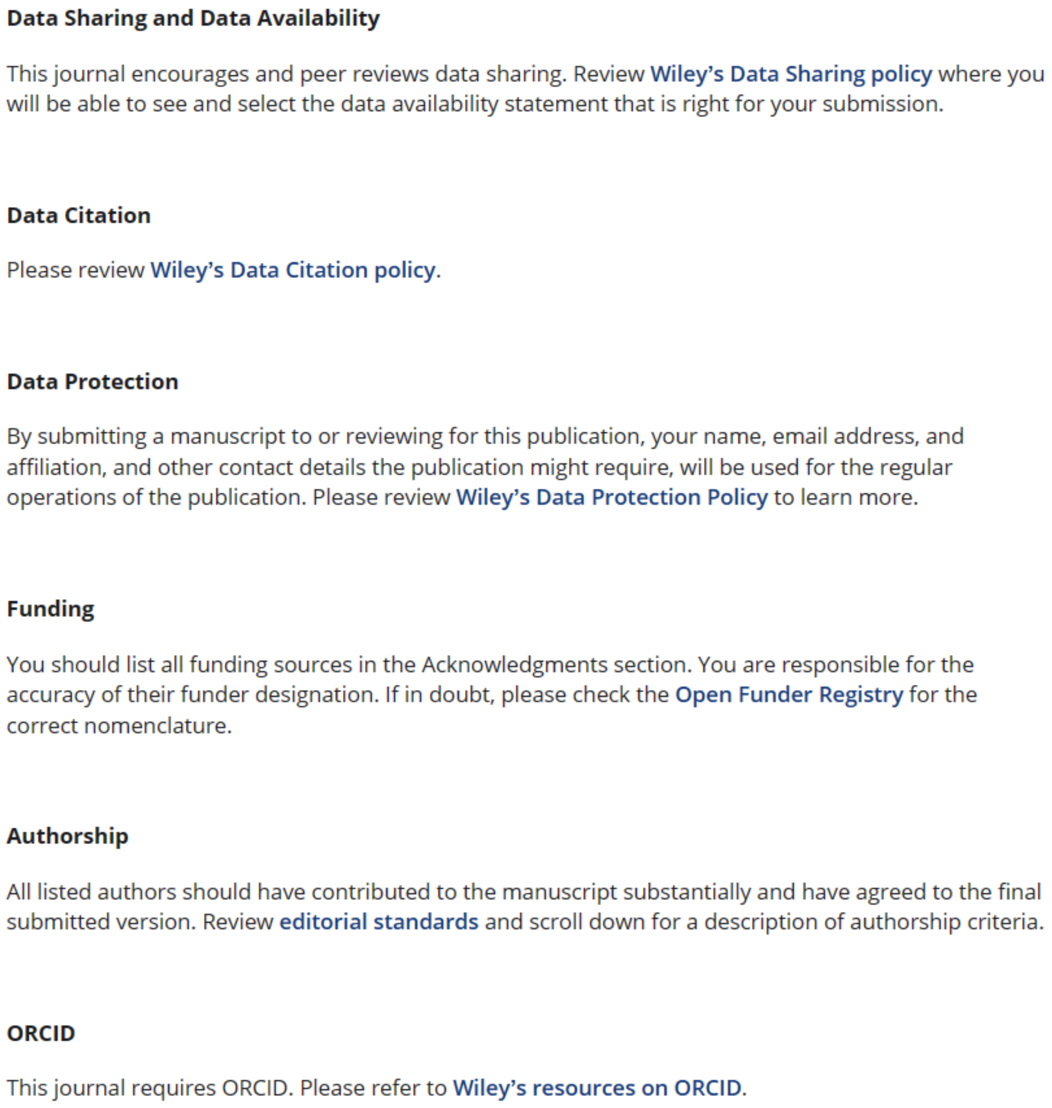

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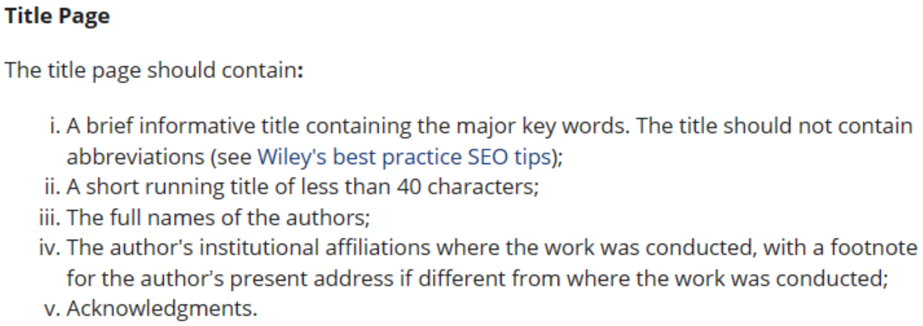

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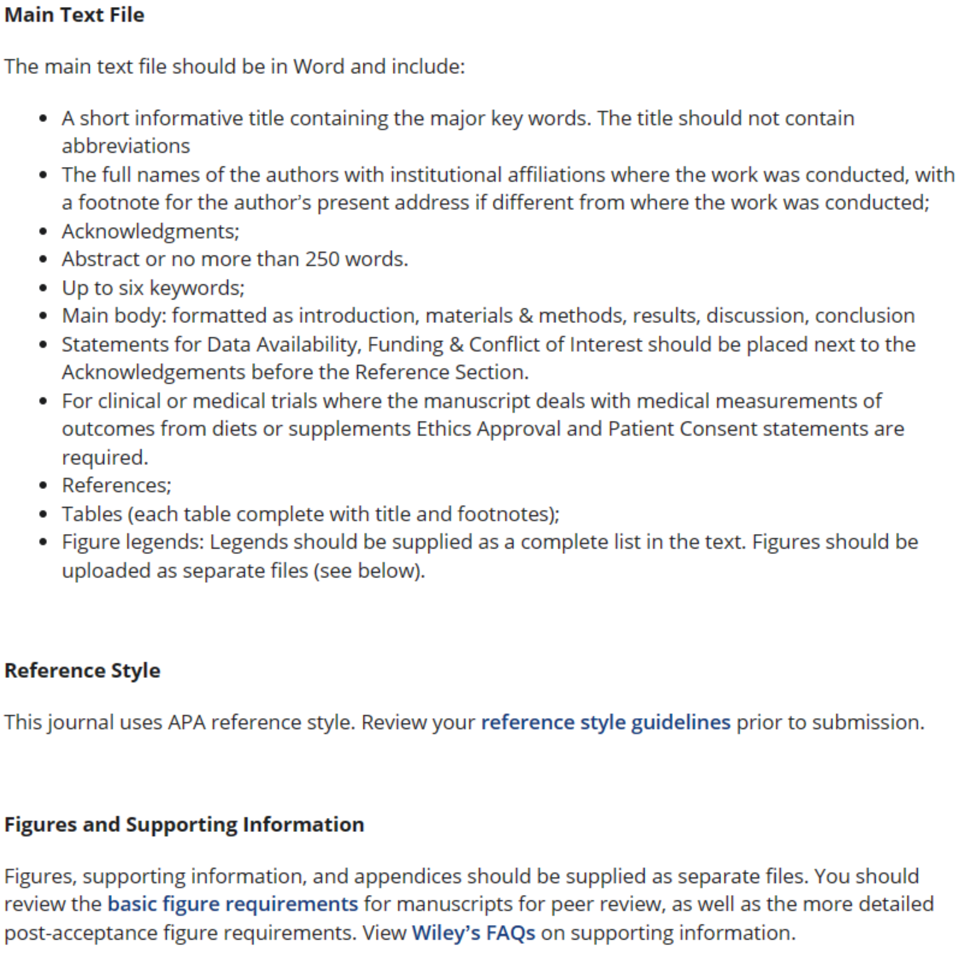

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- The full names of the authors with institutional affiliations where the work was conducted, with a footnote for the author's present address if different from where the work was conducted;
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- Abstract or no more than 250 words.
- Up to six keywords;
- Main body: formatted as introduction, materials & methods, results, discussion, conclusion
- Statements for Data Availability, Funding & Conflict of Interest should be placed next to the Acknowledgements before the Reference Section.
- For clinical or medical trials where the manuscript deals with medical measurements of outcomes from diets or supplements Ethics Approval and Patient Consent statements are required.
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- Tables (each table complete with title and footnotes);
- Figure legends: Legends should be supplied as a complete list in the text. Figures should be uploaded as separate files (see below).

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| **Article Type** | **Description** | **Word Limit** | **Abstract / Structure** | **Other Requirements** |
|---|---|---|---|---|
| **Book Reviews** | Commissioned by the Editor | 1000 limit | No | |
| **Editorial** | Commissioned by the editor | Brief article to introduce a volume, issue or special issue of 800 words including references. | No | |
| **Letter to the Editor** | Correspondence about articles published in GFS or topical themes. | 800 words, no more than 1 display item | | |

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| **Methods and Techniques Notes** | A methods and techniques note is a paper that describes a new method or technique or a significant improvement in a recognised method. The paper should state the importance of the methodology to grassland or forage science and the situations in which it can be applied. Authors must provide sufficient details of methods and results (including controls, accuracy, precision) to allow the method to be assessed and repeated. Where possible the results of the new method or technology should be compared to | Authors should make clear during submission whether the manuscript is to be considered for publication as a full paper, short communication, or methods and techniques note |  |  |

| | | | | |
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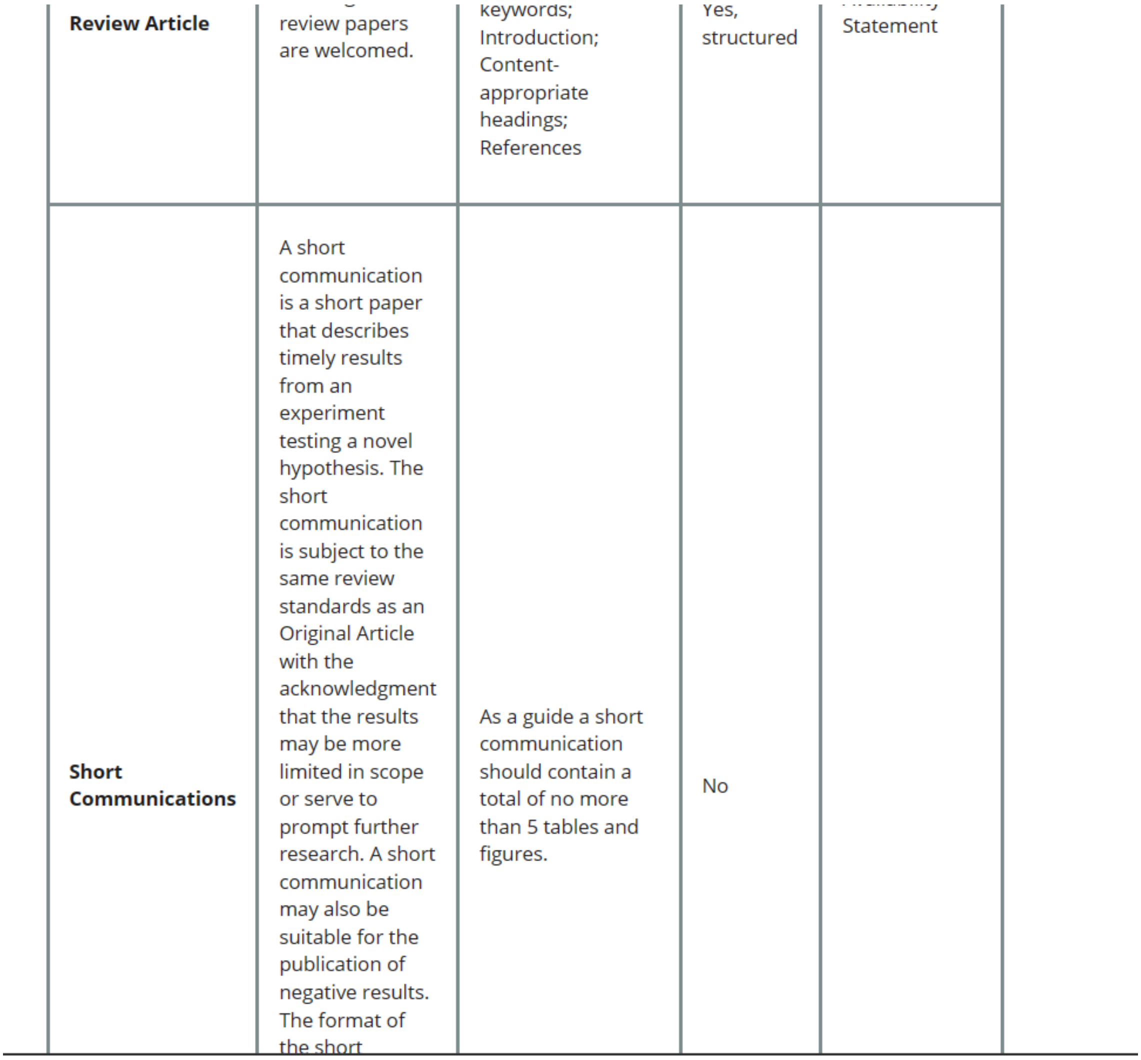
| | should be compared to existing methods. | | | |
| **Original Article** | A full-length research paper that describes novel research that is within the scope of Grass and Forage Science. | There is no word limit for Original Articles which should be using the following general structure:<br>Manuscript structure: Abstract (250 words maximum); Keywords; Introduction; Materials and Methods; Results; Discussion; Conclusion (if applicable)*; Acknowledgements (if applicable); References. | Yes, Structured | Data Availability Statement |
| **Review Article** | Full length review papers are welcomed. | Manuscript structure: Abstract (250 words maximum); keywords; Introduction; Content-appropriate | Yes, structured | Data Availability Statement |



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| **Review Article** | review papers are welcomed. | keywords;<br>Introduction;<br>Content-appropriate headings;<br>References | Yes, structured | Statement |
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| | | | | |
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| **Communications** | or serve to prompt further research. A short communication may also be suitable for the publication of negative results. The format of the short communication is the same as an original article without additional subheadings, while Results & Discussion should be combined. | total of no more than 5 tables and figures. | | |

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**To Obtain Research Resource Identifiers (RRIDs):**

1. Use the Resource Identification Portal, created by the Resource Identification Initiative Working Group.
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Model Organisms: "Experiments were conducted in c. elegans strain SP304 (RRID:CGC_SP304)"

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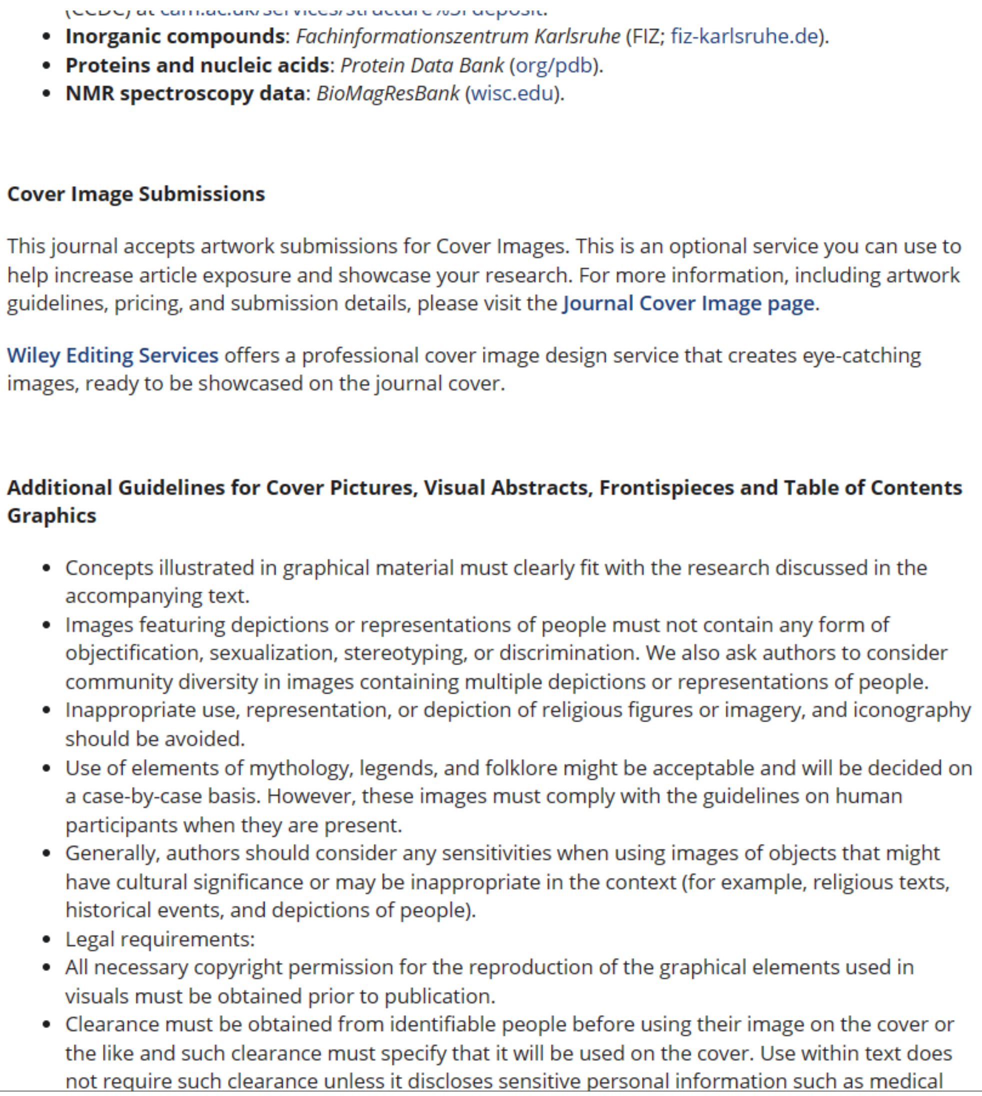

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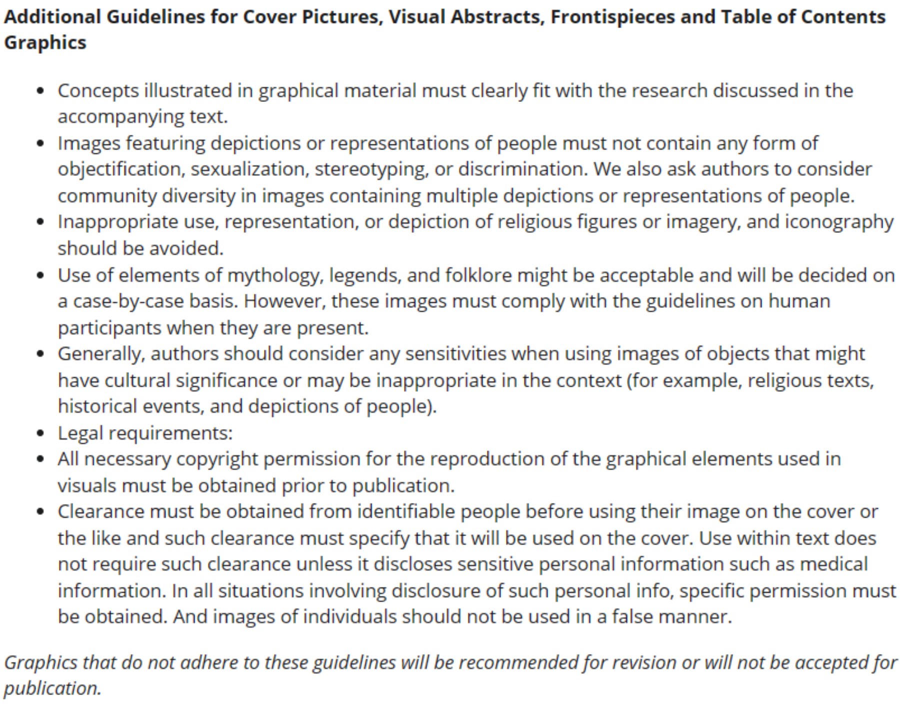

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*Graphics that do not adhere to these guidelines will be recommended for revision or will not be accepted for publication.*

# VITA

Carolina dos Santos Cargnelutti nasceu em 21 de junho de 1999, em São Borja, Rio Grande do Sul, Brasil, filha de Jairo Cargnelutti e Ione Teresinha dos Santos Cargnelutti. Teve seu primeiro contato com a agricultura desde muito nova, ao crescer na propriedade rural da família, com criação de gado de corte em um sistema baseado em pastagens, além da produção de soja. Frequentou o ensino fundamental e médio na cidade de Ijuí. Em 2017, Carolina iniciou a faculdade de Agronomia na Universidade Regional do Noroeste do Estado do Rio Grande do Sul (UNIJUI). Como estudante de pesquisa durante a graduação, Carolina passou quatro anos trabalhando com manejo de pastagens e melhoramento genético de plantas, sob a supervisão do Dr. Emerson André Pereira. Durante sua graduação, recebeu um prêmio do Programa Institucional de Bolsas de Iniciação Tecnológica e Inovação (PIBITI) da UNIJUÍ. Fez intercâmbio cultural em 2022 na International Language Academy of Canada (ILAC) em Toronto. Carolina completou seu estágio final na EMBRAPA Pecuária Sul – um centro de pesquisa brasileiro localizado em Bagé, Rio Grande do Sul. Carolina se formou como engenheira agrônoma em fevereiro de 2022. Em abril de 2022, Carolina ingressou no Grupo de Pesquisa em Ecologia do Pastejo (GPEP) para iniciar seu mestrado no Programa de Pós-Graduação em Zootecnia na UFRGS, sob a coordenação de Paulo César de Faccio Carvalho e coorientação de Christian Bredemeier. Em junho de 2022, ingressou na Aliança SIPA – uma iniciativa sem fins lucrativos para promover Sistemas Integrados de Produção Agropecuária. Em 20233, fez parte do comitê organizador de dois simpósios internacionais de destaque: XI Simpósio Internacional sobre Nutrição de Herbívoros em Florianópolis e IV Simpósio Internacional sobre Sistemas Integrados de Produção Agropecuária em Bento Gonçalves. Junto com seu mestrado, co-liderou um protocolo experimental de longo prazo em Sistemas Integrados de Produção Agropecuária, que foi tema de sua dissertação.