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Centro de Ciências Biológicas e da Saúde
Universidade Federal de Mato Grosso Do Sul

Ranchers' Intentions to Adopt Biodiversity Conservation Schemes in the Pantanal: Exploring the Role of Social Ecological and Behavioral Approaches

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Campo Grande
Fevereiro 2025

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Tese apresentada como requisito para a obtenção do título de **Doutor em Ecologia**, pelo Programa de Pós Graduação em Ecologia e Conservação, Universidade Federal de Mato Grosso do Sul.

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Dedico este trabalho à minha avó Dina, que sonhava em me ver doutor.

Agradecimentos

À Deus por ter me dado serenidade, coragem, sabedoria, me mantido cuidadoso. Agradeço a graça e pelas bençãos que recebi, muitas vezes sem pedir e pelos livramentos que passei durante todo esse tempo. E agradeço a Ele por Gênesis 12:1-4.

Ao meu mestre e orientador, Fabio de Oliveira Roque, sou profundamente grato por seu papel essencial em minha formação ao longo desses seis anos, desde o mestrado. Destaco sua valiosa contribuição na concepção e desenvolvimento do projeto que culminou nesta dissertação, oferecendo inúmeras sugestões. Agradeço também sua dedicação em me auxiliar, sua paciência ao revisar meus manuscritos e sua disponibilidade para esclarecer minhas muitas dúvidas. Ainda agradeço as suas valiosas lições também para me tornar um ótimo profissional e para a vida.

A meus pais, David e Sonia, por me incentivarem a continuar em frente no caminho da pesquisa cientifica. Em alguns momentos de cansaço físico e emocional, os dois estavam sempre ao meu lado para me orientar. Sempre me apoiaram para eu seguir meus sonhos. São pessoas em que me espelho a cada dia e espero ser a pessoa de quem eles se orgulham em dizer que eu já sou.

Agradeço também aos meus irmãos pelo companheirismo durante este tempo.

Agradeço a minha maravilhosa esposa Vanessa por estar comigo me apoiando e cuidando de mim até mesmo nas noites mal dormidas e paciência nos momentos que eu precisava me ausentar conduzindo meus trabalhos.

Aos meus tios, em especial a Dalete sempre incentivando os meus estudos e sempre me apoiar e tirar tempo para me ouvir e conversar. Aos meus tios que secretamente oravam por mim e torciam pelo meu sucesso, mesmo sem estarmos em contato frequente. Aos meus avôs que sempre oram e lembram de mim em seu devocional.

Ao Dr. Rafael Chiaravalloti pela coorientação e apoio à essa pesquisa e sempre procurando expandir o grupo de pesquisa para uma melhor formação.

Ao Dr. Pierre Cyril por todo o apoio que recebi durante o período de intercâmbio. Sua ajuda tornou a estadia muito mais fácil e prazerosa. Mesmo nas discussões sobre queijo, carne e viagens.

Ao Dr. Alan Covich pela disposição em sempre ajudar, ler e comentar nos trabalhos e sempre disposto a conversar sobre o futuro da pesquisa e política, me fazendo estudar mais sobre meu próprio país para poder enviar comentários mais embasados sobre meu próprio ponto de vista sobre meu país.

Ao grupo de pesquisa de Coexistência pela disposição para discussões sobre nossos trabalhos e apoio sempre que necessário.

Aos amigos que acompanham a minha trajetória a apoiaram, por vezes acreditando em mim mais do que eu mesmo, seja nos últimos anos ou aos de longa data.

Aos técnicos e professores do laboratório que auxiliaram no meu aprendizado tanto na teoria quanto na prática em aulas ou acompanhando em atividades de campo.

Ao Programa de Pós-Graduação em Ecologia e Conservação (PPGEC), pelo apoio no desenvolvimento deste trabalho.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES), pela bolsa concedida.

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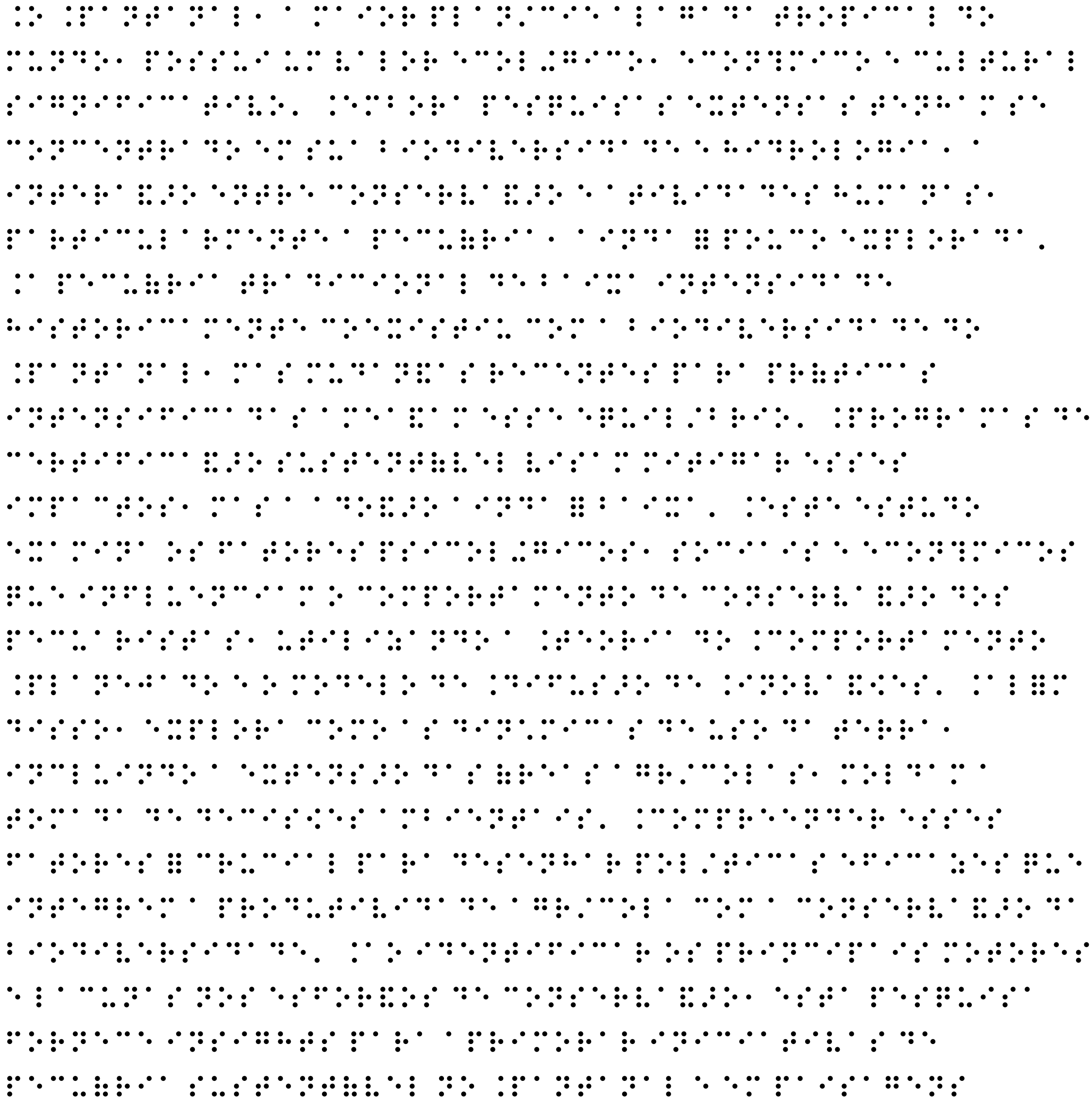
General abstract

The Pantanal, the world's largest tropical wetland, holds significant ecological, economic, and cultural value. While extensive research has focused on its biodiversity and hydrology, the interaction between conservation and human activities, particularly cattle ranching, remains underexplored. Traditional low-intensity ranching has historically coexisted with the Pantanal’s biodiversity, but recent shifts toward intensified practices threaten this balance. Sustainable certification programs aim to mitigate these impacts, yet adoption remains low. This study examines the psychological, social, and economic drivers influencing ranchers' conservation behavior using the Theory of Planned Behavior and the Diffusion of Innovation framework. Additionally, it explores how land use dynamics, including the extent of agricultural farmland, shape environmental decision-making. Understanding these factors is crucial for designing effective policies that integrate agricultural productivity with biodiversity conservation. By identifying key drivers and gaps in conservation efforts, this research provides insights to enhance sustainable ranching initiatives in the Pantanal and similar biodiversity-rich agricultural landscapes globally.

Resumo geral

O Pantanal, a maior planície alagada tropical do mundo, possui um valor ecológico, econômico e cultural significativo. Embora pesquisas extensas tenham se concentrado em sua biodiversidade e hidrologia, a interação entre conservação e atividades humanas, particularmente a pecuária, ainda é pouco explorada. A pecuária tradicional de baixa intensidade historicamente coexistiu com a biodiversidade do Pantanal, mas mudanças recentes para práticas intensificadas ameaçam esse equilíbrio. Programas de certificação sustentável visam mitigar esses impactos, mas a adoção ainda é baixa. Este estudo examina os fatores psicológicos, sociais e econômicos que influenciam o comportamento de conservação dos pecuaristas, utilizando a Teoria do Comportamento Planejado e o modelo de Difusão de Inovações. Além disso, explora como as dinâmicas de uso da terra, incluindo a extensão das áreas agrícolas, moldam a tomada de decisões ambientais. Compreender esses fatores é crucial para desenhar políticas eficazes que integrem a produtividade agrícola com a conservação da biodiversidade. Ao identificar os principais motores e lacunas nos esforços de conservação, esta pesquisa fornece insights para aprimorar iniciativas de pecuária sustentável no Pantanal e em paisagens agrícolas semelhantes, ricas em biodiversidade, globalmente.

Resumo em Braille



Resumo popular

O Pantanal é a maior área alagada tropical do mundo e tem uma importância enorme para a natureza, a economia e a cultura. Muita gente já estudou sua biodiversidade e seus rios, mas ainda sabemos pouco sobre como a pecuária e a conservação do meio ambiente se relacionam. A criação de gado tradicional sempre fez parte do Pantanal sem prejudicar a natureza, mas, nos últimos anos, práticas mais intensivas têm colocado esse equilíbrio em risco. Existem programas de certificação sustentável para minimizar esses impactos, mas poucos pecuaristas aderem a eles. Este estudo investiga o que leva os pecuaristas a adotarem (ou não) práticas sustentáveis, considerando fatores psicológicos, sociais e econômicos. Além disso, analisa como o uso da terra – como a expansão da agricultura – influencia as decisões ambientais dessas pessoas. Entender esses fatores é essencial para criar políticas que conciliem a produção agropecuária com a conservação da biodiversidade. No fim das contas, essa pesquisa busca contribuir para tornar a pecuária no Pantanal mais sustentável e ajudar a proteger outras áreas ricas em biodiversidade ao redor do mundo.

Resumo em vídeo

Figura 1. Ao escanear o “QR code” você será redirecionado para você será direcionado para o um vídeo no YouTube com um breve resumo falado sobre este trabalho. Alternativamente pode seguir este link: https://youtu.be/ij50oTgslZo .

General introduction

The Pantanal, the largest tropical wetland on Earth, is a region of immense ecological, economic and cultural significance (Junk & de Cunha 2005, Schulz et al. 2019, Thomas et al. 2019). While extensive research has explored its biodiversity, hydrology, and ecological dynamics, the interplay between environmental conservation and human activities, particularly cattle ranching, remains a critical area of study (Pereira et al. 2024). Historically, scientific investigations have primarily focused on ecological assessments, with limited emphasis on integrating social with the environmental and sustainable production dimensions (Folke et al. 2016, Rockström et al. 2023). However, the increasing environmental pressures on the Pantanal, driven by shifting land use practices, infrastructure development, and climate change, highlight the urgent need for interdisciplinary research approaches.

Cattle ranching is one of the dominant land uses in the Pantanal, occupying over 90% of the region and supporting approximately 3.8 million heads of cattle (Oliveira et al. 2016). Traditional, low-intensity cattle ranching (Ítavo et al. 2008) has historically coexisted with the Pantanal's biodiversity, allowing for the maintenance of large tracts of native vegetation and healthy populations of iconic species such as jaguars, giant otters, and hyacinth macaws (Alho 2005, Wantzen et al. 2006, Jaeger 2018). However, recent shifts towards intensified ranching practices, including the replacement of native grasslands with exotic species to increase cattle density, are threatening this balance (Tortato et al. 2022, Wantzen et al. 2024) aligned with construction of infrastructures that can alter the Pantanal's dynamics (Ely et al. 2020, Wantzen et al. 2024). While sustainable certification programs such as Boi Orgânico and Fazenda Pantaneira Sustentável have emerged to promote environmentally responsible ranching play crucial role in mitigating of environmental and social impacts of agricultural practices, adoption rates remain low, necessitating a deeper understanding of the factors influencing ranchers' willingness to engage in conservation efforts.

The decision-making processes behind ranchers' adoption of sustainable practices are complex and influenced by multiple psychological, economic, and social factors (Obrecht et al. 2019, Curry et al. 2009). The Theory of Planned Behavior (TPB) and the Diffusion of Innovation (DOI) framework offer valuable insights into how individual attitudes, perceived social pressures, and behavioral control impact the likelihood of adopting conservation initiatives (Ajzen 1991, Ajzen 2011). Additionally, land use dynamics play a significant role in shaping conservation behavior, with factors such as the extent of agricultural farmland on a property influencing a rancher's willingness to engage in environmental stewardship (Lesch & Wachenheim 2014). Economic considerations, personal values, and external market forces further contribute to these decisions, underscoring the need for targeted policy interventions and incentive structures to encourage sustainable practices. It is crucial to determine whether the areas experiencing the most significant landscape transformations are also home to populations that are most adaptable, especially in terms of their ability to modify their behavior to tailor initiatives to such areas (Cimellaro et al. 2016).

Identifying the gaps and trends in the scientific production, understanding the drivers of conservation behavior, and identifying key areas of action among ranchers in the Pantanal is crucial for designing effective policies and programs that balance agricultural productivity with biodiversity conservation. By examining the psychological and social determinants of

sustainable ranching adoption, as well as the broader land use dynamics at play, this study aims to provide actionable insights that inform conservation strategies and enhance the effectiveness of existing certification initiatives. As global pressures on food security and environmental sustainability intensify, reconciling these competing demands within the Pantanal offers valuable lessons for other biodiversity-rich, agricultural landscapes worldwide.

Chapter 1 - Emerging Trends in Socio-Ecological Studies on the Pantanal Wetland Revealed Through Bibliometric Networks

Abstract

The Pantanal, the world's largest tropical wetland, is a unique ecological and cultural region facing increasing environmental pressures. Understanding its future requires an integrated approach that bridges social and ecological systems. While research on the Pantanal has expanded, knowledge gaps persist, particularly regarding human-environment interactions. Traditional disciplinary boundaries have historically limited synthesis efforts, focusing on hydrology, climate, species inventories, and ethnozoology. However, recent studies emphasize the need for interdisciplinary approaches that incorporate diverse knowledge systems, including traditional and indigenous perspectives, to address pressing socio-ecological challenges. This study employs a bibliometric analysis to assess research trends in the Pantanal, identifying key intersections between social and environmental sciences. We examine international co-publication patterns and the integration of ecological research with other disciplines, providing insights into the evolution of research and policy implications. Our results reveal a growing shift from single-discipline studies toward interdisciplinary approaches, alongside increased international collaboration, particularly from Germany, the U.S., and Latin America. Despite this progress, research on climate scenarios, decision-making, and socio-ecological dynamics remains limited. Aligned with global agendas (IPBES, CDB, IPCC, RAMSAR, UNEP), research in the Pantanal increasingly emphasizes systemic and integrative perspectives. Expanding initiatives such as Pontes Pantaneiras and Nooledi to foster co-constructed knowledge and interdisciplinary collaborations will be crucial for sustainable development. Addressing research gaps through integrative agendas, increased funding, and stronger science-policy interfaces can enhance conservation strategies and ensure the long-term resilience of this vital wetland.

Resumo

O Pantanal, a maior planície alagável tropical do mundo, é uma região ecológica e cultural única que enfrenta crescentes pressões ambientais. Compreender seu futuro exige uma abordagem integrada que conecte os sistemas sociais e ecológicos. Embora a pesquisa sobre o Pantanal tenha se expandido, ainda existem lacunas significativas, especialmente em relação às interações entre humanos e o meio ambiente. Esforços de síntese tradicionais foram historicamente limitados a disciplinas específicas, concentrando-se em hidrologia, clima, inventários de espécies e etnozoologia. No entanto, estudos recentes destacam a necessidade de abordagens interdisciplinares que incorporem diversos sistemas de conhecimento, incluindo saberes tradicionais e indígenas, para enfrentar desafios socioecológicos urgentes. Este estudo utiliza uma análise bibliométrica para avaliar tendências de pesquisa no Pantanal, identificando interseções-chave entre as ciências sociais e ambientais. Examinamos padrões de coautoria internacional e a integração da pesquisa ecológica com outras disciplinas, fornecendo insights sobre a evolução dos estudos e suas implicações para políticas públicas. Nossos resultados indicam uma transição crescente de estudos disciplinares para abordagens interdisciplinares, além do aumento da colaboração internacional, especialmente da Alemanha, dos EUA e da América Latina. Apesar desse avanço, ainda há poucos estudos sobre cenários climáticos, tomada de decisão e dinâmicas socioecológicas. Alinhada a agendas globais (IPBES, CDB, IPCC, RAMSAR, UNEP), a pesquisa no Pantanal vem enfatizando perspectivas sistêmicas e integrativas. A ampliação de iniciativas como Pontes Pantaneiras e Nooledi, promovendo a co-construção do conhecimento e colaborações interdisciplinares, será essencial para o desenvolvimento sustentável. O enfrentamento das lacunas de pesquisa por meio de agendas integrativas, maior financiamento e fortalecimento das interfaces ciência-política pode aprimorar estratégias de conservação e garantir a resiliência de longo prazo desse importante bioma.

Introdução

The Pantanal, the largest continuous tropical wetland on the planet, is characterized by its complex hydrology and diverse ecosystems and it is a distinctive ecological and cultural region experiencing growing environmental pressures (Junk & de Cunha 2005, Schulz et al. 2019, Thomas et al. 2019). Understanding the trends and future changes in this region requires examining the nexus between social and ecological systems. Research in this area is expanding at the crossroads of social and environmental sciences, emphasizing the importance of integrated strategies to tackle intricate environmental and social issues (Folke et al. 2016, Rockström et al. 2023). There is a growing emphasis on incorporating perspectives from various cosmologies, including traditional, indigenous and local knowledge, to enhance environmental management and address the challenges confronting the Pantanal (Schulz et al. 2019). However, there is a need to clarify and map these emerging research trends to develop targeted, context-specific approaches that effectively address the unique socio-ecological challenges of the Pantanal.

Despite significant advancements in research on the Pantanal over the past three decades (see Junk Schulz et al. 2019, Tomas et al. 2019, Wantzen 2024), critical knowledge gaps persist, particularly regarding the interactions between human communities and the natural environment (Pereira et al. 2024). Historically, synthesis efforts on the Pantanal have been confined to traditional disciplinary boundaries, focusing on areas such as species inventories, hydrology, climate, and ethnozoology (e.g. Alho & Sabino 2011, Junk et al. 2011, Lima et al. 2019, Severo-Neto et al. 2023, Marques et al. 2025). Additionally, books have compiled knowledge on various dimensions of the Pantanal, particularly the role of flood pulses and fluvial dynamics in shaping both cultural and ecological systems (Wantzen 2024). More recent syntheses have expanded to topics such as offsetting, research agendas, and the effects of fire (e.g. Thomas et al. 2019, Pereira et al. 2024). However, scientific production trends on the Pantanal have yet to be analyzed through a scientometric approach, which could offer valuable insights into research gaps and emerging directions. Addressing these gaps requires a comprehensive understanding of research networks, emerging trends, and the role of local organizations (Schulz et al. 2019, Wantzen 2024), which can be effectively explored through bibliometric analyses. Additionally, strengthening collaborations between scientists, policymakers, and traditional knowledge holders is essential for developing more effective conservation strategies and fostering sustainable development initiatives tailored to the unique socio-ecological dynamics of the Pantanal.

Through a bibliometric analysis, our study aims to identify patterns and intersections between social and environmental sciences in the Pantanal. We assess the integration of ecological research with other disciplines and examine international co-publication trends to provide insights that will help shape future research and inform policies supporting the long-term sustainability of this vital ecosystem. By investigating these tendencies, we aim to provide a clearer picture of how research on the Pantanal is evolving and highlight key collaborations that may catalyze future studies on its socio-ecological dynamics.

Methods

Pantanal

The Pantanal, situated in the heart of South America—primarily in Brazil—is the world's largest and

most well-preserved wetland, spanning 17,930 km² and retaining 80% of its original vegetation (Junk et al. 2006). Human presence in the Pantanal spans roughly 5,000 years, starting with Tupi-Guarani tribes who established themselves in the region. Despite this extensive history of habitation, the current population remains sparse, concentrated mainly in small towns along the Pantanal's borders, near the major rivers, and within the scattered ranches throughout the basin (Junk et al. 2005). The origin of these ranches dates back to European colonization and the introduction of cattle in 1737 (Girard et al. 2012). For centuries, cattle ranching has been the dominant economic activity in the area (Junk et al. 2005). However, the region has recently faced increasing threats from infrastructure expansion, intensified cattle ranching, and severe wildfires, with the 2020 fires alone estimated to have destroyed 30% of the entire biome (Tomas et al. 2019, LASA 2020).

Bibliometric search and analysis

In this study, we conducted a standardized search in the Web of Science Core Collection for indexed papers in two steps to capture the available literature and both for the period between 1945 (initial mark of the database) and December 2024 since it was accessed in January 2025. First, we searched for general studies on the Pantanal using the keyword “Pantanal”. In the second step, we refined the search to focus on studies at the intersection of the Pantanal and social sciences, using the keywords: Pantanal AND (Ethnoecology OR "Social system*" OR "Ecological system*" OR Conservation OR Anthropology OR "Ecological economy" OR "ecosystem service*" OR ethnozoology OR Ethnobotany OR "socio-environmental"). We then used the VOSviewer 1.6.9 software to analyze the main research topics (hereafter referred to as terms) based on keyword co-occurrence patterns (van Eck & Waltman 2010) for both steps. We only considered the 60% more relevant terms that repeated at least ten times across the papers to avoid too broad of terms (such as study and analysis).

Results

For the first step, using the keyword “Pantanal” we obtained 3510 articles, published between 1957 and 2025 (papers scheduled to be published in a future issue do appear in the online form with a future date of publication) with a start of increase in publication numbers occurring in the early 1990s. Meanwhile, there were 850 papers focused on social and socio-ecological focused studies that only started getting momentum in the late 2000s (Figure 1).

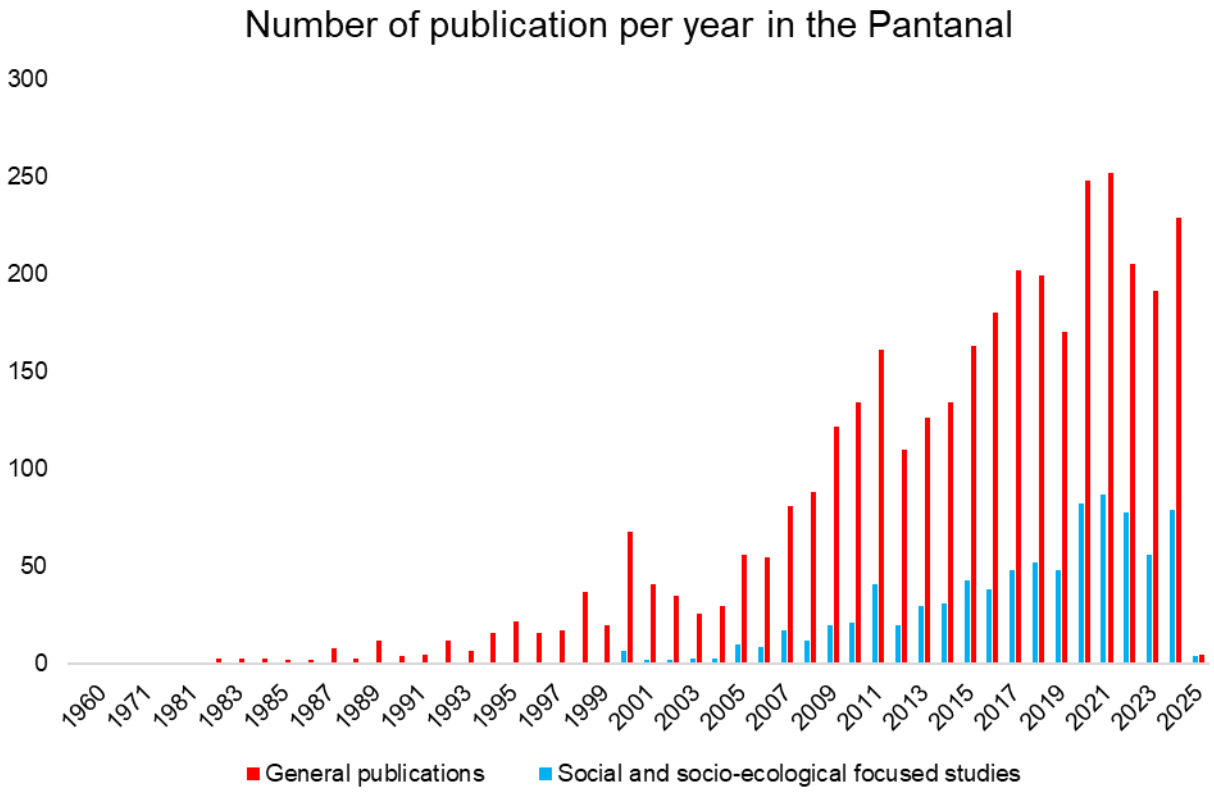


Figure 1. Research on the Pantanal. a) interviewing fisherman regarding the effects of fires through their perspectives; b) interviewing ranchers in the Pantanal regarding their intention to adopt conservation schemes in their properties; c) number of general publications and regarding social and socio-ecological focused studies per year on the Pantanal.

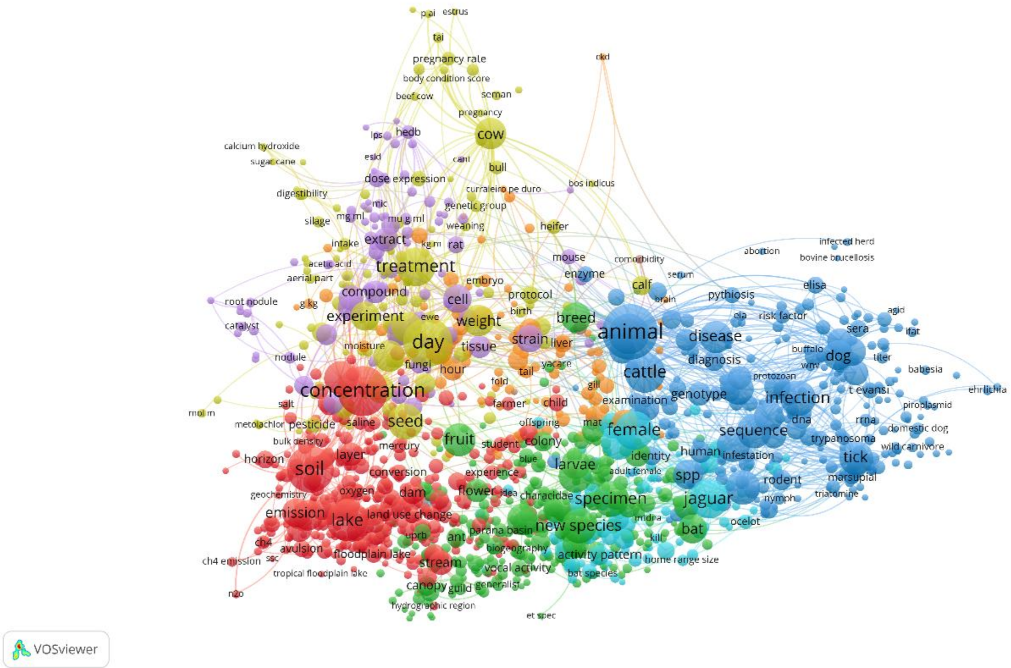
In this first set, there were 1,465 terms that met our criteria. The most recurrent terms were “Animal”, “Concentration”, “Day”, “Soil”, and “Lake” (which were used 653, 529, 524, 462, and 370 times across all articles respectively) (Figure 2a). It was organized in 8 clusters: Yellow, that was mostly related to cattle raising; Orange, mostly related to cattle physical measurements; Purple, mostly related to animal microbiology; Red, mostly related to environmental characteristics; Green, mostly related to phylogeny studies; Light-blue, mostly related to species occurrences; and Dark-blue, mostly related to animal health.

The studies over time shows an increase from terms that were more focal studies, such as species natural history to more broad and integrated studies such as emissions, resolutions, and especially in more recent years, terms such as “Fires” and “Wildfires” also started appearing in face of recent events of historical fires in the Pantanal (Figure 2b).

As for the second set of articles, social and socio-ecological focused studies, they were obtained using the keyword combination: Pantanal AND (Ethnoecology OR "Social system*" OR "Ecological system*" OR Conservation OR Anthropology OR "Ecological economy" OR "ecosystem service*" OR ethnozoology OR Ethnobotany OR "socio-environmental"). For this second set, where we focused more on social studies in the Pantanal, there were 428 terms that met our criteria. The most recurrent terms were “Population”, “Jaguar”, “Mato Grosso”, “Richness”, and “Basin” (that repeated 367, 233, 207, 204, and 154 times across the articles from this set) and were divides into 7 clusters: Red, mostly related to biomes and their use; Green, mostly related to ecology; Yellow, mostly related to genetics; Light-blue, mostly related to human-wildlife conflict and predator-prey dynamic; Dark-blue, mostly focused on animal behavior, habitat use, and ecological factors; Purple, mostly related to habitat use and population dynamics in wildlife ecology; and Orange, which is mostly terms that do not really fit into one cluster but is rather in between more than one (Figure 2c).

The second set of terms too show the same pattern of change in topics from more focused studies (terms such as “jaguar”, “caiman”, and “kill”) to broader studies (such as “scenario”, “beta diversity”, and land use change”), however, the social studies appear more in later studies, indicating that the social aspects of these studies are only in recent years been more applied and indicating a new concern on this topic in the Pantanal (Figure 2d).

a)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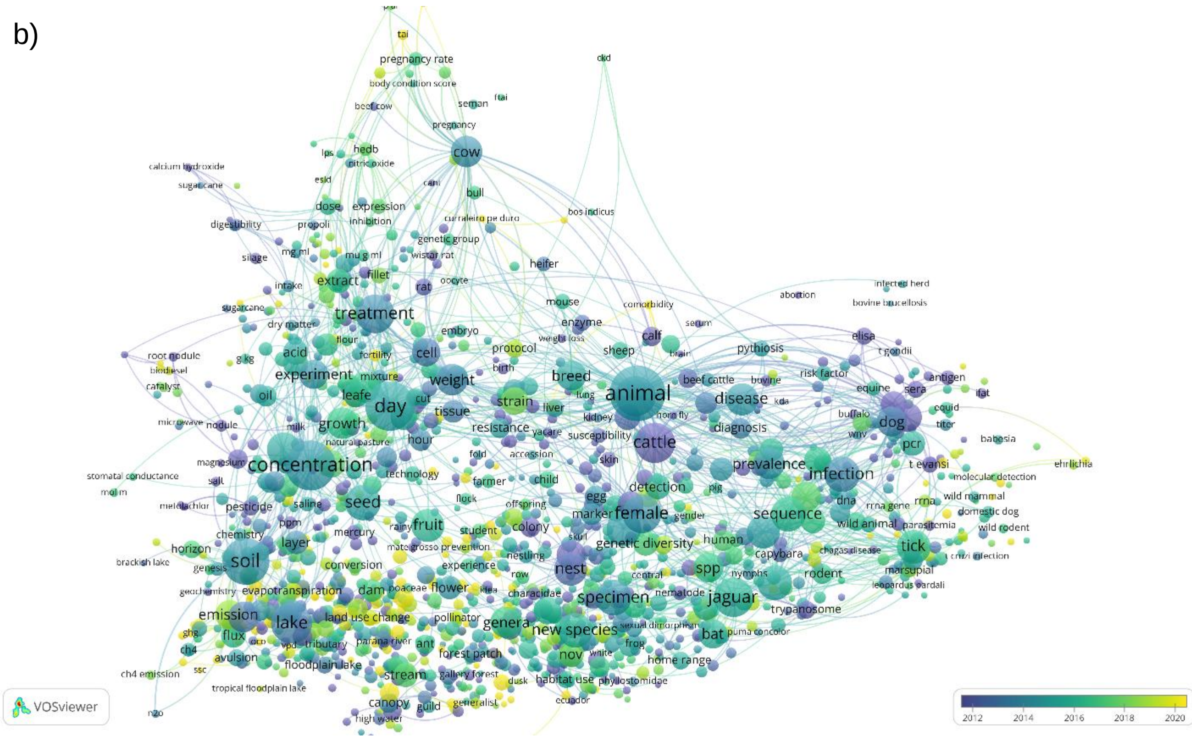
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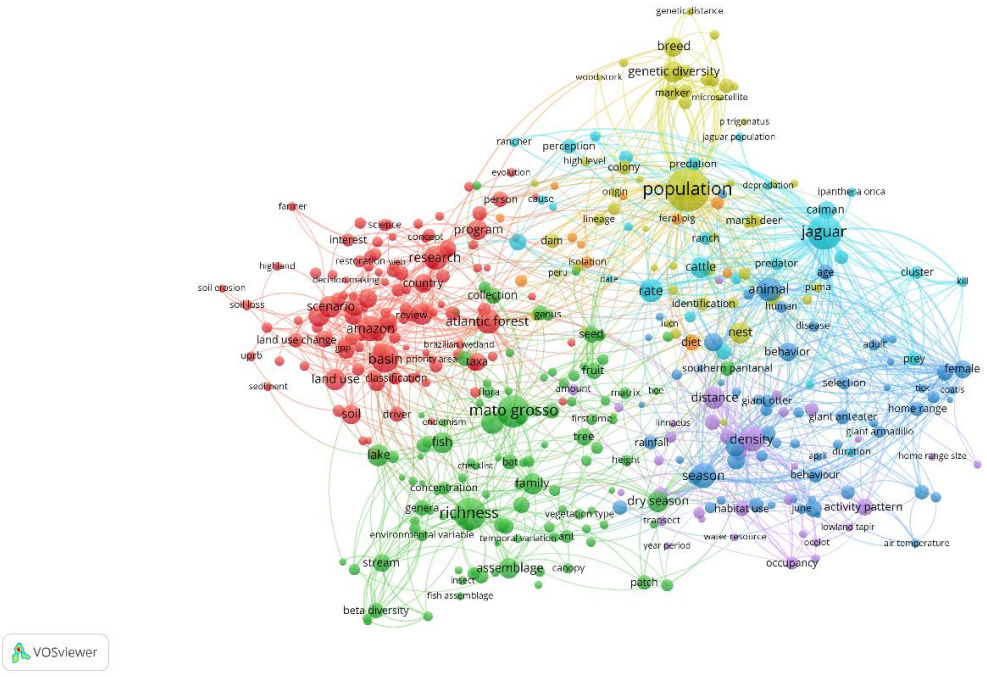
c)



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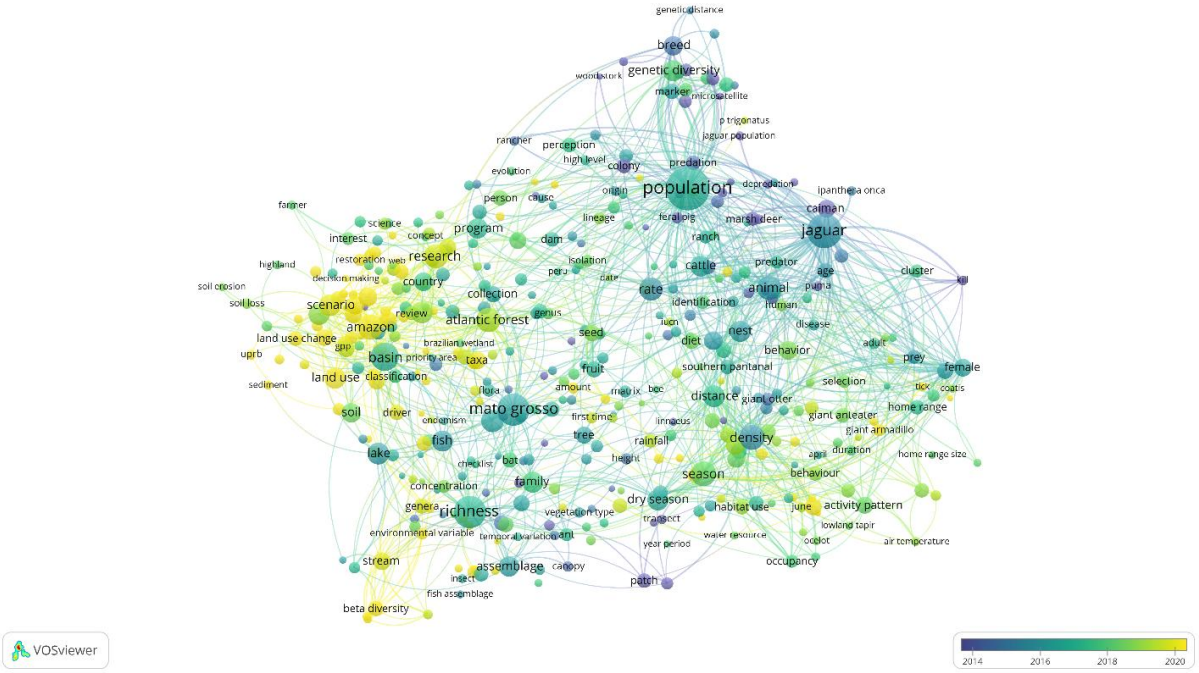


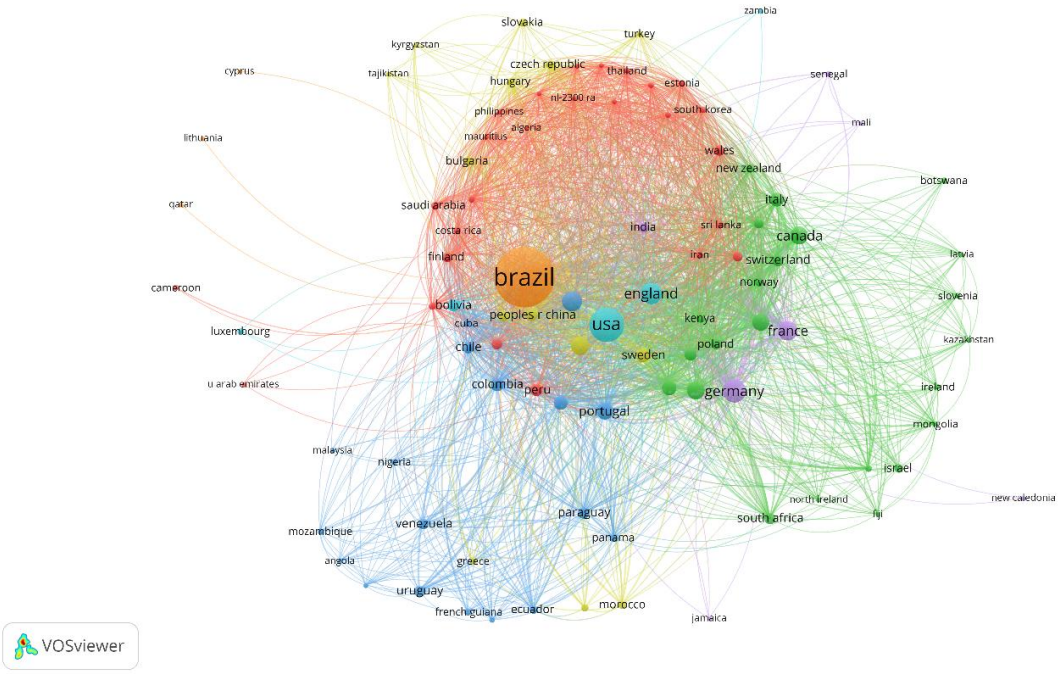
Figure 2. Term maps. a) it represents the cluster map for the studies on the Pantanal as a whole; b) it represents the term map over time for the Pantanal as a whole; c) represents the cluster map for studies in the Pantanal that is in the interface Ecology/Social Studies; and d) represent the term map over time for the interface Ecology/Social Studies. The circles represent each recurrent term across the papers and it's size the relative occurrence. The lines represent a co-occurrence of two terms in papers and the thickness the relative amount they co-occurred. The colors of the circles in "a" and "c" represent clusters that shows a higher tendency of these

terms to occur together in papers and the colors of the circles in “b” and “d” represent the period when the term was most used according to the label. The images are showing only the 1000 most relevant links.

A total of 97 countries were affiliated with the published articles in the first step, representing a global distribution. However, a pattern emerged in which publications tended to cluster among specific regional groups, including collaborations between countries in Eastern Europe and North Africa (such as Morocco, Russia, Turkey), Western European nations (such as France, Germany, Netherlands), and Latin American countries (such as Mexico, Cuba, Uruguay). Additionally, some country combinations formed clusters that functioned more as hubs, facilitating broader international collaboration, such as Brazil, USA and China in separate clusters (Figure 2a). However, when we look the timeframe from the publishing countries, we see a disparity in period of publication, with the more developed countries showing earlier on the publication timescale (USA, Germany, Canada) alongside mostly the countries where the Pantanal is located (Brazil, Bolivia and Paraguay) and the developing countries (such as Indonesia, Marocco, and South Africa) only appearing mostly in recent years (Figure 2b).

Regarding the countries affiliated with the second set, there were 83 papers, which followed similar clustering patterns and timeframes as observed in the first set. Notably, certain countries played key roles in forming these clusters, while most developing nations only began appearing in the publications in more recent years (Figures 2 b and c).

a)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israel
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new caledonia
paraguay
fiji
venezuela
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mozambique
panama
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greece
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morocco
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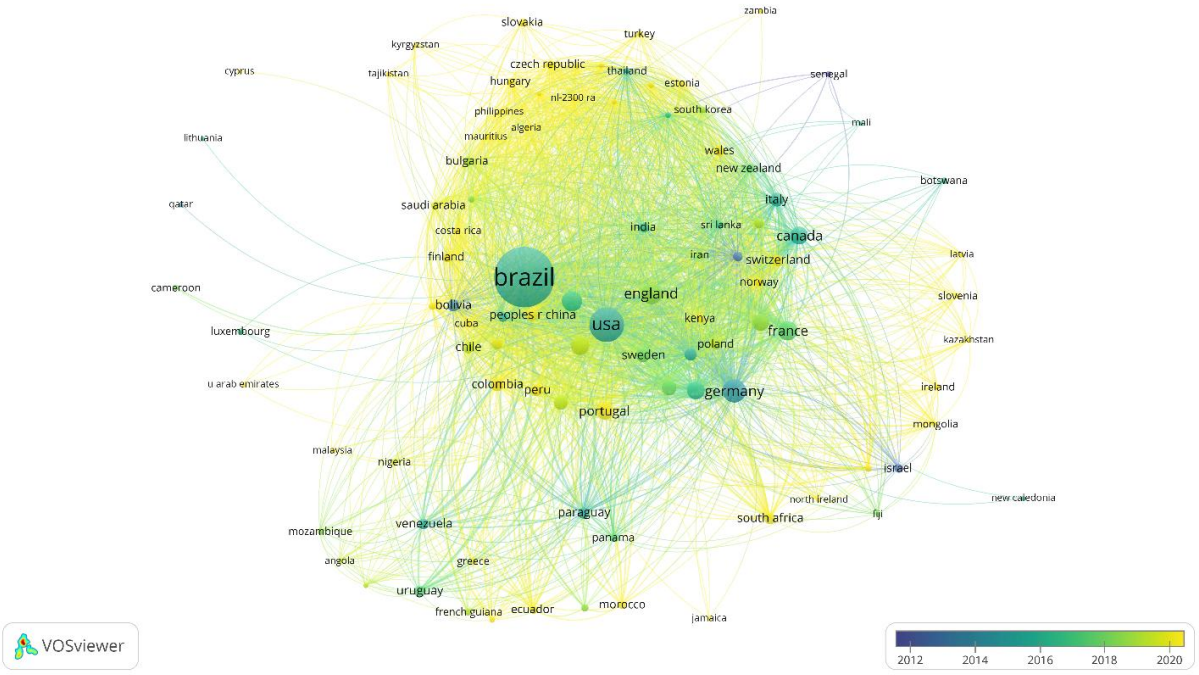
b)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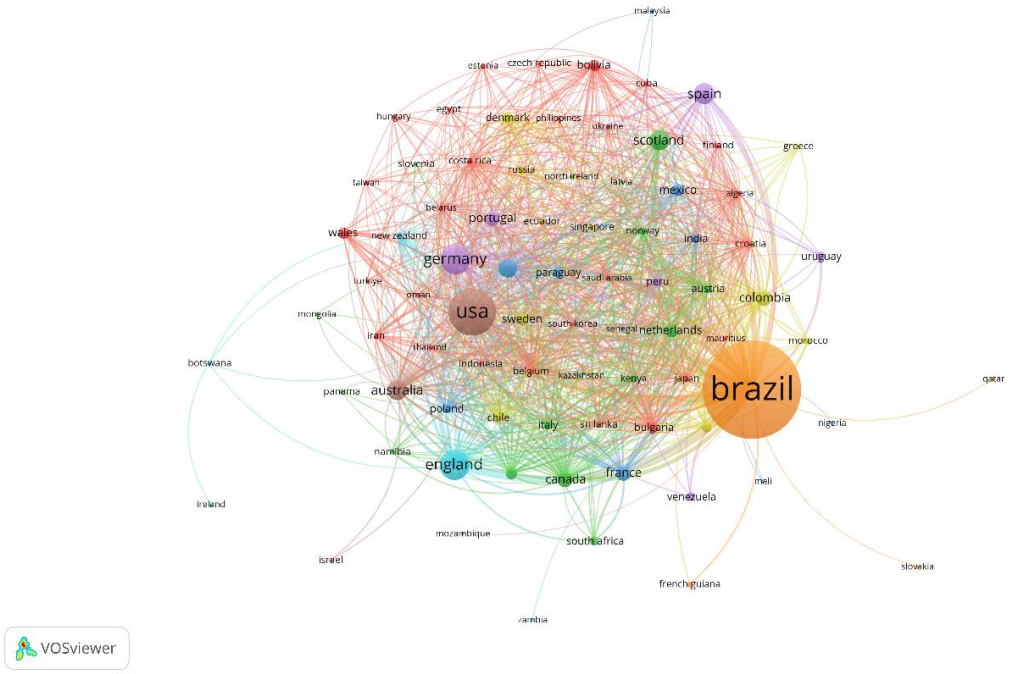

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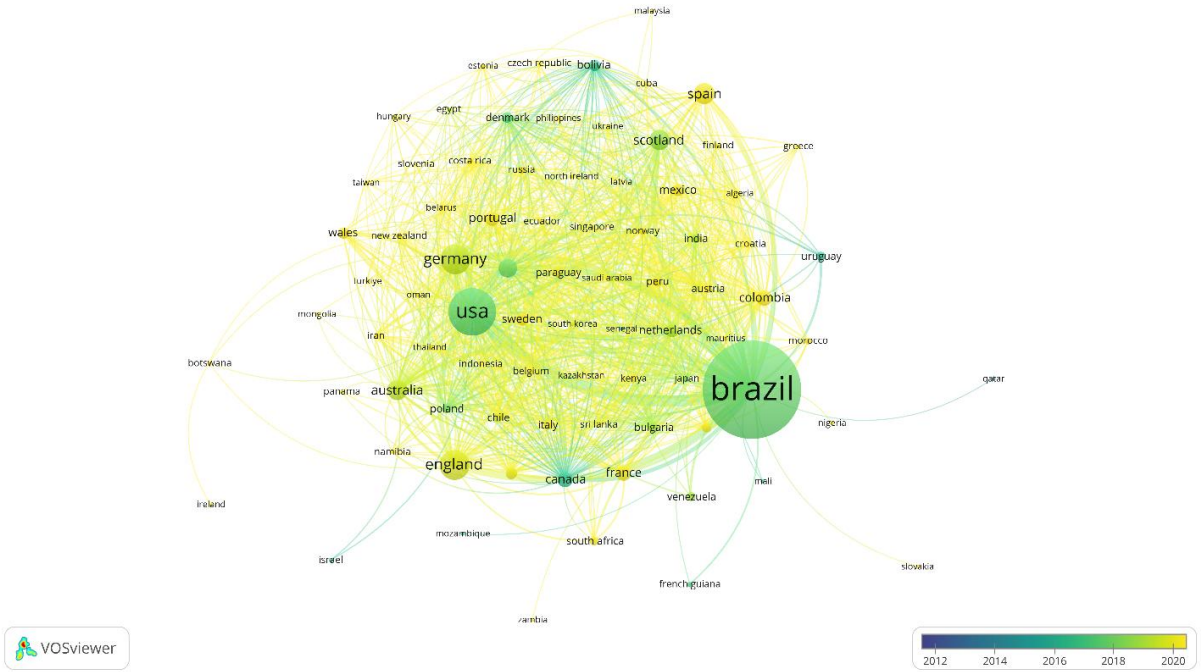

Figure 2. Country map. a) represents the country map per cluster; b) represents the country map over time; c) represents the countries map per cluster on studies that involve social and anthropological aspects; and d) represents the country map over time on studies that involve social and anthropological aspects. The map in “a” and “b” shows the 97 countries affiliated to at least one paper on papers that were publishes on the topic of Pantanal and “c” and “d” shows the 83 countries affiliated to at least one paper on papers that were publishes on the topic of social and anthropological studies in the Pantanal. The circles represent each country across

the papers and it’s size the relative amount of papers affiliated to them. The lines represent a co-affiliation of two countries of papers and the thickness the relative amount they co-affiliated papers. The colors of the circles in “a” and “c” represent clusters that shows a higher tendency of these countries to publish together the period when the country most published papers according to the label and the colors in “b” and “d” represent the period when the country most published papers according to the label. The images are showing only the 1000 most relevant links.

Discussion

Our results indicate a growing body of research on the Pantanal in recent decades, accompanied by a shift from single-discipline studies to more integrated approaches. This trend has been coupled with an increase in international scientific collaboration and greater participation from developing countries in research on the Pantanal, particularly Germany and and EUA, and more recently from Latin America. Recent studies emphasize the need for integrating multiple disciplines to address the complex social-environmental challenges facing the Pantanal focusing on topics like climate and landscape future scenarios, coexistence and decision-making, however, these studies are still few in number. This includes combining ecological, hydrological, and social sciences to better understand and manage the Pantanal wetland's resources (Eufemia et al. 2018, Schulz et a. 2019, Gonçalves et al. 2024, Wantzen 2024).

Socio-ecological studies is a very interdisciplinary field that can help examine long-term human-environment interactions; there still is a notable lack of research specifically focused on the Pantanal, indicating an area for future exploration (see Lazos-Ruíz et al. 2021). Our study showed that less than a third of the papers involved socio-ecological aspects yearly throughout the last two decades, however, terms related to human health, diseases and psychological aspects of the locals are still either lagging on inexistent. Building a collaborative interface between science, policy, and decision-making is essential for sustainable development in the region. This involves creating functional networks to generate solutions for the region's environmental challenges especially based on consolidated data (Tomas et al. 2019). The evolving focus of studies in the Pantanal suggests that researchers are increasingly prioritizing interdisciplinary approaches. This shift is evident in the transition from studies focused on cattle raising and physical measurements (e.g. soil properties, water physical-chemical analysis) to broader research on biomes, land use, and solutions for human-wildlife conflicts and fishing in the region. The continued use of satellite imagery and remote sensing technologies remains essential for monitoring flood dynamics and vegetation changes (Evans et al. 2010, Souza et al. 2020, Milien et al. 2023) and we detected this trend in our search with terms of “movement ecology”, “spatial distribution”, and “camera trap” appearing in recent years both in the general search for Pantanal and in the social and socio-ecological focused studies. These tools can also be applied to analyze psychological aspects, as discussed in Chapter 3, and are instrumental in tracking land use and fire occurrences, such as through MapBiomas. Understanding the spatial and temporal variability of the Pantanal’s ecosystems is crucial for assessing how local communities are affected and developing strategies to mitigate the social impacts of these environmental changes.

International collaborations, particularly between Latin America and Europe, have been increasing, facilitated by science diplomacy. These collaborations help address asymmetries and promote meaningful engagement, enhancing the impact and reach of research (McManus et al. 2020, Echeverría-King et al. 2023). Brazilian researchers, in particular, have been active in international collaborations, contributing significantly to global research topics and benefiting from increased access to international funding and higher impact factors (McManus et al. 2020). International cooperation is crucial for transitioning to sustainable practices by supporting policy development, fostering innovation, and building global partnerships. These efforts help align international and national priorities, ensuring a

cohesive approach to sustainable development (Adanma & Ogunbiyi 2024). The participation of developing countries is playing a more prominent role in Pantanal research and this is evident in the increased involvement of local researchers and institutions in international projects, which helps in addressing local environmental and socio-economic challenges (McManus et al. 2020, Echeverría-King et al. 2023). While it is essential to emphasize that while international collaboration is highly valuable, it is equally important to avoid colonialist practices, parachute science, and other extractive research approaches that often results in inequitable authorship and a lack of sustainable, long-term collaborations (Dahdouh-Guebas et al. 2003, Stefanoudis et al. 2021, Odeny & Bosurgi 2022). We also highlight the need to strengthen national long-term research networks, such as PELD, PPBio, and other programs involving local institutions to leader collaboration with foreign collaborators to ensure that local contexts and needs are adequately addressed. Large national and international research networks focused on the Pantanal are crucial for evidence-based discussions on large-scale processes, including social, ecological, and economic dynamics (see Manring 2014). In the case of the Pantanal, for example, this includes tele couplings involving major buyers of Brazilian commodities, such as China, the United States, and the European Union.

While this type of study provides a valuable broad overview of scientific production in a given region, it is essential to recognize its limitations. One major constraint is the potential underestimation of research published in languages other than English, a particularly significant issue in the social sciences, where local and regional studies may not always be represented in international databases as well as books that sometimes are classics and/or pioneers in a desired field (e.g. Junk & de Cunha 2005). Additionally, the selection of keywords can introduce bias, as certain terms may be more prevalent due to disciplinary conventions rather than actual research trends. Furthermore, word clouds and similar visualizations rely on term frequency, which, while useful for identifying dominant themes, may obscure the early emergence of new research areas and the contributions of smaller, specialized research groups.

In summary, in syntony with global agendas (IPBES, CDB, IPCC, RAMSAR, UNEP, among others), research in the Pantanal is increasingly recognizing the importance of integrating social and environmental sciences to address big challenges (Ioris 2013, 2016, Thomas et al. 2019, Wantzen 2024). There is a call for more systemic and integrative perspectives that incorporate traditional and local knowledge with scientific research to enhance environmental management and policymaking (Eufemia et al. 2018, Schulz et a. 2019). Key areas of growth include biocultural diversity, wildfires, and collaborative science-policy interfaces. However, significant gaps remain, particularly in socio-ecological studies, which can be addressed through interdisciplinary research programs, integrative agendas, and increased funding in this field. Furthermore, expanding existing initiatives—such as Pontes Pantaneiras and Nooledi—to emphasize the co-construction of knowledge will be crucial in fostering sustainable development in this vital wetland.

Capítulo 2 - Assessing the willingness of cattle ranchers towards certification schemes in the Pantanal by integrating different perspectives from social science

Abstract

Cattle ranching is a vital activity in the Pantanal, South America's largest wetland, producing nearly one million calves annually. Traditional ranching supports biodiversity by preserving large herbivores, carnivores, and birds. However, this biome faces increasing threats from land-use changes, mega wildfires, and infrastructure expansion, intensifying harmful practices. Certification schemes promoting biodiversity conservation while respecting traditional ranching methods have been proposed, yet adoption remains low. This study investigates psychological factors influencing ranchers' adoption of certification schemes using the Theory of Planned Behavior (TPB) and Diffusion of Innovation (DOI). Through surveys, we analyzed which TPB constructs—Attitude, Subjective Norm, and Perceived Behavioral Control (PBC)—and their underlying beliefs influenced adoption intentions. Additionally, we identified key adoption drivers through DOI. Results indicate that Behavioral Beliefs and Attitudes significantly shaped ranchers' intentions. While Pantaneiro cultural values played a role, financial benefits and cost-effectiveness were also key considerations. DOI analysis suggested that increased support and better information could enhance adoption. Although Subjective Norms had no significant impact, and PBC was weak under TPB but better explained by DOI, both highlight avenues for future environmental education efforts. To ensure effective conservation, certification programs should target attitudes, emphasizing financial incentives and biodiversity benefits while providing strong support and promotion to enhance adoption.

Resumo

A pecuária é uma atividade fundamental no Pantanal, a maior planície alagada da América do Sul, produzindo cerca de um milhão de bezerros anualmente. A pecuária tradicional contribui para a biodiversidade ao preservar grandes herbívoros, carnívoros e aves. No entanto, este bioma enfrenta ameaças crescentes devido às mudanças no uso da terra, megaincêndios e expansão da infraestrutura, que intensificam práticas prejudiciais. Esquemas de certificação que promovem a conservação da biodiversidade sem comprometer os métodos tradicionais foram propostos, mas a adesão ainda é baixa. Este estudo investiga os fatores psicológicos que influenciam a adoção desses esquemas pelos pecuaristas, utilizando a Teoria do Comportamento Planejado (TCP) e a Difusão de Inovações (DI). Por meio de pesquisas, analisamos quais elementos da TCP—Atitude, Norma Subjetiva e Percepção de Controle Comportamental (PCC)—e suas crenças subjacentes influenciam as intenções de adoção. Além disso, identificamos os principais fatores de adoção com base na DI. Os resultados indicam que as Crenças Comportamentais e as Atitudes tiveram grande influência nas intenções dos pecuaristas. Embora os valores culturais pantaneiros tenham desempenhado um papel, benefícios financeiros e viabilidade econômica também foram fatores-chave. A análise da DI sugeriu que maior apoio e melhor acesso à informação poderiam aumentar a adoção. Embora as Normas Subjetivas não tenham tido impacto significativo e a PCC tenha sido fraca na TCP, mas melhor explicada pela DI, ambos os modelos destacam caminhos para futuras iniciativas de educação ambiental. Para garantir uma conservação eficaz, os programas de certificação devem focar na mudança de atitudes, enfatizando incentivos financeiros e benefícios para a biodiversidade, além de oferecer suporte e promoção para impulsionar a adoção.

Introduction

Cattle ranching in the Brazilian Pantanal, the biggest continuous wetland in South America, plays a pivotal role in both economic development and biodiversity conservation. Ranchers raise approximately 3.8 million heads of cattle producing 1 million calves per year (Oliveira et al. 2016). Nearly 3,000 ranches occupy over 90% of the Pantanal (Tomas et al. 2019, Chiaravalloti et al. 2023). Despite, or perhaps because of, widespread, low-intensity cattle ranching, 0.3 heads/hectare focused on extensive use of native grasslands which does not require major changes to the native ecosystems (Ítavo et al. 2008), the Pantanal continues to support significant biodiversity and is considered of great importance for national and international conservation (Alho 2005, Wantzen et al. 2006, Jaeger 2018). This includes healthy populations of threatened species such as jaguar (Panthera onca), giant otter (Pteronura brasiliensis), marsh deer (Blastocerus dichotomus), pampas deer (Ozotoceros bezoarticus), and hyacinth macaw (Anodorhynchus hyacinthinus) (Tomas et al. 2019). Nearly 80% of the Pantanal is still covered by native vegetation (Projeto MapBiomas 2023). Given the ubiquity of cattle ranching, economic development and conservation of the Pantanal ultimately depends on the practices adopted by cattle ranchers (Chiaravalloti et al. 2023).

Recent changes to more intensive land use and agricultural production, as well as future infrastructure and transportation plans, hydroelectric development, and climate change are now threatening the Pantanal, its ecosystems, and biodiversity (Tortato et al. 2022, Wantzen et al. 2024). A growing number of ranchers have been switching from traditional practices to intensified cattle ranching, mostly by replacing native vegetation with exotic grasses; their main goal is to expand production by increasing cattle density from 0.3-0.5 to 1-3 cattle/hectare (Ítavo et al. 2008). In addition, native vegetation loss has been increasing along an arc that is moving from the eastern flank of the Pantanal towards the west (Guerra et al. 2020). The constructions of a waterway and several small-hydroelectric dams in the headwaters of the Paraguay River Basin, which continue to be debated by policymakers, will further exacerbate recent ecological declines in the Pantanal by altering its dynamics, for example, the water pulse (Ely et al. 2020, Wantzen et al. 2024). Combined with climate change, these planned developments could have devastating impacts and are likely to further increase the frequency and intensity of droughts, heat waves and wildfires (Libonati et al. 2020, Marengo et al. 2022, Girard et al. 2024). The wildfire season of 2019 and 2020, which killed as many as 17 million vertebrates, serves as a warning of future calamities if business continues as usual (Libonati et al. 2020, Tomas et al. 2021).

Certification schemes and traceability of cattle chains may empower producers to align with both international and national sustainability (Newton et al. 2015). This not only enhances their financial returns but also facilitates the creation of diverse environmental goods and services (Oya et al. 2018). Consequently, if well implemented, this practice significantly contributes to bolstering food security and biodiversity conservation efforts. Given the growing apprehensions of importing nations regarding the environmental and social implications of agricultural production, pivotal export markets have shown a heightened interest in implementing certification schemes within the cattle chain. These schemes play a crucial role in establishing and upholding management standards to address and mitigate concerns related to the environmental and social impact of agricultural practices.

As a strategy to protect the Pantanal from further habitat conversion, Embrapa

Pantanal, alongside regional universities, NGOs, and government and private sectors, initiated various initiatives. These efforts aim to develop certification programs, such as Boi Orgânico (Organic Cattle) and Fazenda Pantaneira Sustentável (FPS - Pantanal Sustainable Ranch), promoting sustainable practices and adding value to products (Associação Pantaneira de Pecuária Orgânica e Sustentável 2001, Embrapa Pantanal 2018). For instance, FPS has demonstrated a 22% increase in cattle pregnancy rates while upholding rigorous biodiversity conservation standards (Ascom Famato 2022, December 12). Despite these benefits, low adoption rates persist, underscoring the need to understand ranchers' perspectives on sustainable ranching and certification programs, especially the existing ones in their first stages. Therefore, large-scale conservation efforts in the Pantanal must maintain traditional ranching practices while embracing best management practices.

To understand the drivers towards certifications schemes it is necessary to understand the psychological aspects that are important to an individual or a community, these include professional development, increased income, professional satisfaction, consumer protection, among others (Obrecht et al. 2019, Curry et al. 2009). Two frameworks widely used to understand such psychological and social aspects are the Theory of Planned Behaviour (TPB), and the Diffusion of Innovation (DOI). The Theory of Planned Behaviour (TPB) and the Diffusion of Innovation (DOI) framework can be effectively integrated to understand farmers' intentions to adopt sustainable practices. TPB emphasizes that behavior is driven by attitudes, subjective norms, and perceived behavioral control, which influence the intention to act (Ajzen 1991, Ajzen 2011). In the context of sustainable agriculture, a farmer's attitude towards conservation, the social pressure from peers or policy, and their confidence in the ability to implement sustainable methods play key roles. DOI, on the other hand, highlights the stages through which innovations—like sustainable farming practices—spread, emphasizing early adopters, social networks, and communication channels as critical to the rate of adoption (Rogers 1962). When combined, these theories suggest that while a farmer’s intention to adopt sustainable practices may be shaped by their attitudes and perceptions (TPB), the spread of these practices through the farming community will depend on how innovations are perceived, communicated, and supported by early adopters and change agents (DOI). Therefore, promoting sustainable farming requires addressing both the internal motivations of individual farmers and the broader diffusion process within the agricultural community (Bopp et al. 2019, Jambo et al. 2019). In this context, the case of cattle certification and initiatives in the Pantanal is a good model to explore the connections and applicability of these theories because there has never been such an understanding about these aspects in the Pantanal. If fact, there has been few attempts to apply any psychological theory to conservation at all, and even the existing ones are more focussed on human well being (see McKinnon et al. 2016).

In this study we investigate the psychological aspects that drive rancher’s participation/adoption of certification schemes using the TPB and DOI. We identify the impact of attitude, subjective norm, and perceived behavioral control as well as the key factors on ranchers' intention to adopt a conservation scheme; we also identify the beliefs that drive their intentions to adopt sustainable cattle ranching schemes in their properties in the Pantanal, through the theoretical lens of the TPB (Ajzen 1991, Ajzen 2005) and DOI (Rogers 1962). Our results could aid policymakers in how to adjust current policies and tailor new

policies and programs to stimulate the adoption of biodiversity conservation programs and certifications by cattle farmers in the Pantanal and help design better strategies to scale up the ongoing initiatives.

Methods

Study area

The Pantanal wetland is located in the center of the Upper Paraguay River Basin in South America encompassing 179,300 km^2 across Brazil (78%), Bolivia (18%), and Paraguay (4%) (Figure 1; Adámoli 1981, Mereles et al. 2000, Ministerio de Medio Ambiente y Agua 2017). The Brazilian Pantanal stretches from southern Mato Grosso (MT; 35%) into Mato Grosso do Sul (MS; 65%) states. The region is characterized by well-defined dry and wet seasons, with rainfall concentrated in the summer (November–March). The latter produce a seasonal flood pulse with monomodal hydrological signature (Junk & Wantzen 2004, Penatti et al. 2015, Tomas et al. 2019). These seasonal floods influence animal and plant communities, nutrient cycling, and primary productivity (Wantzen et al. 2023). The landscape consists of a mosaic of floodable and non-floodable grasslands, forests, open woodlands, and temporary or permanent aquatic habitats (Damasceno-Junior & Pott 2022). It is also home to substantial populations of vulnerable (or higher) species according to the IUCN and ICMBio (2025), such as jaguars (Panthera onca), giant otters (Pteronura brasiliensis), swamp deer (Blastocerus dichotomus), pampas deer (Ozotoceros bezoarticus) and hyacinth macaw (Anodorhynchus hyacinthinus).

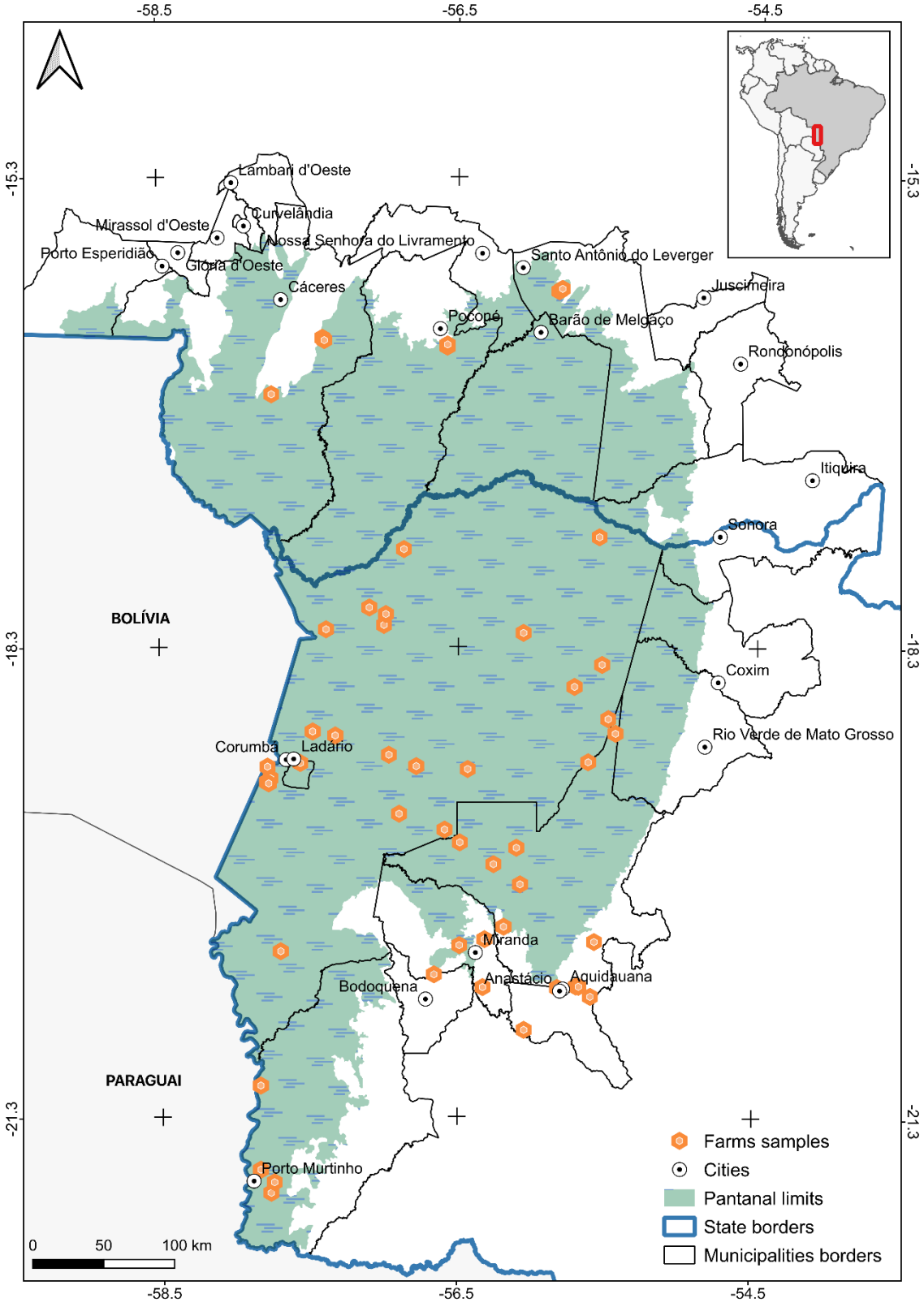

Figure 1. Location of the properties of the ranchers interviewed in the Brazilian Pantanal and adjacent areas.

The existing network of protected areas is far from the 17% recommended by the Aichi Targets for terrestrial ecosystems and represents little biodiversity in the Pantanal (for Brazil: Oliveira et al. 2017). For example, strictly protected areas (International Union for Conservation of Nature [IUCN] Categories Ia and II of protected areas; see Dudley 2008) cover 14,800 km^2 (5.71%) of the Pantanal. Private protected areas (Private Natural Heritage Reserve in Brazil and Private Nature Reserve in Paraguay, also IUCN category) are scattered in the Pantanal floodplains, ranging in size from less than 1.00 to 1,174.00 km^2, covering 3,046.53 km^2 (1.7% of the total Pantanal area). In Brazil, there are two Environmental Protection Areas, but only one fully within the boundaries of the Pantanal (basically under the IUCN IV category, but often including restricted use categories); in Bolivia, two of these areas are classified as Natural Areas of Integrated Management and comprise 4,528 km^2 (2.9%). In addition, there are two UNESCO Biosphere Reserves in the Upper Paraguay Basin region: the Pantanal Biosphere Reserve in Brazil and the Chaco Biosphere Reserve in Paraguay, both of which contain several different types of protected areas such as nuclear zones and management areas. These sites in Brazil are also listed as Ramsar Sites (see MMA 2024) There are seven indigenous lands in the region covering ~11,724 km^2 (7.4%), which should be considered as a protected area according to the IUCN. However, protected areas need to at least triple to achieve the Aichi Goals (Tomas et al. 2019).

Cattle ranching in the Pantanal began in the seventeenth century and today is the predominant economic activity (Machado & Costa 2018), being conducted by approximately 3,000 farms on the Brazilian side. Cattle graze at relatively low densities, averaging 0.1 to 0.8 head per hectare on native and cultivated pastures, respectively. The farms are relatively large, with 36.2% with 5,000 to 10,000 ha, 29.3% with 10,000 to 30,000 ha, 6.1% with 30,000 to 60,000 ha, and 0.7% with more than 60,000 ha. Cattle densities are not uniform, as they depend on the vegetation cover of each property, water pulse, buffer zone and even political and international regulations depending on who the buyer is. However, farms located in central and frontier zones, as well as farms more modified by the replacement of native vegetation by cultivated pastures, have higher potential cattle densities.

The theory of planned behavior (TPB)

The TPB assumes volitional behavior originates from individuals' intentions to perform a specific behavior (Ajzen 1991). Since it is impossible to measure a behavior before it has been acted, a measure of intention would help to predict a specific behavior (Ajzen 2005). In this study, the intention measures are the "intention of a rancher in the Pantanal of conservation schemes in the Pantanal in the next three years".

The original TPB framework (Ajzen 1991) also underpins the idea that intention is determined by psychological constructs: attitude, subjective norm, and perceived behavioral control. Attitude is the degree to which execution of the behavior is positively or negatively evaluated, subjective norm refers to a person's perception of the social pressure upon them to perform or not perform the behavior, and perceived behavioral control is the perceived own capability to successfully perform the behavior (Beedell & Rehman 2000, Wauters et al. 2010).

Each of these constructs are dictated by individual beliefs. Attitude is driven by behavioral beliefs, subjective norm is dictated by normative beliefs, and perceived behavioral control is dictated by control beliefs (Figure 2). Each belief can be divided by composites,

such as expectations and motivation, facilitators, and perceived power (Ajzen 1991).

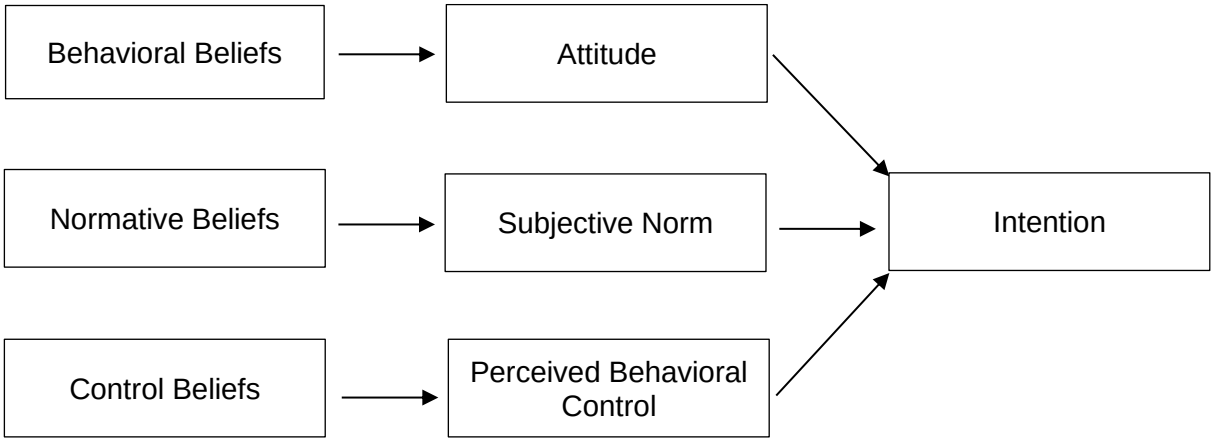

Figure 2. Beliefs and Constructs of the Theory of Planned Behaviour (Adapted from Ajzen 1991).

Diffusion of Innovation theory (DOI)

The Diffusion of Innovation theory is widely recognized as an effective model for driving technological change by tailoring innovations to meet the needs of various adopter groups. It emphasizes the importance of communication and peer networks in facilitating the adoption process. In essence, the theory explains how new ideas, products, practices, or philosophies are gradually embraced by individuals and groups over time (Kaminski 2011).

Here we identified through a questionnaire (presented together with the TPB questionnaire) the main aspects that one considers when choosing to adhere to a conservation scheme adapting the framework proposed by Rogers (1983) to conduct in the Pantanal.

TPB and DOI questionnaire and semi-structured interviews

An application of the TPB framework is usually constructed in two steps. The first step is to evaluate which beliefs are the driving forces in the population under study. These beliefs are identified through semi-structured interviews with a small sample of the population. In these initial interviews, we focus on three main questions around: 1) advantages and disadvantages of specific behavior (e.g. adoption of conservation scheme) used to measure behavioral belief, 2) key references or important stakeholders that play a role in the adoption of the specific behavior used to measure normative belief, and 3) factors or circumstances that it would make it easier or prevent ranchers from adopting the behavior used to measure control beliefs. The initial interviews are also used to test items on the other constructs: attitude, perceived behavioral control, subjective norm, and intention (Ajzen 1991, Ajzen 2011).

We interviewed 13 ranchers, from August 2021 to December 2021, that live in the Pantanal using the snowball format of sampling, which led to three items for intention, four items for attitude, three for subjective norm and five for perceived behavioral control, four items for behavioral belief, four items for normative belief and two for control beliefs. As explained, regarding the beliefs each item was divided into two questions or composites, which we used to measure expectations and motivation, facilitators, and perceived power. Each question was structured using a five-point Likert scale, with one being the most negative answer and five being the most positive. The statements used to measure each item were based on the instructions of Fishbein and Ajzen (2010). Before applying the survey, a pretest was carried out with ten ranchers and two specialists, to ensure that the questions could be clearly understood. For more detailed description see Borges et al. (2016).

After the questionnaire was structured for the TPB, the questions for the DOI was adapted from the Roger's (1983) and added to the questionnaire and carefully inspected as to avoid repeated questions, since some questions from both theories overlap.

In the second step, after the pretest was carried out and the questions were adjusted for clarity, a second round of interviews was carried out where 82 ranchers were contacted and invited to participate in the survey, either by telephone or during a visit to their ranch. We sought free, prior informant consent with all ranchers before carrying out the interview, in accordance with IRB protocol. Upon acceptance, ranchers were invited to fill out the survey face-to-face with one interviewer. The data collection, for the second round of interview, took place from August 2021 until November 2021. We interviewed 82 ranchers in the region. All the interviews were conducted in Portuguese. The study was approved by the Brazilian Ethics Committee (process number: CAAE 34296720.7.0000.5161) and by Smithsonian Institution Human Subjects Review Board (protocol number: HS20024).

Statistical analysis

We carried out a Partial-Least-Square Structural Equation Modeling (PLS-SEM) analysis to analyze the data from TPB. This analysis is considered the best approach while dealing with latent constructs (or variables that are impossible to measure and are evaluated by indicators) (Marsh et al., 2004). The analysis consists of first establishing the quality of the links between attitude, subjective norms and perceived behavioral control and its indicators. The quality of the analysis is measured by the composite reliability, average variance extracted and the heterotrait–monotrait ratio. Second, we analyse the full model, looking at the link between the latent variables with the beliefs (Behavioral Beliefs, Normative Beliefs, and Control Beliefs). We evaluate the strength of the model by looking at the links between latent constructs (named path) and the link between the latent construct and its indicators (named loadings) and the link between the beliefs and its indicators (named weights).

In order to avoid using unique values to define the strength of the connections, we also carried out a bootstrap of 10,000 samples, creating confidence intervals and discarding those variables that have more than 5% of values below zero as not significant. For further details see Borges et al. (2016) and Ajzen (1991).

For the DOI, each question was considered as a variable, we had a total of 29 variables. The fist step was to carry out a VIF analysis checking which variables were too similar to be analysed together. We deleted 3 variables, reducing the model to 26 variables. Second, we carried out a subset regression, which created all possible models with all variables and evaluated those with the lowest Bayesian Information Criterion, adjusted-r factor, and Mallows' CP (Frost 2020). Then we run a bootstrap analysis with the best model creating confidence intervals and discarding those variables that have more than 5% of values below zero as not significant.

Results

We interviewed 82 ranchers throughout Pantanal (Figure 1). 85.7% were male and the average age was 55.7 years (SD of 11.7 years and SE of 1.4 years). The ranchers had a mean experience of 23.3 years in ranching (SD of 13.9 years). On average the ranchers had 5925.5 ha (SD 16116.4 ha).

TPB results

Our measurement model satisfied all the quality controls, which meant that we could carry out the structural evaluation. The structure evaluation showed among the latent constructs, Attitude played the most important role in the ranchers' intention to adopt a sustainable certification scheme in the Pantanal. The loading between Attitude and Intention was 0.76 (CI 0.56-0.94). While loadings from both Subjective Norm (0.03, CI -0.172-0.24) and Perceived Behavioral Control (0.089, CI -0.042-0.22) to Intention were not significant (Figure 3).

Attitude was significantly explained by two main beliefs. The recognition of the Pantaneiro Culture (0.69, CI 0.31-0.94) and the possibility of Financial Gains from the certification scheme (0.33, CI 0.042-0.60) had significant weights. Protection of Wildlife and the need to Increase Area of Exotic Pasture did not play a significant role (weights -0.16, CI -0.37-0.09; and 0.18, CI -0 .35-0.09 respectively) (Figure 4).

Interestingly, the indicators around normative beliefs also significantly explained the subjective norms. Thus, neighbors (0.79, CI 0.41-0.99) and family's (0.44, CI 0.02-0.82) play

a role in ranchers' decisions on the management of the ranch (Figure 3). However, as explained Subjective Norm did not play a significant role in Intention to adopt a sustainable ranching certification scheme. Therefore, family and neighbors seem important drivers, yet not for this specific behavior.

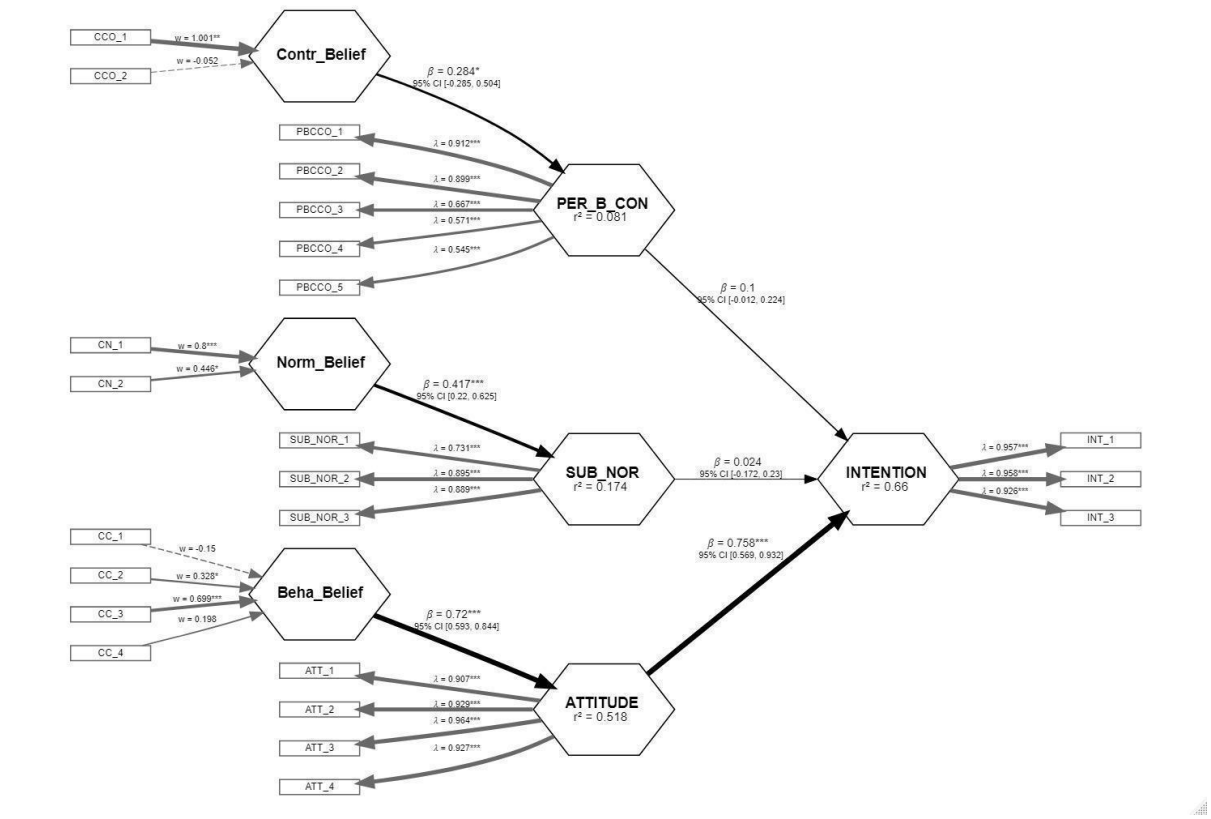

Figure 3. Results for the integrated model for Theory of Planned Behaviour. The hexagons represent constructs, the rectangles are the Items of the constructs (composites). Arrows between constructs are β coefficients and numbers inside constructs are the r2. Arrows going from the Items to the constructs are formative weights, and arrows going from constructs to Items are reflexive loadings (>0.5). CCO = Control Beliefs; CN = Normative Beliefs; CC = Behavioral Beliefs; Contr_Belief = Control Beliefs; PBCCO = Perceived Behavioral Control / Capacity and Control; Norm_Belief = Normative Beliefs; SUB_NOR_1;2;3 = Subjective Norm; Beha_Belief = Behavioral Beliefs; ATT = Attitude; PER_B_CON = Perceived behavioural Control; SUB_NOR = Subjective Norm; INT = Intention.

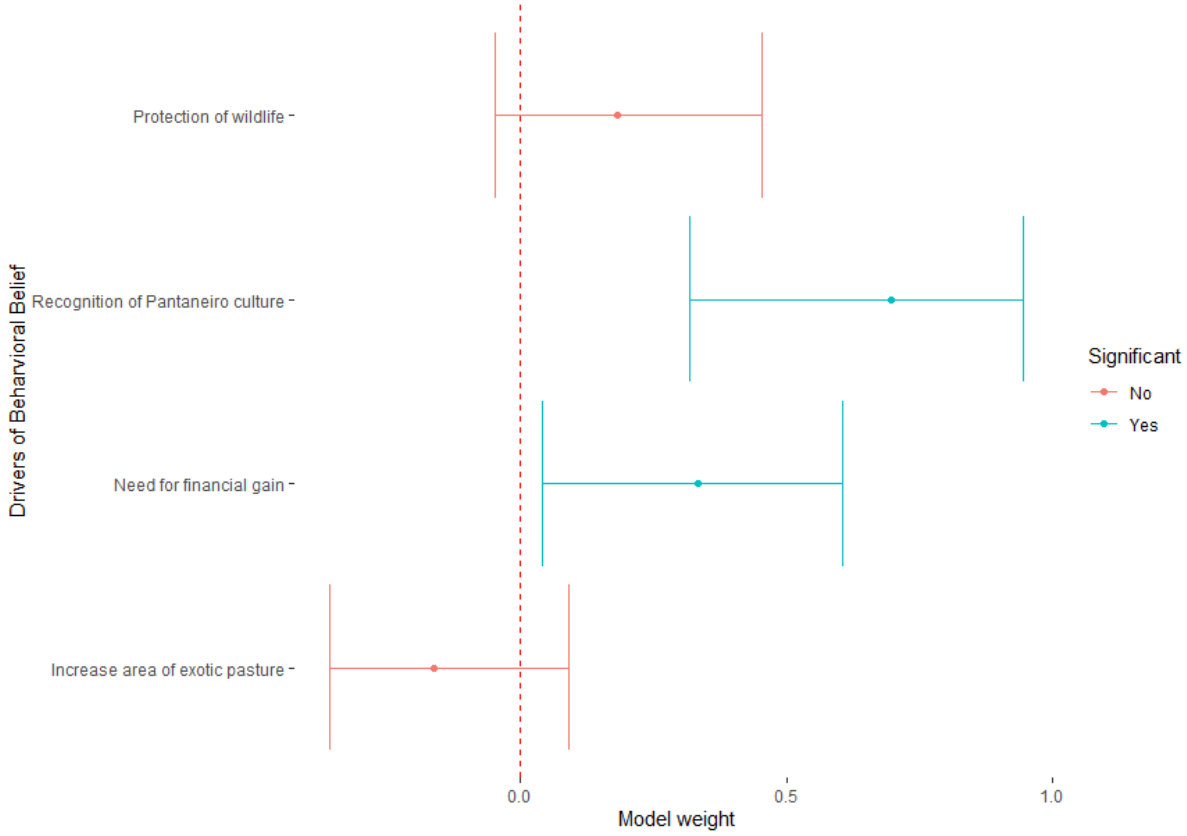

Figure 4. Weight of drivers of behavioral beliefs.

DOI results

The model that showed the best result was the one with six variables (Figure 5). The results of the bootstrap showed that all variables in the model were significant, with no one of them touching the zero. The variable with the strongest correlation with intention to adopt was support to tackle ranching challenges. This means that ranchers would be willing to adopt the certification scheme should it provide technical support in terms of daily management activities. The model also showed that government support was negatively correlated with the intention to adopt.

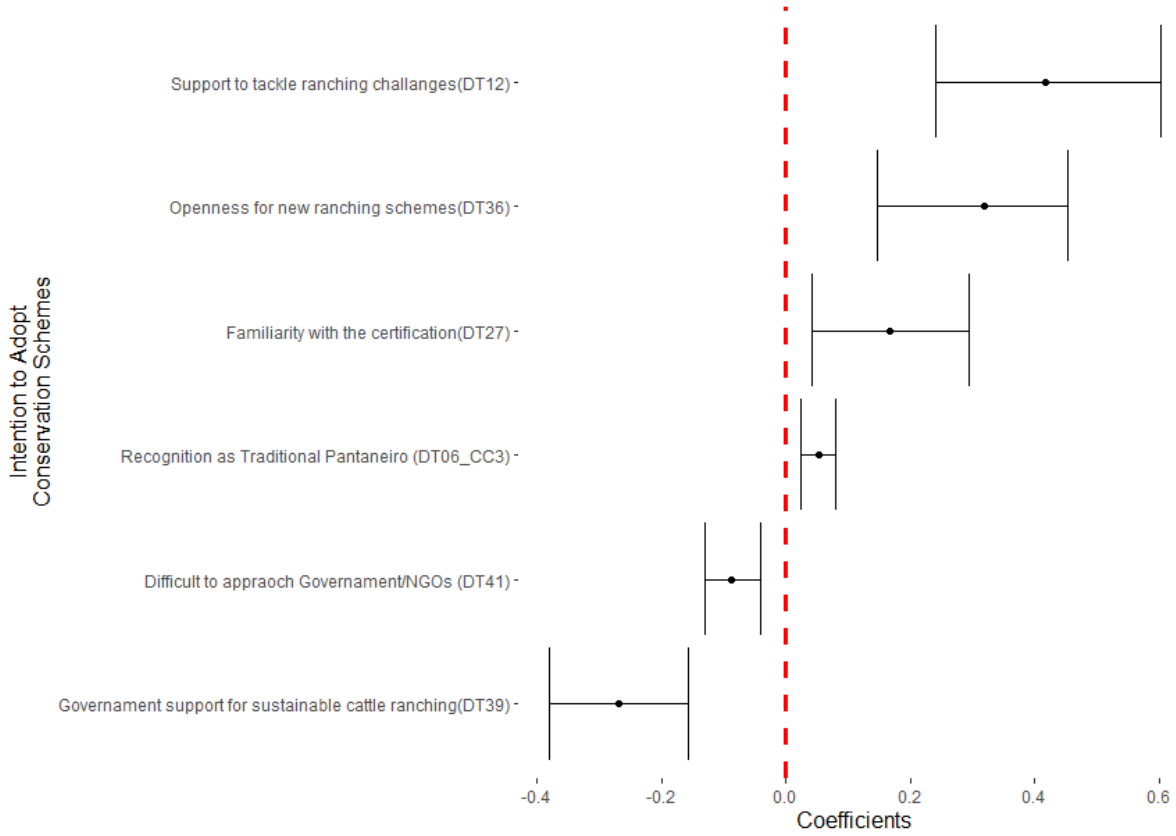

Fig 4. Weight of factors from the DOI model on interviewed intentions to adopt conservation schemes in their properties in Pantanal. The further left from the red dashed line the more negatively that factor influences Intention, the further right the more positively it influences Intention.

Discussion

Conservation biology is a crisis discipline (Soulé 1985), and we have to make constant decisions on how to best protect the "good relations between nature and people" (Sandbrook 2015). However, given the scale of change and the urgency of actions, there is not much room for mistakes. Conservation biology schemes must be based on scientific evidence to minimize mistakes and error (Burgman et al. 2023). Our approach using the TPB and DOI toward stakeholders' participation in a sustainable cattle ranching scheme in the Pantanal wetland presents a framework to achieve this goal. By using sociological and psychological methods to answer the same question we were able to see what the most important drivers of intention to adopt were and what was dictating ranchers' willingness to engage in the sustainable ranching program, that is: a) ranchers are primarily motivated by their own personal beliefs and values concerning biodiversity conservation; and b) certification schemes through the farming community will depend on how innovations are perceived, communicated, and supported by early adopters and change agents in the Pantanal. Thus, both theories being complementary of one another in our study. Therefore, by mixing these approaches we were also able to bring both qualitative and quantitative information, allowing us to verify the major aspects of adoption while also uncovering a more detailed explanation of why they are occurring (Drury et al. 2011). We argue that by bridging these two different methods, and in fact disciplines, we were able to provide a more clear and straightforward answer to practitioners and policy makers on how to engage with local stakeholders.

The Theory of Planned Behavior (TPB) is a well-established psychological framework for understanding and predicting human behavior (Manstead & Parker 1995, Armitage & Conner 2001, Kepatuhan et al. 2008), despite some criticism by not including self-regulation mechanisms of behaviour change (see Hennessy et al. 2020). Ranchers' attitudes toward biodiversity conservation can significantly impact their willingness to adopt practices, such as certification, that promote it (Greiner 2015). Attitudes in this context could be viewed from two angles. In the Pantanal, traditional ranchers that live in the regions for decades can be particularly linked with "traditional values" (what they call the "Pantaneiro culture"). Our results clearly show that Pantanal culture is an important factor in both frameworks, even though in the TPB it did not ultimately strongly affect intention. Other farmers might view it as an economic opportunity, such as through certification. Ranchers' attitudes may also depend on how they perceive the benefits and costs of biodiversity conservation practices. Positive attitudes are more likely when they see tangible advantages, such as improved soil quality, more resilient livestock, or financial incentives for conservation efforts (Lalani et al. 2016). In fact, we found that financial gains have significant loads, many ranchers answered that certification schemes are good when they provide some kind of return, some mentioned financial return, and some are more interested in recognition.

Our results indicate that subjective norms do not significantly influence Intention toward certification schemes among Pantanal ranchers. Subjective norms reflect the perceived social pressure from peers, families, or community members. While social influences could affect ranchers' intentions, this factor may be underestimated due to cultural aspects, as ranchers emphasized their decision-making power over their private lands during interviews. This aligns with previous findings by Nolan et al. (2008) that subjective norms can be underdetected, particularly when it is a nonconscious influence (Bargh 2006).

The DOI results, in addition, shows that support to solve challenges in the property, ranchers' openness to new paths, familiarity with a program, and recognition of the ranchers' as Pantaneiros in culture are more important factors in the spread of a certification scheme. Conversely, reduced approachability of government support diminishes the intention to participate in these schemes. These perspectives highlight the need for a broader discussion on the implementation and expansion of such initiatives, aiming for success rather than stagnation or decline due to insufficient adoption by ranchers. Interestingly, the higher the government support for sustainable cattle ranching the lower the ranchers' intention to adopt such programs.

In our context, the TPB and DOI framework are complementary, the TPB being about the constructs important for adoption, which is the benefits that a certification scheme could bring them, either financial or through a certification (meaning their product has a differential in the market) while the DOI is more for the spread of it after the early adopters have already started and the others start to see positive and beneficial results.

Regarding perceived behavioral control, which refers to how much individuals believe they can influence their own actions, ranchers did not exhibit significant reliance on this factor. They likely feel confident in their ability to adopt conservation practices, even if they lack specific knowledge, as this could be easily obtained through rural unions or private consultants. However, this perception of control should be interpreted cautiously, as it may stem from an "illusion of control," where ranchers overestimate their actual ability to control outcomes (Thompson et al. 1998, Yarritu et al. 2013).

Considering the alignment between the TPB and DOI, as well as the complementary results regarding the adoption and dissemination of schemes, the early phases of implementation in the Pantanal appear to be characterized by a highly conservative approach among ranchers. This caution is likely due to the sensitivity of the biome, which operates under a unique environmental regime with a specific annual window for production. Therefore, new conservation schemes and biodiversity conservation programs linked to production should not only account for their potential benefits to both conservation and production but also address the factors influencing ranchers' intentions and decision-making, which are crucial for the successful spread of these schemes.

Implications of our findings to Biodiversity Conservation

To encourage biodiversity conservation among ranchers, it is crucial to consider these TPB and DOI components that most account for their representation of ranchers' intention. As we find that attitudes affect ranchers' intention to adhere to conservation schemes the most, we suggest the certification schemes should have their main focus on attitudes. For example, developing a strategy for how to shape certification programs for the Pantanal through the lens of recognition and identification and also showing what clear benefits might arise from these schemes. Furthermore, highlighting success stories and demonstrating that conservation practices can coexist with profitable ranching can be persuasive. In fact, market-based instruments are considered an important tool to slow down the current global species extinction rate and loss of ecosystem services (Bayon & Jenkins 2010).This finding supports the idea of positive externalities, in which beneficiaries pay for those who are producing the environmental goods (Gomez-Baggethun & Ruiz-Perez 2011), making the conservation of natural pastures and forests worth more than if they were deforested and replaced by exotic

grasses (Spangenberg & Settele, 2016).

Although Subjective Norms did not explain Intention and Perceived Behavioral Control explain Intention but to a very small degree, we believe that they should also be considered for further investigation and as complementary strategies in changing their view on these aspects in the long run. For example, educating ranchers about the ecological, economic, and social benefits of biodiversity conservation can help improve their attitudes toward it. This is particularly relevant due to feedback mechanisms during the implementation and behavior. Engaging in a behavior can lead to unexpected outcomes, both positive and negative. It can also influence how others respond, either positively or negatively, and may uncover unforeseen challenges or helpful factors. This feedback has the potential to alter an individual's beliefs about their behavior, societal norms, and their ability to control situations. Consequently, it can shape their future intentions and actions (Fishbein & Ajzen 2010) and how a certification scheme will spread through the community. Under this perspective, promoting community engagement and creating a supportive network among ranchers can influence subjective norms positively. When ranchers see that their peers are also adopting conservation practices and gaining benefits, they are more likely to follow suit. Providing ranchers with the necessary resources, technical support, and knowledge can enhance their perceived control over adopting conservation measures. Reducing regulatory barriers and offering incentives can also improve their sense of control.

Capítulo 3 - Does the rancher’s intention to adopt conservation schemes depend on the level of agricultural farmland in their properties?

Abstract

Reconciling agricultural production, food security, and biodiversity conservation remains one of humanity's greatest challenges. Livestock farming plays a key role in global food security, supporting 1.3 billion people and contributing 40% of agricultural output. However, balancing agricultural expansion with conservation efforts is critical, particularly in regions undergoing rapid landscape change. This study examines how the extent of farmland on a property influences ranchers' intentions to adopt conservation and certification schemes, using the Pantanal as a case study. We intention of interviewed ranchers in Pantanal then analyzed land use data from MapBiomas and applied a Generalized Linear Model (GLM) in their property to estimate if their intention to adopt certification schemes related to land use, then we extrapolated this result to the whole Pantanal. The results indicate that ranchers are more inclined to adopt conservation schemes on properties with a higher proportion of converted farmland. Significant predictors of conservation intention included the percentage of grassland, amount of pasture, and proximity to conservation units or Indigenous lands. These findings underscore the complexity of conservation decision-making and highlight the need for context-sensitive policies that align with ranchers’ land use dynamics. Integrating conservation with agricultural productivity can enhance both ecological resilience and economic sustainability, fostering long-term commitment to conservation programs in working landscapes like the Pantanal.

Resumo

Conciliar a produção agrícola, a segurança alimentar e a conservação da biodiversidade continua sendo um dos maiores desafios da humanidade. A pecuária desempenha um papel fundamental na segurança alimentar global, sustentando 1,3 bilhão de pessoas e contribuindo com 40% da produção agrícola. No entanto, equilibrar a expansão agrícola com os esforços de conservação é essencial, especialmente em regiões que passam por rápidas mudanças na paisagem. Este estudo investiga como a extensão das áreas agrícolas em uma propriedade influencia a intenção dos pecuaristas de adotar esquemas de conservação e certificação, utilizando o Pantanal como estudo de caso. Para isso, entrevistamos pecuaristas da região, analisamos dados de uso da terra do MapBiomas e aplicamos um Modelo Linear Generalizado (GLM) para estimar se a intenção de adotar certificações está relacionada ao uso da terra. Em seguida, extrapolamos esses resultados para todo o Pantanal. Os resultados indicam que os pecuaristas têm maior propensão a adotar esquemas de conservação em propriedades com uma maior proporção de terras convertidas para uso agrícola. Os principais fatores preditivos da intenção de conservação incluíram a porcentagem de campos nativos, a quantidade de pastagens e a proximidade de unidades de conservação ou terras indígenas. Esses achados ressaltam a complexidade da tomada de decisão na conservação e destacam a necessidade de políticas sensíveis ao contexto, que alinhem a conservação com a dinâmica do uso da terra. Integrar conservação e produtividade agrícola pode fortalecer a resiliência ecológica e a sustentabilidade econômica, promovendo um compromisso duradouro com programas de conservação em paisagens produtivas como o Pantanal.

Introduction

Reconciling agricultural production, food security and biodiversity conservation are some of the biggest global challenges facing humanity (Zabel et al. 2019) and it is expected to increase in line with population growth in the coming years to sustain more than 9 billion people by the year 2050 (Beddington 2011). Livestock farming is an important pillar in food security ensuring food and nutritional stability for nearly 1.3 billion people and representing 40% of the global agricultural outputs (World Bank 2022). There are initiatives aimed at improving food production around the world, including new practices for more sustainable livestock farming, such as adopting sustainable certification, improving animal welfare and health, allowing coexistence with a great diversity of native species, minimizing the carbon footprint, and providing a fair lifestyle for people (Broom et al. 2013). Considering that the livestock farming sector, is especially important for biodiversity conservation, as it is an important driver of biodiversity loss worldwide, scientists and conservation professionals are increasingly interested in the factors that motivate human behavior for more sustainable livestock production (Borges et al. 2016, Senger et al. 2017) , particularly for beef production that has been estimated to cover 25 to 35% of the worlds pasture, around 30 million square kilometers (Asner et al. 2004, Stehfest et al. 2009, Conant 2010). However, successfully influencing behavior (to a e more sustainable aimed practices) change depends on predictors of human behavior being correctly diagnosed and using this knowledge in conservation decision-making and initiatives (John et al. 2010). In addition, it is essential to identify whether the places that will undergo the greatest landscape changes are those whose populations are most resilient, particularly regarding the capacity for behavior change (Cimellaro et al. 2016).

The adoption of conservation practices by ranchers is a critical component in safeguarding biodiversity and promoting sustainable land use (Painter et al. 2020, Byerly et al. 2021). However, the decision to implement new practices often hinges on various factors, including economic considerations, personal values, and the characteristics of the land they manage (see Pienaar et al. 2017, Ranjan et al. 2019, Savari 2023). One significant factor that may influence a rancher's intention to adopt conservation practices is the extent of agricultural farmland within their property (Lesch & Wachenheim 2014). The balance between maintaining productive agricultural land and preserving natural habitats can create a complex decision-making environment for ranchers. For example, a rancher with extensive farmland may prioritize agricultural productivity over conservation efforts due to the economic benefits of farming. On the other hand, a rancher with limited farmland or areas of lower productivity may be more inclined to set aside portions of their property for conservation, as the potential trade-offs are less impactful on their income. Understanding how the presence and extent of farmland impact their intention to engage in conservation practices is crucial for developing strategies that effectively integrate agricultural productivity with environmental stewardship.

The Pantanal's unique combination of biodiversity, agricultural development, and socio-economic factors make it an ideal study case for exploring how land use dynamics shape conservation behavior (i.e. conservation efforts, conservation intention), and the findings from such research can inform broader strategies to enhance conservation outcomes in other agricultural landscapes facing similar pressures (Tomas et al. 2019). The Pantanal is

one of the world's largest tropical wetlands, characterized by a rich mosaic of habitats that support high biodiversity, including numerous endangered species (Junk & Wantzen 2004, Penatti et al. 2015). The region is also a cultural landscape where traditional cattle ranching coexists with natural ecosystems (Bicalho & Araújo 2021). This blend of natural and human-altered environments makes the Pantanal a dynamic setting to study how land use influences conservation behavior. In recent decades, the Pantanal has experienced increasing pressure from agricultural expansion, particularly cattle ranching and soy cultivation (Song et al. 2021), although specific legislation has been preventing the Pantanal from having land converted into crops (e.g. lei do Pantanal, Estado do Mato Grosso do Sul 2023). The expansion often leads to the conversion of natural habitats into farmland, creating a pressing need to understand how landholders balance agricultural production with conservation behavior. The varying degrees of land conversion across properties provide a natural gradient for studying how agricultural intensity impacts conservation behavior. The Pantanal features a range of land use practices, from traditional, low-impact cattle ranching to more intensive agricultural activities (Chiaravalloti et al. 2023). This diversity allows researchers to explore how different levels of agricultural development influence ranchers' conservation behavior. For instance, ranchers managing more intensively farmed land might prioritize different conservation strategies compared to those on less altered landscapes. The Pantanal is highly susceptible or adaptable to environmental changes, such as seasonal flooding and drought, which are exacerbated by climate change and land use alterations. These factors create a sense of urgency for conservation, as unsustainable agricultural practices could have long-lasting negative impacts on the region's ecological balance. Studying conservation behavior in this vulnerable landscape offers valuable lessons on how to enhance conservation outcomes under changing environmental conditions. The Pantanal is already the focus of various conservation initiatives, but these efforts often face challenges due to conflicting land use priorities. By examining how ranchers' intentions align with or diverge from these conservation goals, such as the sustainable practices in the new Pantanal law (Estado do Mato Grosso do Sul 2023), researchers can identify gaps and opportunities to improve the effectiveness of conservation programs in the region.

This study explores the relationship between the level of agricultural farmland on a property and the rancher's intention to adopt conservation/certification schemes (hereafter referred to as conservation programs) practices, offering insights into how land use dynamics shape conservation behavior and identifying opportunities to enhance conservation outcomes in agricultural landscapes.

Methods

Study area

The Pantanal wetland, located in the Upper Paraguay River Basin, spans 179,300 km² across Brazil, Bolivia, and Paraguay (Figure 1). It has distinct wet and dry seasons, with seasonal floods shaping its biodiversity, nutrient cycles, and productivity. The landscape is a mix of floodable and non-floodable grasslands, forests, woodlands, and aquatic habitats. For further details see "*Study area*" in chapter 2.

Figure. 1. Brazilian Pantanal (dark gray) located in South America.

Ranchers' intention

In this study, a rural owner's intention was defined as follows: a farmer anticipates the adoption to conservation/certification schemes, on at least part of the property, in the next three years. To do so we utilized the ranchers' response regarding their intention from chapter 2. The data is also available at the DOI 10.5522/04/28293263 in the UCL data repository. Three items assessed participants' intention to adopt conservation programs, measured on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). The degree of intention was assessed using a mean of the intentions for each of the interviewed.

Land Use Projection

For the land use analysis, we used the data available from MapBiomas (Souza et al. 2020) considering the categories available in the Pantanal both natural and converted areas and we also added categories derived from MapBiomas (such as porc_Farming or porc_Grassland, where "porc" means percentage as in percentage of the property covered in such category) to facilitate the analysis as they were not explicit in the MapBiomas (Table 1). The categories of percentages also aids in diluting the effects of the size of the properties that are highly variable in the Pantanal, varying from 4 ha to 64 thousand ha in our interviews. We calculated the amount of each category in each of the interviewed property. From these categories we conducted a Generalized Linear Model (GLM) between the intention and the categories for each of the interviewed property.

Table 1. Categories used on the analysis from MapBiomas. In the Non MapBiomas categories, “porc” means percentage (as in percentage of the property covered in that category). The reference Column indicates which categories were compiled together and especially for the Non MapBiomas why they were used.

	Categories	Reference
MapBioms categories	NO_DATA Forest formation Savanna formation Floodable forest (beta) Forest plantation Wetland	
	Grassland Pasture Sugar cane Mosaic of uses	Blanco et al. (2022) Lesch & Wachenheim (2014)
	Urban area Other non-vegetated areas Rocky outcrop Mining River lake	
	Soybean Other temporary crops Forest/non-forest natural Farming Grassland Pasture Soybean	Blanco et al. (2022) Lesch & Wachenheim (2014)
	River Lake	
Non MapBiomas categories	Size of closest conservation unit Distance to closest conservation unit Size of closest indigenous area Distance to closest indigenous area Closest conservation unit or indigenous area Size closest conservation unit or Indigenous area Distance to closest conservation unit or indigenous area	Guerbois & Fritz (2017)
	Size of property in pixels Porc forest/non forest natural Porc farming Porc grassland Porc pasture Porc soybean Porc river lake	Blanco et al. (2022) Lesch & Wachenheim (2014)

After selecting the model with the GLM, we calculated the amount of each of the categories from MapBiomas for each property in the Pantanal Registered in the CAR (Cadastro Ambiental Rural). Then we applied the model from the GLM to calculate the mean intention for each property in the Pantanal.

Results

For details on the properties that were interviewed refer to chapter 2.

Among the categories used for model selection, the Percentage of Grassland (Estimate = -4.664e-03; p-value < 0.05), Amount of Pasture (Estimate = -1.052e-05; p-value < 0.05), and Distance to Conservation Units/Indigenous Land (Estimate = 3.935e-06; p-value < 0.05) were significantly correlated with the intention to adopt conservation schemes, with the values of estimate indicating a negative correlation between Amount of pasture and Percentage of grassland with the Intention (the lower the Amount of pasture and Percentage of grassland the higher the intention), and positively correlated with the distance to Conservation units/Indigenous lands (the further from a site of this category the higher the intention). Using the GLM-derived function for this correlation, we applied it for each of the properties using categories from the model and the values for each of these categories in each property and projected the mean values for Intention for all properties in Pantanal (Figure 2.). Size of property was not significant in our results, as well as the other categories presented in table 2.

The intention values for all properties in the Pantanal in our results ranged from 0 to 2.02 on a scale of 0 to 5.

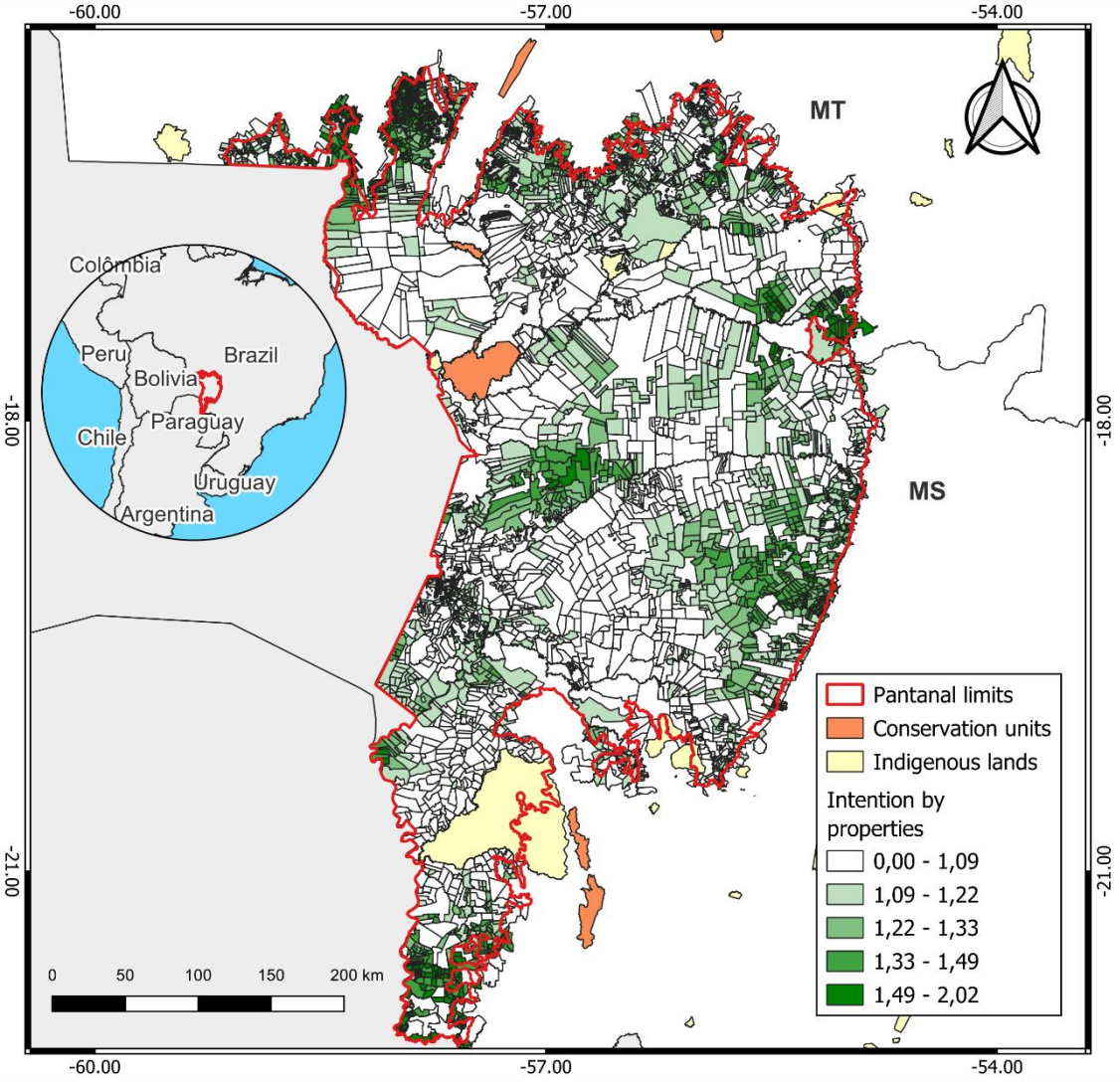

Figure 2. Projection of the intention to adopt conservation schemes in the Pantanal.

Discussion

The results of our study present a counterintuitive finding that challenges our initial prediction. We anticipated that ranchers with properties containing more conserved land would have a stronger intention to adopt conservation practices, as these areas might be perceived as more valuable for preservation, and larger properties would have lower Intention of adoption. However, our results study reveal that ranchers are actually more inclined to adopt certification schemes on properties where a larger portion of the land has already been converted to agricultural farmland. Counterintuitively, size of property, which usually influences ranchers' intentions and behaviors, particularly in the context of land use and wildlife interactions (Godar et al. 2012) was not significant in our results.

Although the intention values in our results ranged from 0 to 2.02 on a scale of 0 to 5, this should not be interpreted as a low overall intention for the entire Pantanal, as several factors not included in our analysis—such as income, herd size, political engagement, and personal circumstances—may also influence intention and adoption. Instead, this scale should be understood as indicating relatively lower or higher intention in a given area compared to the broader Pantanal region.

This unexpected outcome suggests several possible explanations. One potential reason could be that ranchers on more developed properties may feel a greater sense of urgency to implement conservation practices to mitigate the environmental impacts of agricultural expansion (see Painter et al. 2020). As farmland increases, the pressure on remaining natural habitats intensifies, possibly prompting ranchers to take action to preserve what is left or to restore degraded areas. Which is the case of the Pantanal Arch – that is the border of the Pantanal with other Brazilian biomes – where more of the land has been converted compared to the central areas of the Pantanal (Souza et al. 2020).

Another factor might be the economic dynamics at play. Ranchers managing properties with significant agricultural development may have more financial resources or access to incentives that support conservation initiatives. For example, programs such as Agri-Environment Schemes (AES) and Payments for Ecosystem Services (PES) have significantly promoted the adoption of conservation agriculture, although, their effectiveness is often constrained by a limited variety of incentive options (Bakali et al. 2023). Additionally, these ranchers might view conservation practices as a way to enhance the sustainability of their agricultural operations, improve soil health, or secure long-term productivity, thus aligning conservation with their economic interests. Even if conservation practices do not directly lead to higher prices in the domestic market, they could improve the competitiveness of their products in international markets—particularly in regions like Europe—where consumers and regulators increasingly favor goods produced with environmentally responsible practices (De Canio & Martinelli 2021). By integrating conservation into their operations, ranchers can position themselves as sustainable producers, potentially opening doors to new markets and securing a competitive edge abroad.

Conversely, motivations of ranchers with less converted land may feel less immediate pressure to adopt conservation practices, they may see the preservation of natural land cover as a sufficient form of conservation. Since their land has already been minimally impacted by agricultural practices, they might believe that maintaining the status quo is enough to protect the environment (see Ozlu et al. 2022). This could lead to a perception that additional

conservation measures are unnecessary or even redundant, as they view the natural landscape itself as inherently resilient. Additionally, conventional approaches might stem from a generational viewpoint on land stewardship, where there's a solid social or authentic connection to the land in its normal state. These ranchers might prioritize conservation practices that align with maintaining the landscape as it has been for decades, rather than implementing new conservation schemes that require changes to their usual practices or even having to invest time and money in such schemes (Fischer et al. 2012, Guadilla-Sáez et al. 2019). Furthermore, these ranchers' attitudes might influence and/or be influenced by policy and outreach efforts. Conservation programs often emphasize active measures to protect and restore biodiversity (Grantham et al. 2010, Redford et al. 2018), but for ranchers who already have significant natural land cover, these approaches may not resonate. This gap highlights a potential need for tailored conservation strategies that acknowledge and integrate the value these ranchers place on passive conservation, encouraging them to adopt measures that align with their values without feeling pressured to change long-standing practices (Lindsey et al. 2009, Reiter et al. 2021). Ranchers' conservation behavior are shaped by their relational values, sense of self-efficacy, and concerns regarding property rights, and those who perceive themselves as stewards of nature and recognize the environmental value of their land are more inclined to implement conservation practices (Wardropper et al. 2024).

However, maintaining the status quo in minimally impacted agricultural lands is not sufficient to protect the environment (Lee et al. 2019, Adegbeye et al. 2020, Calatrava et al. 2021). Research consistently shows that adopting sustainable farming practices, such as conservation tillage, organic farming, and integrated pest management, can significantly enhance soil health, reduce greenhouse gas emissions, and improve overall environmental sustainability. These practices are crucial for achieving long-term agricultural productivity and environmental protection.

In sum, ranchers tend to favor conservation practices that align with traditional methods, as these are often perceived to offer ecological benefits while seamlessly integrating into their existing practices. This preference underscores the importance of designing conservation strategies that respect and build upon established land-use traditions, since in Latin America, ranchers integrate conservation practices that align with their production goals, motivated by utilitarian and stewardship values (Calle 2019). Although financial incentives and community involvement can provide crucial support for the adoption of conservation measures, a deeper understanding of the socioecological dynamics inherent to traditional landscapes is vital (Dorresteijn et al. 2015, Guadilla-Sáez et al. 2019). By incorporating these dynamics into policy and program design, conservation efforts can become more context-sensitive, fostering greater acceptance and ensuring long-term sustainability. Ultimately, bridging traditional practices with innovative conservation approaches is key to achieving both ecological and socioeconomic resilience.

Practical implications of our study

The results emphasize the intricate nature of conservation-related decision-making and point to the necessity for customized strategies when encouraging conservation practices among landowners. They suggest that conservation programs might achieve better outcomes by focusing on ranchers with more developed properties, where there is a stronger inclination toward adopting conservation measures, and by equipping them with the necessary tools and

resources to implement these practices effectively. For ranchers managing less developed lands, efforts could be directed towards building awareness about the long-term advantages of proactive conservation and offering incentives that align with their current land management approaches, such as Payments for Environmental Services that encourage the preservation of native vegetation remnants beyond legal requirements can serve as a strategy to reward conservation efforts.

In conclusion, the study illustrates that the connection between agricultural land use and conservation intentions is complex and shaped by a variety of social, economic, and environmental factors. This finding highlights the importance of understanding each landholder's unique context when creating and deploying conservation policies and programs, ensuring they align with the distinct motivations and challenges of different rancher groups.

General conclusions

Research in the Pantanal is increasingly embracing interdisciplinary approaches that integrate social and environmental sciences to address global sustainability challenges, aligning with international agendas such as IPBES, CBD, IPCC, RAMSAR, and UNEP (Ioris 2013, 2016, Thomas et al. 2019, Wantzen 2024). There is a growing emphasis on incorporating traditional and local knowledge into scientific research to improve environmental management and policymaking (Eufemia et al. 2018, Schulz et al. 2019). Key research priorities include biocultural diversity, wildfire management, and strengthening science-policy collaborations. However, critical gaps persist in socio-ecological studies, underscoring the need for interdisciplinary research programs, integrative agendas, and increased funding. Expanding initiatives like Pontes Pantaneiras and Nooledi to foster co-constructed knowledge will be vital for advancing sustainable development in the region.

Regarding conservation adoption in the Pantanal, findings suggest that ranchers exhibit a cautious approach to new schemes, largely due to the biome's unique environmental regime and production constraints. The integration of the Theory of Planned Behavior (TPB) and Diffusion of Innovation (DOI) frameworks indicates that conservation and certification schemes must consider both ecological and economic benefits while addressing key behavioral drivers influencing ranchers' decision-making. To ensure successful adoption and dissemination, these initiatives should align with existing production cycles and local socio-economic conditions.

Moreover, ranchers tend to favor conservation practices that complement traditional land-use methods, as these are often seen as ecologically beneficial and easier to integrate into their operations. In Latin America, conservation adoption is commonly driven by both utilitarian and stewardship values (Calle 2019), highlighting the importance of designing policies that align with producers' goals. While financial incentives and community engagement are crucial in supporting conservation efforts, a deeper understanding of socio-ecological dynamics is necessary for crafting context-sensitive policies that enhance acceptance and long-term sustainability (Dorresteijn et al. 2015, Guadilla-Sáez et al. 2019). Bridging traditional practices with innovative conservation strategies is essential for achieving ecological resilience while maintaining economic viability.

Ultimately, this study underscores the complex interplay between agricultural land use and conservation intentions, shaped by diverse social, economic, and environmental factors. Effective conservation policies must be tailored to the specific motivations and challenges faced by different rancher groups, ensuring that interventions are both practical and impactful in fostering sustainable land management.

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