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An assessment of ecosystem services for the Brazilian Pantanal and Upper Paraguay River Basin: Socioeconomic instruments for biodiversity conservation and the sustainable use of natural resources

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Review board

To my lovely wife Thayne and
our beloved daughter Olga.

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With profound gratitude,

Fábio Bolzan

Summary

General abstract

This thesis addresses the importance of valuing ecosystem services (ES) as well as the spatialization of Nature's Contributions to People (NCP), using the Brazilian Pantanal and the Upper Paraguay Basin as a model. We highlight the challenges faced in the management and conservation of ES in these regions, including the need for public policies that recognize the value of nature's contributions to people (NCP). Nature's contributions to people in the Pantanal and Upper Paraguay Basin include material benefits such as food, water, wood, and medicine, as well as non-material benefits such as recreation, tourism, spirituality, and mental health. We address the importance of valuing and spatializing nature's contributions as powerful tools for developing strategies and policies that balance economic growth with environmental protection in our study area. We discuss the main challenges and opportunities of ES monetization and how the congruence or divergence between people's needs for nature's contributions can be an interesting model used to support decision-making by both public and private entities in a more assertive and efficient way.

Resumo geral

Esta tese aborda a importância da valoração dos serviços ecossistêmicos (SE) bem como a espacialização das Contribuições da Natureza para as Pessoas (CNP), utilizando como modelo o Pantanal brasileiro e a Bacia do Alto Paraguai. Destacamos os desafios enfrentados na gestão e conservação dos SE nessas regiões, incluindo a necessidade de políticas públicas que reconheçam o valor das CNP. As contribuições da natureza para as pessoas no Pantanal e na Bacia do Alto Paraguai incluem benefícios materiais, como alimentos, água, madeira e medicamentos, bem como benefícios não materiais, como recreação, turismo, espiritualidade e saúde mental. Abordamos a importância da valoração e espacialização das contribuições da natureza como ferramentas poderosas para o desenvolvimento de estratégias e políticas que equilibrem o crescimento econômico com a proteção ambiental na nossa área de estudo. Discutimos os principais desafios e oportunidades da monetização dos SE e como a congruência ou divergência entre as necessidades das pessoas pelas contribuições da natureza pode ser um modelo interessante usado para subsidiar tomadas de decisão tanto por entes públicos quanto privados de forma mais assertiva e eficiente.

General introduction

Wetlands are ecosystems characterized by the presence of water in sufficient quantity to influence vegetation and fauna and can include a wide variety of habitats, such as freshwater swamps, mangroves, marshes, lakes, rivers, and estuaries (Junk 1993, da Cunha et al. 2015, Sieben et al. 2018). These ecosystems are essential for maintaining biodiversity, as they harbor a great variety of plant and animal species, many of which are endemic. In addition, wetlands perform vital functions for the planet, such as climate regulation, water purification, flood prevention, and protection against erosion (Mitsch et al. 2013). They are also important for fishing, agriculture, and tourism, providing food, raw materials, and leisure opportunities for local communities and visitors (Metcalfe et al. 2018).

However, wetlands are threatened by various human activities (Hu et al. 2017). Urbanization, for example, leads to the degradation and loss of wetland areas. Intensive agriculture can also cause damage to wetlands with the suppression and conversion of native vegetation inside and/or surrounding of wetlands, exerting pressuring on people and nature with the excessive use of fertilizers and pesticides which can contaminate the water and soil, in addition to accelerating erosion and silting processes (Guerra et al. 2020b, Roque et al. 2021, Wantzen et al. 2023). When wetlands are lost or poorly managed, it can increase, for instance, the risk of flooding, which can expose human lives, property, biodiversity and its related ecological functions and ecosystem services. Wetlands also provide important cultural services, such as recreational opportunities, spiritual and religious values, and traditional knowledge and practices (Almeida-Gomes et al. 2022). Many indigenous and local communities rely on wetlands for their livelihoods, using them for fishing, hunting, and gathering. In addition, wetlands also have aesthetic and educational values, providing opportunities for nature-based tourism activities and environmental education (Chiaravalloti et al. 2022).

These benefits that people obtain from nature are called Ecosystem Services (ES) or Nature Contribution to People (NCP) and they are essential for human survival and for the functioning of ecosystems worldwide (Díaz et al. 2015, 2018, Chaplin-Kramer et al. 2019). Nevertheless, they are often considered free and therefore not valued properly. As a result, ecosystems are frequently degraded or destroyed in the name of economic development, without considering the associated environmental and social costs and consequences (Nordhaus 2019, Malhi et al. 2020).

Ecosystem services valuation (ESV) can be used to inform public policies, evaluate development projects, and promote ecosystem conservation and it may represent a way of internalizing the externalities of human actions (Lienhoop and Schröter-Schlaack 2018, Camacho-Valdez et al. 2020, Bolzan et al. 2021). ESV is an interdisciplinary research area that involves economists, ecologists, biologists, geographers, and other specialists with several approaches, including contingent valuation, travel cost valuation, hedonic valuation, and production valuation (Costanza et al. 1997, de Groot et al. 2012). ESV has been widely used in developed countries such as the United States and Europe, but it is still relatively new in developing countries such as Brazil (Watson et al. 2019). Additional, ESV is becoming increasingly important, working to ensure that ecosystem services are valued and that their conservation and sustainable use is prioritized in development decisions (Costanza 2020).

One of the challenges of ESV is that it requires a comprehensive understanding of the ecological, social, and economic factors that influence ecosystem services (Santos-Martín et al. 2019, Kieslich and Salles 2021). This requires collaboration between different disciplines and stakeholders, including scientists, policymakers, and local communities. ESV also requires the development of appropriate methods for valuing ecosystem services, which can be complex and context specific(Santos-Martín et al. 2019). Despite these challenges, the ESV has the potential to be a powerful tool for managing and conserving ecosystems (Sannigrahi et al. 2019). By assigning a monetary value to ecosystem services, the ESV can provide support and, consequently, more assertiveness in decision-making (Huu Loc et al. 2020, Bherwani et al. 2020). This can lead to more sustainable and equitable development that considers the needs of both people and the environment (Ellis et al. 2019).

Another useful approach to decision-making and prioritization of areas for conservation, restoration or production is the spatial representation of the contributions of the nature and people's needs (Guerry et al. 2015, Chaplin-Kramer et al. 2019). Understanding where people's needs are greatest for certain benefits of nature can significantly facilitate the allocation of resources, the development of more efficient public policies that consider people's well-being as well as the sustainable use of natural resources. In this sense, this work was divided into two chapters using the Upper Paraguay Basin and the Brazilian Pantanal as the study area.

In the first chapter, we explore the importance of recognizing and valuing the multiple services provided by nature, which sustain life on our planet. The degradation and loss of these services have led to significant challenges for sustainable development, including climate change, biodiversity loss, and food and water insecurity. To address these challenges, public policies are needed to maintain and enhance ecosystem services. The development of such policies requires a comprehensive understanding of the economic, social, and cultural values of these services. In recent decades, the discussion of ecosystem services has mostly focused on their monetization and economic valuation. However, there are still many regions and ecosystems where such approaches are underdeveloped, and others where local scales and particularities have not been properly considered. This chapter provides an overview of the challenges and opportunities associated with the valuation of ecosystem services for sustainable development. We discuss the importance of a pluralized valuation approach that includes environmental, social, and cultural values, and the need for financial incentives for conservation to be followed by education and communication programs. We also highlight successful local initiatives that can be scaled-up in the coming years, such as the Project Fazenda Pantaneira Sustentável (Santos et al. 2017) and the ‘Manancial Vivo’ Program (Sone et al. 2020). We suggest that the development of effective ecosystem services valuation processes requires the involvement of multiple stakeholders and the integration of scientific, economic, and social perspectives. By recognizing and valuing ecosystem services, we can promote sustainable development and ensure the well-being of current and future generations.

The second chapter provides a comprehensive overview of the importance of wetland ecosystems and of the ecosystem services they provide to people’s needs. This chapter introduces the concept of “Wetspots” (i.e., areas where the contributions of nature and the needs of people are very high), using for this the material and non-material dimensions of ecosystem services, highlighting landscapes or municipalities that provide disproportionate benefits to people. Finally, the document presents case studies and examples of public policies aimed at protecting wetlands and their ecosystem services. Overall, this document emphasizes the urgent need to protect and conserve wetlands for the benefit of both the environment and human society.

The last part of this work, appendix, contains of hyperlink to the main scientific articles and chapters of books published during the doctoral course and that contributed directly or indirectly to the consolidation of the chapters of this thesis as well as to the improvement of our skills. In general, these works present proposed agendas for the Brazilian Pantanal and the Upper Paraguay Basin with the aim of improving public conservation policies, promoting collaboration between science, policy, and development, and addressing the challenges in one of the largest and most diverse wetlands of the world. The comprehensive study highlights the significance of local biodiversity in providing cultural ecosystem services for tourism, recreation, and sustainable development, while also calling for further research on indigenous culture and spiritual values. Additionally, the study underscores the interconnectedness of ecosystem services with human perceptions and practices, emphasizing the need to preserve these services in the face of potential threats from development projects.

Monetary value of the ecosystem services of the Pantanal and its surroundings: first approximations and perspectives

Abstract

Although they occupy only 3% of the global surface area wetlands represents 43.5% of the global monetary value provided by ecosystem services (ES). The Pantanal is one of the biggest wetland areas and provides many types of ES as goods and services for humanity, including a highly diversified flora and fauna; food, freshwater, and pastureland; climate stability and flood control; scenic beauty, recreation, spiritual and cultural diversity, and wellbeing. Here, we updated the monetary valuation of ES for the Pantanal and Upper Paraguay River Basin (UPRB) based on recent ecosystem maps and more detailed land cover classifications. Hence, we stimulate further discussions and development of valuation processes.

Valor monetário dos serviços ecossistêmicos do Pantanal e planalto circundante: primeiras aproximações e perspectivas

Resumo

Embora ocupem apenas 3% da superfície global, as zonas úmidas representam 43,5% do valor monetário global fornecido pelos serviços ecossistêmicos (SE). O Pantanal é uma das maiores áreas alagáveis e fornece muitos tipos de SE como bens e serviços para a humanidade, incluindo uma flora e fauna altamente diversificadas; alimentos, água doce e pastagens; estabilidade climática e controle de enchentes; beleza cênica, recreação, diversidade espiritual e cultural e bem-estar. Aqui, atualizamos a valoração monetária dos SE para o Pantanal e a Bacia do Alto Paraguai (BAP) com base em mapas de ecossistemas recentes e classificações mais detalhadas de cobertura da terra. Assim, estimulamos novas discussões e desenvolvimento de processos de valoração.

Introduction

The valuation of multiple ecosystem services (ES) provided by nature and the development of public policies to maintain those services that sustain life on the planet (https://www.millenniumassessment.org; http://www.teebweb.org); (https://www.ipbes.net; https://www.bpbes.net.br) are among the most important challenges facing sustainable development. In recent decades, discussion of this issue has mostly focused on ES monetization (Costanza et al. 1997, Wilson and Carpenter 1999, de Groot et al. 2002, Gómez-Baggethun and Ruiz-Pérez 2011). Although ES economic valuation has been performed in many parts of the planet, there are still many regions and ecosystems for which such approaches are underdeveloped, and others where local scales and particularities have not been properly considered (Tammi et al. 2017).

ES monetization, commoditization, and valuation have been shown to be powerful tools for the development of public and private policies focused on ecosystem management and conservation (Tallis and Polasky 2009, Kumar et al. 2013, Alkemade et al. 2014, Trischler and Charles 2019). The description of the monetary value of stocks, demands and flows of ecosystem functions at different spatial and temporal scales simplifies the communication on ES importance and opens dialogue opportunities between government, environmental entities, society and market. However, a substantial effort is required to transform such ecological estimates into public policies and effective management plans (Costanza et al. 2017).

Value of natural wetlands

Wetlands occupy 3% of the global surface area but constitute 43.5% of the global provision of ES. Inland, coastal, nearshore, and marine wetlands sustain and generate a wide range of ES. The monetary value of ES (Davidson et al. 2019) goes beyond the considerable diversity of plants and animals they contain; it includes regulation, provision and cultural services that directly affect society in general. For instance, carbon storage and sequestration contribute significantly to climate regulation (Kayranli et al. 2010), playing an important role in mitigating the effects of climate change (https://www.millenniumassessment.org), as well as controlling the regional dynamics of nutrients, the biochemical and hydrological cycles so essential to fisheries and food security (Bullock and Acreman 2003, Reddy and DeLaune 2008, Huygens et al. 2013, Sueltenfuss and Cooper 2019).

The seminal study of Costanza et al. (1997) provided the first estimate of the global monetary value of the direct benefits provided by wetlands in terms of ecosystem services (US$ 14 trillion/year), later updated to US$ 50.7 trillion/year based on more detailed mapping tools (Costanza et al. 2014). De Groot et al. (2012) provided a more refined value for ES offered by inland wetlands, based on 168 studies, reaching a value of US$ 25,682 per ha/year. More recently, Davidson et al. (2019) estimated the global value of wetland ES as US$ 47.4 trillion/year using new information and a revised coastal and inland wetland classification.

As might be expected, the monetary valuation of ES varies as a function of the methodologies, criteria and types of ecosystem services measured. Establishment of a standard approach to all kinds of wetlands is a challenge owing to their high environmental heterogeneity. For this reason, measuring specific services as indicators for particular areas is an appropriate method to support the development of regional public policy strategies (Trischler and Charles 2019).

The Pantanal and its surroundings

The Pantanal is considered one of the most important ES hotspots in the world, occupying 179,300 km², and located in the center of South America (Tomas et al. 2019). This wetland lies within the central portion of the Upper Paraguay River Basin (UPRB) and receives contributions from the various sub-basins draining the upland savannas of central Brazil, Bolivia and Paraguay. Around 80% of Pantanal native vegetation remains, while some 60% of its Cerrado-covered plateaus have been converted to pasture and croplands (Roque et al. 2016). This ecosystem houses healthy populations of endangered species, such as jaguar (*Panthera onca*), giant otter (*Pteronura brasiliensis*), marsh deer (*Blastocerus dichotomus*), and Hyacinth macaws (*Anodorhynchus hyacinthinus*) (Tomas et al. 2011, 2015, Cavalcanti et al. 2012). The Pantanal is a highly dynamic sedimentary floodplain macro-ecosystem influenced by an annual flood pulse caused by the Paraguay River and its tributaries, and regional geomorphological characteristics (Junk 1993, 1999, Kleidorfer et al. 2009, Alho and Sabino 2012). The spatial and temporal heterogeneity of the landscape provides many types of ES as goods for human wellbeing, including a highly diversified flora, fauna and habitat types (biodiversity); food, freshwater and pastureland (provisioning); climate stability and flood control (regulation); scenic beauty, recreation, spiritual and cultural diversity (socio-cultural) (Seidl and Steffens 2000, Sandifer et al. 2015).

Costanza et al. (1997) estimated the value of Pantanal's environmental services at US$ 10,000 per ha/year. However, their evaluation did not consider the heterogeneity of this wetland system, comprising distinct sub-regions (da Silva et al. 1998). Seidl and Moraes (2000) estimated the value of ES in the Nhecolandia Pantanal sub-region at 15.5 billion dollars per year, resulting in a per hectare value that is 50% lower than calculations of Costanza et al. (1997). Seidl and Moraes's study was the first regional study guided and focused on data collected from the Pantanal River basin to provide a detailed ES analysis, using water supply and disturbance regulation as the main services and benefits identified.

In this chapter, we aim to update the monetary valuation of ES for the Pantanal and Upper Paraguay River Basin (UPRB) based on recent available data including ecosystem maps and detailed land cover classifications, and therefore stimulate further discussions and development of valuation processes. We included the UPRB as an integrated unit in our analysis because of the tight functional, ecological, social and economic interdependency between Pantanal wetlands and Cerrado uplands (Hamilton 2002).

Estimating the Pantanal and UPRB ES monetary value

We used the mean unit values from de Groot et al. (2012) and Costanza et al. (2014) to extrapolate estimated values for each land cover type (e.g., grassland, forest, freshwater) in the Pantanal and Upper Paraguay River Basin in Brazil. We regionalized the evaluation using MapBiomas Collection 2.3 datasets (http://mapbiomas.org) to calculate the total area of the different ecosystems and land use types in the Pantanal and on the surrounding plateaus (corresponding to the UPRB).

Based on the map of wetlands, woodland ecosystems (savannas and forests), grasslands and freshwater (Fig. 1), we attributed the values proposed by De Groot et al. (2012) to the following ecosystem services: provision services, regulating services, habitat services and cultural services. Hence, we considered these as ES provided by the natural ecosystems. In the case of landscapes modified by anthropic activities (cattle production and crops), we calculated the net margin value per hectare using the most recent available databases (de Oliveira et al. 2016, Richetti et al. 2017) and we considered these as ES provided by anthropogenic activities.

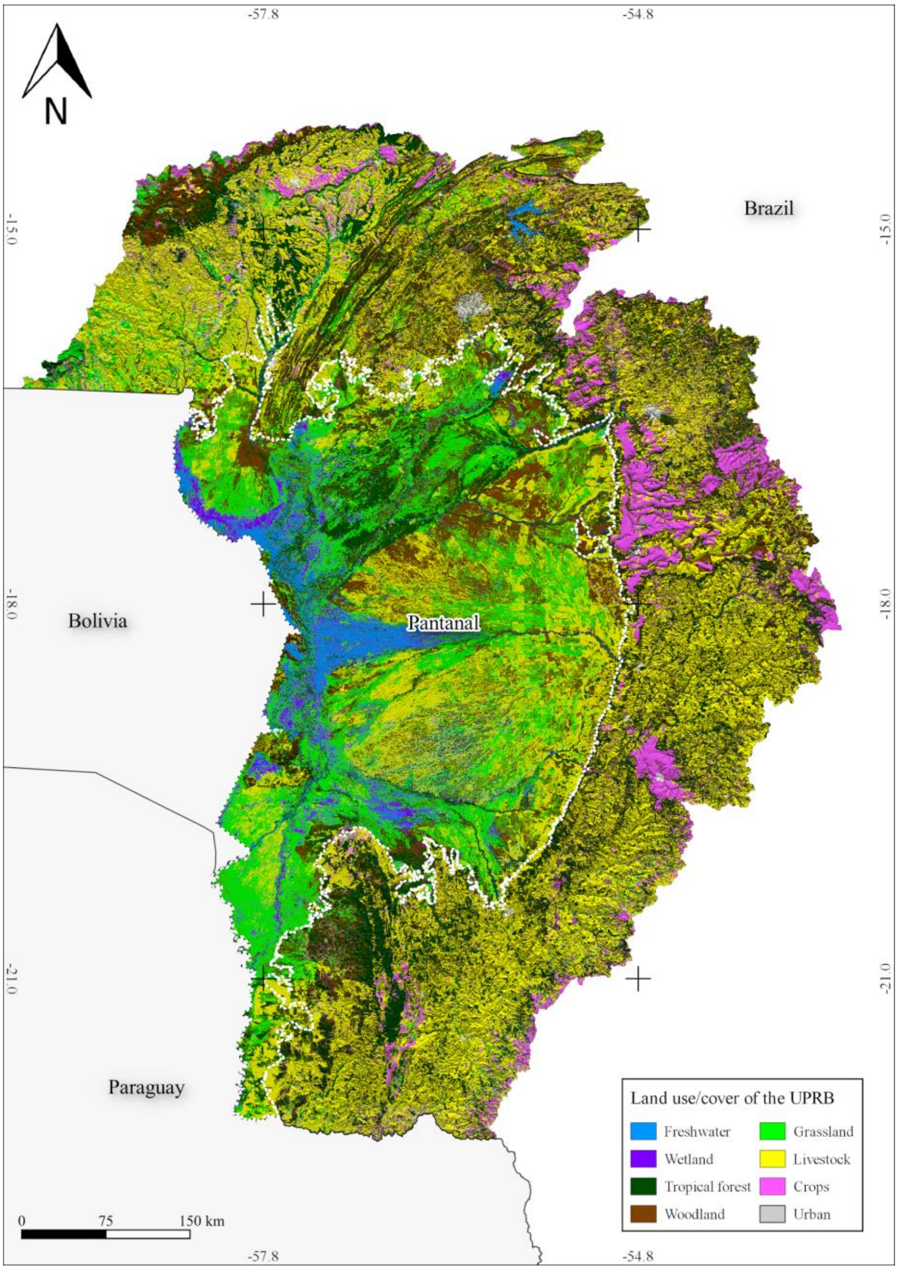

Figure 1. Different ecosystems and land-use types in the Upper Paraguay River Basin (UPRB), Brazil, based on 2017 land cover maps. The white line indicates the boundary between the Pantanal floodplain and the plateau.

First approximation of the UPRB ES monetary value

Our exercise resulted in a total value of US$ 95 billion/year for the UPRB (US$ 2,639.99 per ha/year) of which US$ 59 billion (US$ 3,932.05 per ha/year) being from the Pantanal floodplain (~62%) and US$ 36 billion (US$ 1,712.60/ha/year) from the surrounding plateaus (~38%) (Tab. 1). In terms of average per hectare per year, we find US$ 2,639.99 from the UPRB, US$ 3,932.05 from the Pantanal and US$ 1,712.60 from surrounding plateaus (Tab. 1). When we consider only anthropogenic activities, ~89% of the total net value is from the plateau (US$ 484 of 53 million/year), being the average per hectare per year of US$ 43.21 from the plateau and US$ 20.83 from the Pantanal. On the other hand, if we consider the ES provided by the natural ecosystems, the plateaus provide a value of US$ 35 billion/year (~32%) and the Pantanal of US$ 59 billion/year (~68%) (Tab. 1) On average, per hectare per year for ES, we have US$ 3,650.49 from the plateau and US$ 4,735.76 from the Pantanal.

Our results clearly indicate that the ES value of the Pantanal lands is much higher than currently recognized by the market, society, policy makers, as well as decision makers. Despite this, there is no actual market value for the land since there are neither public policies nor a market for multiple ES values. Our findings open an important window of opportunity to discuss land use and necessary public policies for the Pantanal. The region has considerable potential to conciliate conservation and food production, including restoration programs, payments for ecological services, certifications, and environmental compensation and offsetting mechanisms. Moreover, the monetary value of ES provides an insight into the enormous opportunity represented by economic conciliation of the Pantanal floodplain and the surrounding plateaus.

Table 1. ES values and total areas of different ecosystems and land use systems in the Pantanal floodplain and its surrounding plateaus, and for the entire Upper Paraguay River Basin (UPRB) in Brazil (i.e., Pantanal floodplain and plateaus together).

		Pantanal floodplain		**Plateau**		**UPRB**	
Ecosystems	**US$/ha/year**	**Area(ha)**	**US$/year**	**Area(ha)**	**US$/year**	**Area(ha)**	**US$/year**
Freshwater*	4,267	612,979	2,615,582,844	74,704	318,761,968	687,683	2,934,344,812
Wetlands*	25,682	599,399	15,393,772,052	0	0	599,399	15,393,772,052
Tropical forest*	5,264	4,766,344	25,090,033,711	5,132,841	27,019,272,760	9,899,184	52,109,306,471
Woodland*	1,588	2,143,946	3,404,587,010	3,783,924	6,008,871,677	5,927,871	9,413,458,687
Grassland*	2,871	4,309,942	12,373,843,396	671,824	1,928,805,670	4,981,766	14,302,649,066
Livestock**	20	2,528,129	50,562,588	7,963,344	159,266,885	10,491,474	209,829,473
Crops**	100	26,600	2,659,950	3,254,080	325,407,977	3,280,679	328,067,927
TOTAL		**14,987,340**	**58,931,041,551**	**20,880,716**	**35,760,386,938**	**35,868,056**	**94,691,428,489**
AVERAGE (US$/ha/year)		**3,932.05**		**1,712.60**		**2,639.99**	

*Natural ecosystems. **Anthropogenic activities.

A clear message emerging from our results is that the current monetary gains associated only with the agribusiness (e.g., cattle ranching, soy, maize, sugar cane, cotton, and forestry) are relatively small in comparison with the total monetary value of ecosystem services of untrammeled natural land-cover (Fig. 2 and Fig. 3).

New pieces of the puzzle

Traditional communities and ecosystem services

The cultural richness of the Pantanal is influenced by a mosaic of human cultures in the cross-border region between Brazil, Bolivia and Paraguay. Indigenous populations and traditional people (*Pantaneiros*) coexist in the area, enhancing its cultural richness. The cultural interaction between *Pantaneiros*/indigenous people and natural resources occur in several ways. They use Pantanal areas for fishing, as a source of clean water, for temporary settlements, to capture live bait (crabs and small fish), and to obtain diverse other natural goods. For example, the Pantaneiros use 376 species of medicinal plants, which are used against 18 illness categories (Bieski et al. 2012). A practice inherited from the Guató indigenous culture (Bortolotto and Guarim Neto 2005) is the use of the water hyacinth *Eichhornia crassipes* (Mart.) Solms, (locally called “Camalote”) to make handicrafts. Ceramics produced and painted by Kadiwéu people demonstrate their ethnicity, including geometric representations of their social structure, mystic figures, and legends (Müller 2017). Besides, the black dye for this ceramic is produced from the sap of a native plant species (*Bulnesia sarmientoi*), while the Bocaiúva fruit (*Acrocomia aculeata*) is harvested to produce flour and ice-cream.

Fishing is a key practice in the Pantanal for traditional communities and indigenous people and provides both protein and income.

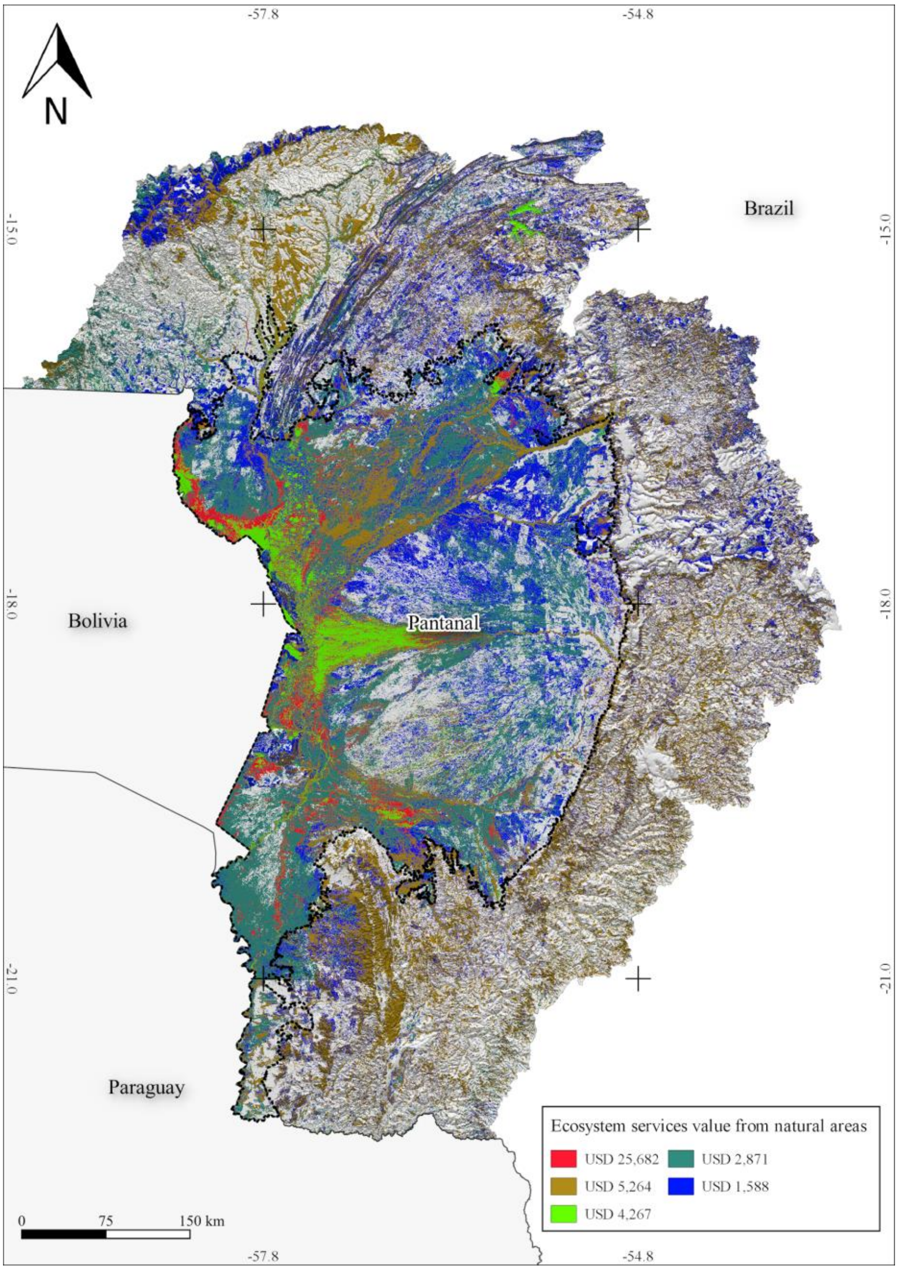

Figure 2. Spatial distribution of the estimated ES values (US$/ha/year) for different natural ecosystems of the Upper Paraguay River Basin in Brazil.

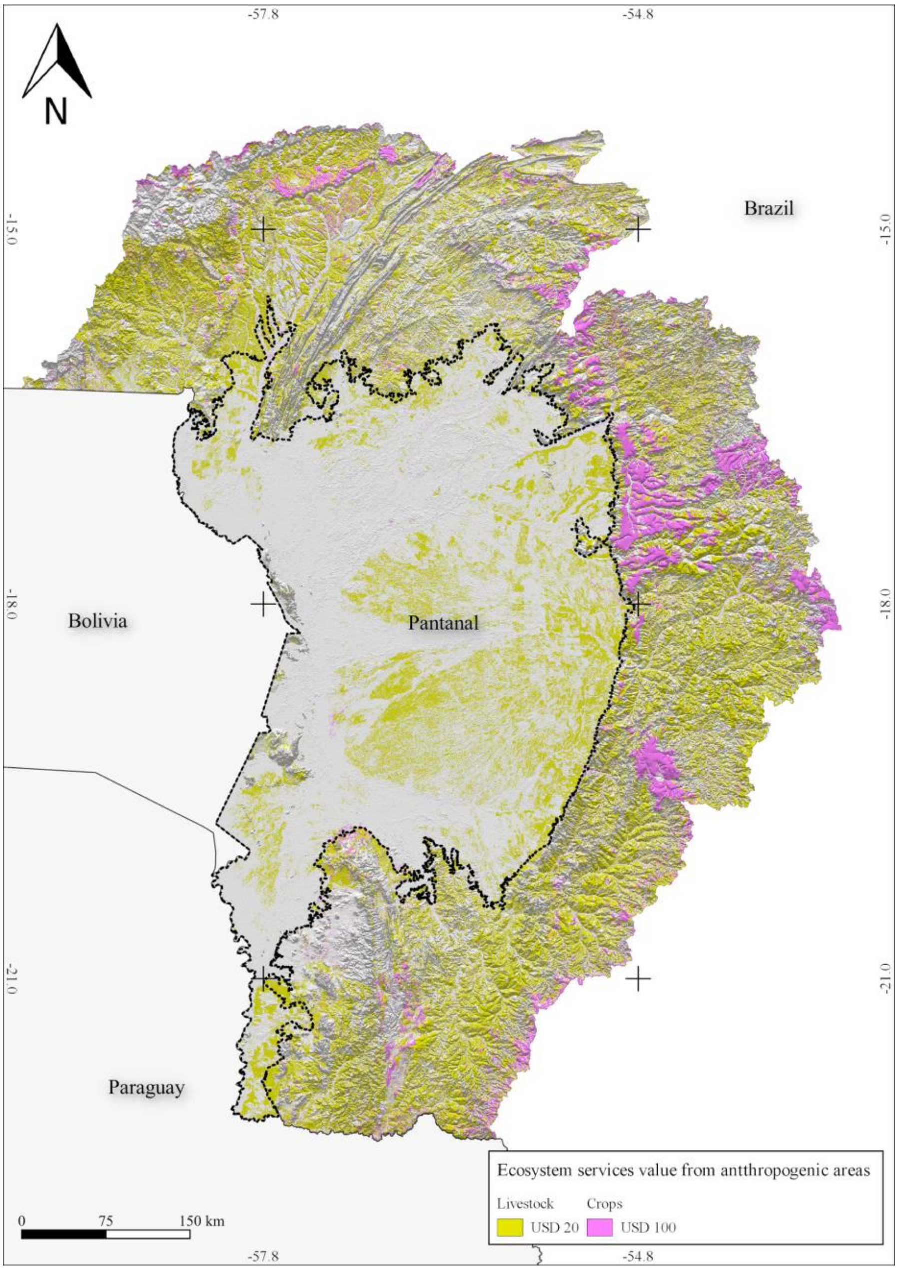

Figure 3. Spatial distribution of the estimated net margin values (US$/ha/year) of anthropogenic areas of the Upper Paraguay River Basin, Brazil.

In a survey carried out on the Paraguay River in the town of Cáceres (Mato Grosso State), only 7% of the respondents worked in agriculture, while 93% were fishermen (Ordonio et al. 2011, Arruda et al. 2014).

Fifteen traditional communities have been recorded in the Brazilian part of the Pantanal wetland; they are distributed mainly along the Paraguay River. These communities are usually composed of an average of 80 fishermen, totaling 1,200 traditional fishermen. This number is smaller than the total number of professional fishermen registered in the southern Pantanal alone (~2,000) (Catella et al. 2014), but highlights the local importance of fishing-based incomes. The average income per fishermen is approximately US$ 300/month (Chiaravalloti 2019), with a yearly income close to US$ 4,320,000 for the fifteen traditional communities, clearly indicating that this is a key activity for the local population and for the Pantanal economy.

The Pantanal may generate US$ 14.40 ha/year for traditional anglers, based on their yearly income (US$ 4,320,000), considering an estimated total area of 300,000 ha for the 15 traditional territories, and an area of 20,000 ha occupied by each community. However, this may be a gross underestimation of the total value. First, not all fishing-associated communities have been identified in the Pantanal and, therefore, remain to be evaluated. In addition, and perhaps most importantly, the value of the Pantanal for local people goes beyond the income generated by fishing. People place great value on locations, which their families have inhabited historically, or regions that have played an important role in their personal lives or family history (Chiaravalloti et al. 2017). Although this type of ES is difficult to valuate without specific methodologies, such as willingness to pay, it represents an important value that must be considered in any management initiative for the region. Hence, at least 300,000 ha of the Pantanal wetland, classified as part of traditional territories, should, in addition to the economic and ecological values, receive enhanced valorization owing to the intrinsic cultural and historic values for those living there.

Other values

Other studies addressing animals and plants have also been relevant to the determination of Pantanal ES values, such as ecotourism (Tomas et al. 2019). Just as an example of such potential, the monetary value of the jaguar (*Panthera onca*) for ecotourism and its contribution to the local economy resulted in a value at 6.8 million dollars/year for the region of the *Encontro das Águas* State Park in the Pantanal of Mato Grosso State (Tortato and Izzo 2017). The values provided by jaguar ecotourism greatly exceed the losses associated with cattle predation, which has been estimated at US$ 121,500/year in a large, representative area (Tortato et al. 2017).

Recreational fishing is highly important for the Pantanal's tourism and economy. In 2016, 14,750 recreational fishermen visited the Mato Grosso do Sul UPRB (Catella et al. 2017). In the towns of Miranda and Corumbá, Mato Grosso do Sul State, this activity provided some 35 to 56 million dollars/year (Shrestha et al. 2002).

Fish also provide ES by regulating food chains, controlling pests, acting in the cycling of nutrients, and offering recreation opportunities (Holmlund and Hammer 1999). At the headwaters that flow into the Pantanal there is a vigorous and growing nature-based tourism market for observing aquatic biodiversity, especially fish (Bessa et al. 2017). However, if tourist activity exceeds visitation limits, there are negative impacts on aquatic biota, such as higher stress responses and negative individual behavioral (Lima et al. 2014).

In addition to wildlife contemplation and ecotourism, other activities, such as the development of productive chains to explore native plants, are also of considerable importance in developing more refined estimates for the value of regional ES. Baru nuts (locally “cumbaru” or “baru”: *Dipteryx alata* Vogel - Fabaceae), for example, have considerable market value and improve the income for many communities and families (Melo 2015). The native Pantanal rice (*Oryza latifolia* and *Oryza glumaepatula*) are also species that can contribute to the economic valuation of this system as a gourmet product for a niche market. These species are naturally abundant in the low-lying areas of the Pantanal impacted by long-lasting floods, can be sustainably exploited by communities, and have great appeal in sophisticated food preparation ((Bertazzoni and Damasceno-Júnior 2011); see also the chapter on monodominant stands). Other species such as the “bocaiuva” palm (*Acrocomia aculeata*), “pequi” (*Caryocar brasiliense*), “guavira” berry (*Campomonesia adamantium*), “mangaba” (*Hancornia speciosa*), “araticum” (*Annona* sp.), “laranjinha-de-pacu” (*Pouteria glomerata*), and several other non-timber products that are traditionally used in the region have been increasingly studied and contribute to aggregate value to the native flora of the Pantanal (Sinatex 2017); see the chapter on native food plants).

One of the major challenges for the monetization of ES based on species in the Pantanal is the spatially aggregated distribution of biodiversity, which limits the estimates to specific regions. For example, jaguars do not occur uniformly throughout the Pantanal area while native rice stands occur only in specific zones of difficult access. Yet, seasonality limits a constant availability of native fruits and will not always be available for harvesting. In addition, recreational fishing is limited to accessible areas on large rivers. Although such ecosystem services are presumably found throughout of Pantanal floodplains, they will not be necessarily converted into commodities and monetarized. Accordingly, future approaches for more refined scenarios must prioritize the analysis of the spatial aggregated distribution of these activities.

Challenges, opportunities, and future

To further the development of the economic valuation of ES values of the Pantanal, it is necessary to advance the regionalization of estimates by providing tools that allow to spatialize the different ecosystems services. This more detailed approach is relevant because on a temporal scale we can fill-in knowledge gaps that can further be applied in land use and its management (Xu et al. 2018, Peçanha et al. 2019).

The development of market measurement systems is an important part of the development of Ecosystem Services Markets, involving basic regional estimates (van Maasakkers 2018). Hence, these relative values can be added to pluralistic valuation methods that reduce discrepancies and broaden the framework of articulations involving human-nature relationships, ecosystem services and biodiversity conservation (Himes and Muraca 2018, Lienhoop and Schröter-Schlaack 2018). However, a great challenge in this approach is the lack of a market for ecosystem services at different governance scales (national, state, municipality). Initiatives such as the REDD+, carbon storage, carbon credit, biobanking and other kinds of monetary activities based on the reduction of climate change drivers and environmental impacts glimpse opportunities, even in the international context.

Large-scale implementation of Payments for Environmental Services (PES) is unlikely in the Pantanal in the short term, owing to the low level of environmental awareness among decision makers and low levels of financial support (Schulz et al. 2015). Moreover, major threats to the Pantanal plain come from upland agribusiness (Roque et al. 2016). Another key challenge is the strong socioeconomic inequality between inhabitants of the Pantanal lowlands and wealthy farmers of the plateau, so that potential suppliers of ecosystem services would face very high opportunity costs to participate in PES schemes. These opportunity costs are related to the privatization of some property rights required for ES exchange initiation, marketization to create opportunities to recover costs, introduction of ES policies or laws, and market facilitation needed to introduce financial or technical resources involving NGOs, universities, and other actors to support the market arrangement (Kolinjivadi et al. 2017).

Such challenges not only apply to PES, but also are valid for any conservation strategy related to ES monetary valuation in the Pantanal, because its lands are mostly private. Hence, we believe that PES, or any kind of financial incentives for conservation, should not be considered a panacea, but instead as part of a pluralized valuation approach that includes environmental, social and cultural values. In addition, financial incentives for conservation should be followed by education and communication programs with the aim of improving the level of environmental awareness among decision makers and stakeholders. It is important to note that, despite the challenges to large-scale PES implementation, there are many successful local initiatives that can be scaled-up in the coming years, such as the Project *Fazenda Pantaneira Sustentável* (Santos et al. 2017), coordinated by Embrapa-Pantanal, and the 'Manancial Vivo' Program (MVP) (Pagiola et al. 2013), which is a partnership between the National Water Agency (ANA) and the municipality of Campo Grande, Mato Grosso do Sul state. The MVP provides funds to farmers who conserve the soil, protect native vegetation, and restore degraded areas in the Guariroba River Basin (Sone et al. 2019). This protected environmental area is the main water supply for Campo Grande. Besides runoff reduction, there were increases in base flow, while soil erosion was reduced by 25% between 2012 and 2016 in the Guariroba River Basin (Sone et al. 2019). The MVP still reaches few farmers, but the results show the importance of applying conservation practices at the farm-level to improve water quantity and quality.

An integrated framework and a more refined analysis of ecological services in the UPBR will not only contribute to achieving a more realistic understanding of the social and economic dynamics of the region but will also contribute to a better integration of views from the various stakeholders and actors. Monetization methods suffer a lot of criticism but, while it may be imperfect, has the advantage of providing valuable information on ecosystem services. Together with social and ecological approaches, stakeholders can use ES monetization to help decision-making (Pascual et al. 2017, Díaz et al. 2018). We believe that a spatially explicit demonstration of the monetary dimension of ecological services will contribute to improve the dialogue between actors (landowners, decision makers, policy makers, investors, conservationists, general society) concerning political solutions capable of reconciliating the often-conflicting demands of agribusiness and biodiversity conservation in the Pantanal over the long-term. In summary, the monetary dimension of ecosystem services should be part of the Pantanal's agenda (Tomas et al. 2019).

Finally, we emphasize that estimates of ecosystem services in the Pantanal are not the same as pricing. In fact, we have shown another value for the biome, as our ES value estimates have underscored the natural potential of this ecosystem to improve local wellbeing. In addition to other regional approaches, this type of estimation can narrow the link between ES and the context of land use and natural area management, providing appropriate information on the economic development and conservation policies for the Pantanal.

“Wetspots”: Exploring socio-ecological landscapes in the Brazilian Pantanal and Upper Paraguay River Basin where nature's contributions matter most to people

Abstract

This chapter addresses the importance of the wetlands of the Pantanal plain and Upper Paraguay Basin (UPRN) in terms of people's demands for the benefits of nature and what nature can offer. We coined the concept of “Wetspot” as a landscape or a municipality that provides contributions from nature where people need it most. We analyzed our data in material (water quality regulation, erosion, and pollination control) and non-material (sacred and ecotourism sites) dimensions spatially superimposed with the location of people. We also explore the use of “Wetspot” incorporated into an Ecological Fiscal Transfer mechanism (ecological ICMS) addressing synergies and tradeoffs against the current Municipal Environmental Index. Our results indicate that there is congruence between people's needs and the benefits of nature in the UPRN Plateau in the material dimension. This can be explained by the greater concentration of people as well as more intensive and demanding agricultural practices, thus representing places where the benefits of nature are most important to people. On the other hand, for the non-material dimension, we found greater consistency in the Pantanal floodplain. This is due to the greater presence of sacred sites and ecotourism in places where nature's contributions are greater. However, there is a low concentration of people both in the “Wetsposts” and throughout the floodplain. We address social and environmental interactions between distant regions of the world, such as tourism and commodity exports, and their implications. These interactions in the context of biodiversity conservation are changing the architecture of threats to nature's contributions, creating challenges and opportunities for efforts towards conservation and sustainable use.

"Wetspots": Explorando paisagens socioecológicas no Pantanal Brasileiro e na Bacia do Alto Rio Paraguai onde as contribuições da natureza mais importam para as pessoas

Resumo

Este capítulo aborda a importância do Pantanal e da Bacia do Alto Paraguai (UPRN) no que se refere as demandas das pessoas pelos benefícios da natureza e o que a natureza está apta a ofertar. Introduzimos o conceito de "Wetspot" como sendo uma paisagem ou um município que provem contribuições da natureza para as pessoas onde elas mais necessitam. Analisamos nossos dados nas dimensões material (regulação da qualidade da água, controle de erosão e polinização) e não material (locais sagrados e de ecoturismo) espacialmente sobreposta com a localização das pessoas. Exploramos também o uso do "Wetspot" incorporado a um mecanismo de Transferência Fiscal Ecológica (ICMS ecológico) abordando sinergias e "trade-off" frente ao Índice Ambiental Municipal atual. Nossos resultados indicam que há congruência entre necessidade das pessoas e os benefícios da natureza no Planalto da UPRN na dimensão material. Isso pode ser explicado pela maior concentração de pessoas bem como de práticas agrícolas mais intensivas e exigente, representando portando, locais onde os benefícios da natureza são mais importantes para as pessoas. Por outro lado, para a dimensão não-material, encontramos maior congruência na planície alagável Pantanal. Isso deve-se a maior presença de locais sagrados e ecoturismo em locais onde as contribuições da natureza são maiores. Porém, há baixa concentração de pessoas tanto nos "Wetspost" quanto em toda a planície alagável. Abordamos as interações sociais e ambientais entre regiões distantes do mundo, como turismo e exportação de comodities e suas implicações. Essas interações no contexto de conservação da biodiversidade estão mudando a arquitetura das ameaças sobre as contribuições da natureza, criando desafios e oportunidades para esforços em prol da conservação e uso sustentável.

Introduction

Wetlands occupy 3% of the global surface area but constitute approximately 41% of the global provision of ecosystem services (ES) (Costanza et al. 2014, Davidson 2014, Gardner and Finlayson 2018, Davidson et al. 2019). Inland, coastal, nearshore, and marine wetlands sustain and generate a wide range of ES (Sieben et al. 2018) and are highly threatened by a range of human activities (Best 2019). The monetary value of ES goes beyond the considerable diversity of plants and animals they contain, it includes regulation, provision, and cultural services that directly affect society in general (Gardner et al. 2015, Eric et al. 2022). For instance, carbon storage and sequestration contribute significantly to climate regulation (Kayranli et al. 2010, Mitsch et al. 2015, Moomaw et al. 2018), playing an important role in mitigating the effects of climate change (Nayak and Bhushan 2022). Wetlands also control the regional dynamics of nutrients, biochemical, and hydrological cycles so essential to fisheries and food security (Bullock and Acreman 2003, Reddy and DeLaune 2008, Huygens et al. 2013, Sueltenfuss and Cooper 2019)

Recognized by their multifunctionality (i.e., ability to simultaneously provide multiple ecosystem functions and services) (Metcalfe et al. 2018), the wetlands are also important for their disproportionate benefits compared to other ecosystems (Costanza et al. 1997, Mitsch et al. 2015, Bolzan et al. 2021). Despite their high socio-ecological benefits and economic values, about two-thirds of the world's natural wetlands have disappeared in the past century, mainly motivated by urban development, tourism, and agriculture (Janse et al. 2019, Camacho-Valdez et al. 2020). Due to the inherent value of the unique ecosystem services performed and provided by wetland ecosystems, there has been great effort to quantify, conserve, and restore the natural functioning of these ecosystems and the services they provide (Mushet and Roth 2020, Xu et al. 2020).

Various models and concepts based on ecosystem services (tab.1) have been useful to assist in planning and managing land use as well as for nature conservation, but many of them do not quantify the beneficiaries of those services (Rieb et al. 2017, Metzger et al. 2021a). In other words, the linkages which establish how ecosystems provide a service that is subsequently used by beneficiaries remain poorly defined for many services (Metzger et al. 2021b). In this way, the Intergovernmental Platform for Scientific Policies on Biodiversity and Ecosystem Services (IPBES) has developed the concept of nature Contribution to People to offer a more inclusive framework for addressing human–nature relationships (Brauman et al. 2019).

The nature contributes to good quality of life in many ways, from providing the basic life support system for humanity to providing material goods and spiritual inspiration (Díaz et al. 2018, Ellis et al. 2019, Normyle et al. 2022) . To connect nature and people's good quality of life, it is important to highlight the distinction between two concepts: the potential NCP and the realized NCP. Potential NCP is the capacity of an ecosystem to provide NCP (Jones et al. 2016, Chaplin-Kramer et al. 2019). For example, the potential of the water quality regulation is the ecosystem capacity to influence the water quality through filtration of particles, pathogens, excess nutrients, and other chemicals, which could in turn support clear water for drink and other essential human activities as food production. But without anthropogenic inputs such fertilizers or land use change to livestock or agriculture from native vegetation, plus time and effort invested, the NCP of water quality regulation will not be realized (fig.1). For non-material NCP, an ecosystem may have the potential to support recreation and tourism, or physical and psychological experience, or yet supporting identities as purpose, belonging, rituals and celebrations. But if people do not actually go there then

Table 1. Overview of concepts used in ecosystem service research.

Concept	Concept description	Concept use
Bundles	Identifies spatially co-occurring ecosystem services (Raudsepp-Hearne et al. 2010)	Exploring ecosystem service spatial relationships
Trade-offs/synergies	Identifies relationships between multiple ecosystem services (Bennett et al. 2009)	Exploring ecosystem service mechanistic relationships
Hot/cold spots	Identifies spatial locations of highest/lowest ecosystem services total value(s) (Reyers et al. 2009)	Exploring best areas for producing ecosystem services
Win-win/lose-lose	Identifies spatially co-occurring optimal or unwanted locations for multiple ecosystem services (Qiu and Turner 2013)	Exploring desirable or degraded area for multiple ecosystem services
Spatial prioritization	Identifies priority areas for ecosystem services and conservation via valuable synergies (Anderson et al. 2009)	Integrating ecosystem services in conservation planning
Bright/dark spots	Identifies spatial locations where ecosystem services deviate from expected (from null model of know or expected drivers) (Frei et al. 2018)	Exploring deviations from expected for ecosystem services

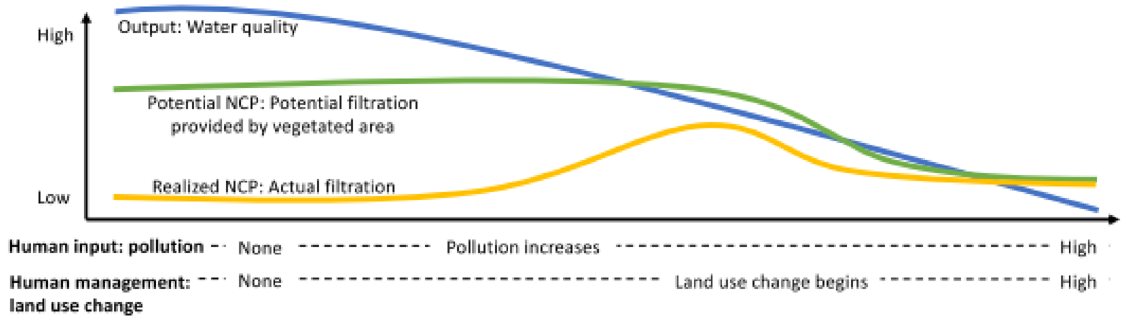

Figure 1. Examples of changes in local co-production of potential NCP, realized NCP, and the output as human pressure increases, represented by pollutant load increases from left to right, as does land use change. The potential of nature to filter water (green line) decreases as people convert vegetation. Realized water filtration (yellow line) is low at the left, because there is no pollution to filter. As pollution increases, realized water filtration increases. As land use change decreases potential filtration, realized filtration also decreases. Eventually land use change ceases; water quality continues to decrease as pollution increases because realized filtration has saturated. Extremely high pollution loads could also degrade the potential NCP (Brauman et al. 2019).

it will not yield benefits realized experiences (Brauman et al. 2019). When considering both nature's contributions and people's needs dimensions (i.e., potential NCP and realized NCP), we can illuminate different points of view to act, both in societal and ecological awareness on the importance of nature's contributions to people and in their integration into decision-making, highlighting where investments in nature may confer the greatest benefit to people, especially those who are most in need (Gould et al. 2020).

In this way and based on the recent frameworks that evaluate the contribution of nature to people (Jones et al. 2016, Chaplin-Kramer et al. 2019), here we propose the concept of "Wetspot" as socio-ecological wetscapes to explore and identify the best areas to produce ecosystem services (i.e., places where the supply of nature's benefits is most demanded by people) (Reyers et al. 2009). We also consider that the ecological services of wetlands may spillover to huge areas, even globally, we also used the idea of contribution of nature to non-directly exposed people (Mcafee 2012, Asah et al. 2014, Carrasco et al. 2017, Liu et al. 2019, Zeng et al. 2021, Carmenta et al. 2023). We used the Brazilian Pantanal and its watershed (Upper Paraguay River Basin) as a model to exemplify our proposal. Under an applied perspective, we used the "Wetspot" concept for identifying priority areas as well as its implications on the context of payments for ecological services in the region of the Brazilian Pantanal.

Our model: Upper Paraguay River Basin and Pantanal

The Pantanal is considered one of the most important ES hotspots in the world, occupying 179,300 km², and located in the center of South America (Tomas et al. 2019) (fig 2.). This wetland lies within the central portion of Upper Paraguay River Basin (UPRB) and receives contributions from the various sub-basins draining the upland

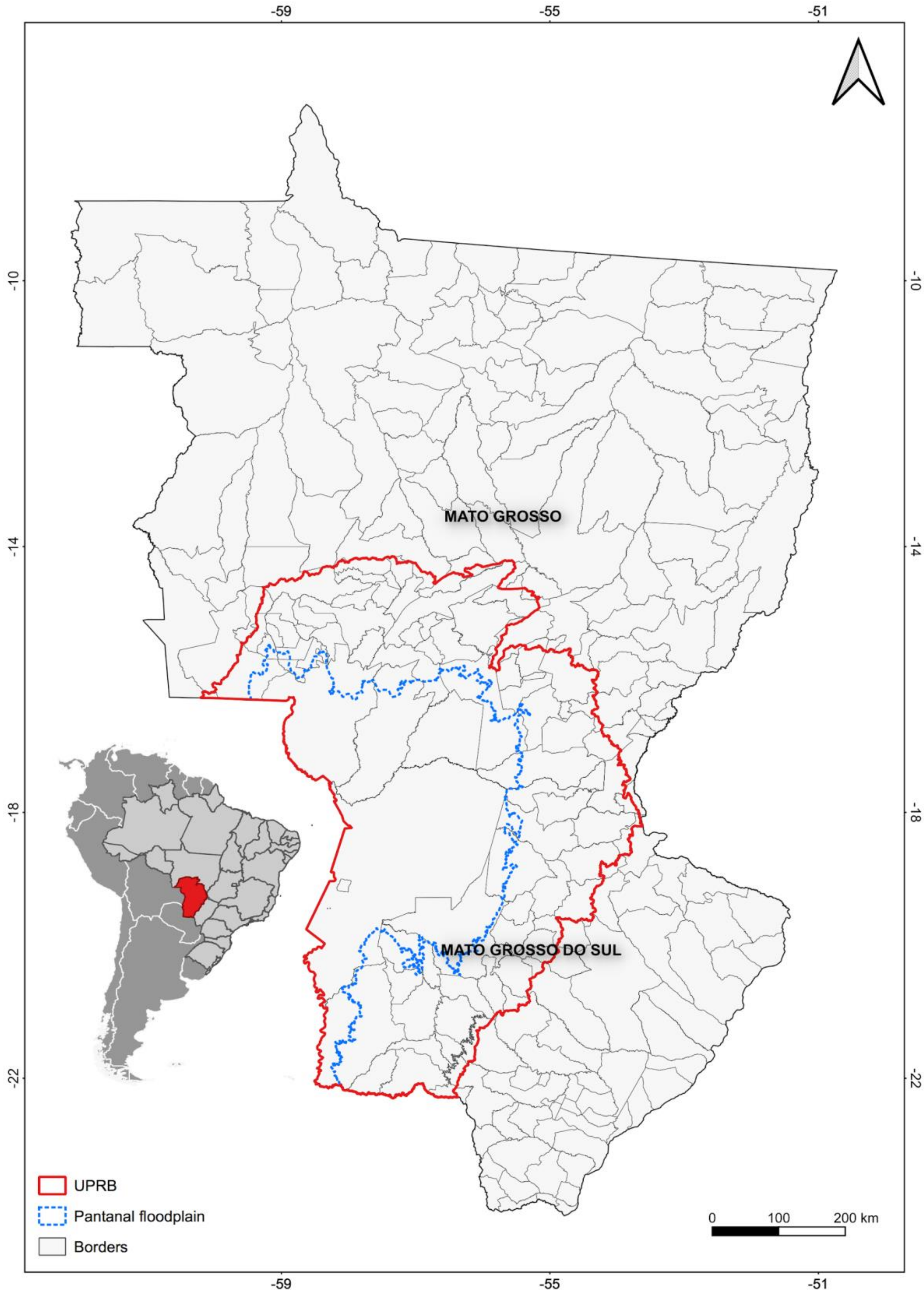

Figure 2. Location map of our study area, showing the positioning of UPRB in South America as well as in Brazil, representing state and municipal boundaries.

savannas of central Brazil, Bolivia, and Paraguay. In Brazil, the Pantanal is located in the states of Mato Grosso (MT; 35%), and Mato Grosso do Sul (MS; 65%) (Tomas et al. 2019). Around 80% of Pantanal native vegetation remains, while some 60% of its savannah covered plateaus have been converted to pasture and croplands (Roque et al. 2016). This ecosystem houses healthy populations of endangered species, such as jaguar (*Panthera onca*), giant otter (*Pteronura brasiliensis*), marsh deer (*Blastocerus dichotomus*), and Hyacinth macaws (*Anodorhynchus hyacinthinus*) (Tomas et al. 2011, 2015, Cavalcanti et al. 2012).

The Pantanal is a highly dynamic sedimentary floodplain macro-ecosystem influenced by an annual flood pulse caused by the Paraguay River and its tributaries, and regional geomorphological characteristics (Junk 1993, 1999, Kleidorfer et al. 2009). The Pantanal works as a large reservoir, causing a lag of up to 5 months between thein flows and outflows. The summer rainfall regime determines the flood season between November and March in the north and between May and August in the south, in this case under the influence of the Pantanal (Marengo et al. 2021). Its geographical location is of relevance since it represents the link between the Cerrado, in central Brazil, the Chaco, in Bolivia, and the Amazon region, in the north. Like the Brazilian savanna, a significant part of the Pantanal region is fire-prone, which have profound effects on the distribution and survival of species. Some of these species have evolved specific adaptations or rely on fire for their reproductive processes (Leal Filho et al. 2021, Oliveira et al. 2022).

The spatial and temporal heterogeneity of the landscape provides many types of ES for approximately 1.1 million inhabitants (Leal Filho et al. 2021), as assets for human well-being, including highly diversified flora, fauna and habitat types (biodiversity); food, fresh water and pasture (supply); climate stability and flood control (regulation); scenic beauty, recreation, spiritual and cultural diversity (sociocultural) (Seidl and Steffens 2000, Sandifer et al. 2015, Bolzan et al. 2021, Chiaravalloti et al. 2022, Almeida-Gomes et al. 2022).

Conceptual framework

To operationalize the mapping of Nature Contribution to People (NCP) to Brazilian Pantanal, we adapt the conceptual framework proposed by Chaplin-Kramer et al (2019a) (fig.3). The framework for assessing nature's contributions to people is based on people's needs for nature's benefits and nature's contribution to meeting those needs. The aim is to provide a spatially explicit framework (i.e., overlaying geospatial layers) for assessing how nature contributes to human well-being and how this can be used to guide public policy and decision-making to prioritize areas for conservation, sustainable used and restoration.

Here, we considered two dimensions of the NCP: material and non-material. For the material dimension, we considered the regulation and provision ecosystem services: water quality regulation and erosion control (regulation) and pollinator-dependent grains (provision). For the non-material dimension, we considered cultural services under the set of tourism potential and sacred places. For each dimension, we considered the human component which consists of the maximum potential benefit based on biophysical conditions and the exposed population, based mainly on their location. With the combination (i.e., overlaying) of the two layers resulting in the component people's needs (PN). Likewise, we considered the natural component that consists of the potential benefits of contributions from nature (NC), being described as the proportion of the maximum potential benefits that are provided by nature. Later we explain in more detail how such layers were generated.

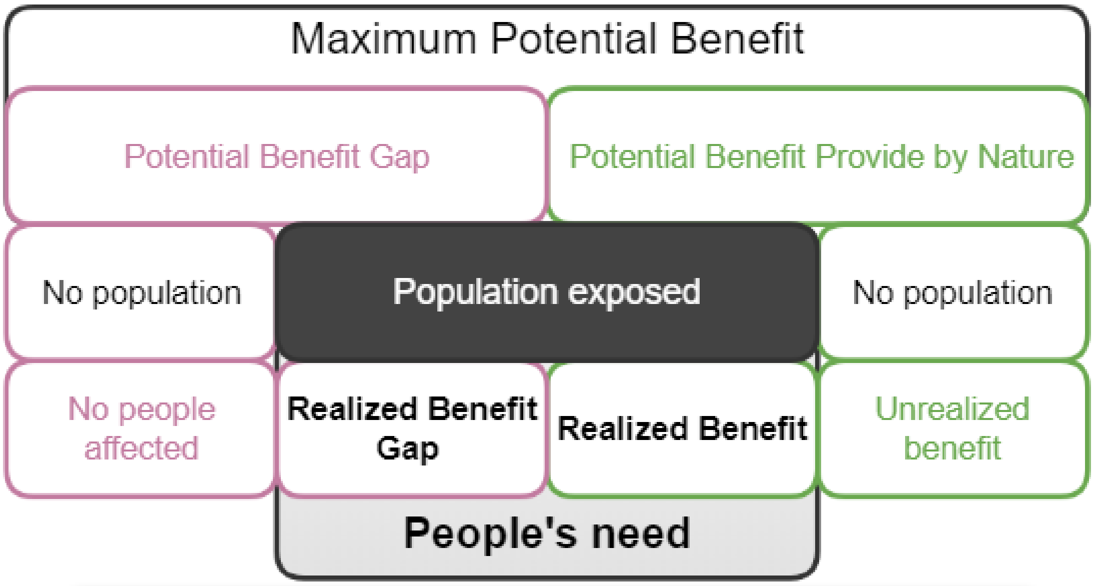

Figure 3. Conceptual framework for calculating nature's contributions to people. We used for this exercise only the following components: Maximum Potential Benefit as being the people's needs and the Potential Benefit Provided by Nature as being Nature's contributions. Finally, we included the population exposed component to represent spatially where people are exposed. Adapted from(Chaplin-Kramer et al. 2019).

Material dimension

Water quality regulation

The proxy used to represent this component was the nitrogen retention capacity by nature. These variables load, export and nitrogen retention were modeled by the InVEST software (https://invest.readthedocs.io/). The modeling of nitrogen retention was carried out considering watersheds and the transport of nitrogen to water bodies. Although the modeling does not represent in detail the nitrogen cycle, the information presents a long-term view on this nutrient, being mainly determined by the use and cover of the soil, associated with the carrying capacity and retention of each use and allied cover of the soil to the morphology of the terrain. This model is inspired by the concept of the sediment delivery rate, where we have a delivery factor to produce these sediments, representing the ability of each cell to be analyzed to transport nutrients without retention and a topographic index, which considers its position in the landscape (Merritt et al. 2003). Thus, in the same way that it was designed and adapted for sediments, this model was adjusted for the transport of nutrients. As a result, we have an ordering of the efficiency of each cell upstream in retaining nitrogen (Chaplin-Kramer et al. 2019).

According to the framework (fig.3), the maximum potential benefit was the total nitrogen load to be mitigated. The retention efficiency (i.e., the amount of nutrients retained by vegetation in the landscape) is the potential benefit provided by nature. The difference between the total load and what is retained as a benefit gap, that is, the export of the nutrient. The exposed population was the rural population which, *a priori*, has greater difficulties in accessing quality water in relation to the urban population with greater possibilities of access to public supply infrastructure.

Erosion control

We used the same layer that was used in the water quality regulation approach regarding nature's contributions, especially due to the biophysical similarity of nature's contribution and operationalization in this work. The maximum potential benefit was the total eroded sediment that needs to be retained / mitigated (Guerra et al. 2020a). The exposed population layer was selected as the estimated population in 2020 (Center for International Earth Science Information Network - CIESIN 2017), regardless of if rural or urban. We used this layer because we consider that erosion can modify the quality of the water and influence its dynamics downstream and the productivity of soils upstream (Assine 2005, Bergier 2013, Louzada et al. 2021).

Pollination

The pollination approach was based on the methodology proposed by (Kremen et al. 2007). This NCP considers that in the areas of habitat around regions with agricultural activity, cells of the agricultural classes with fragments of native vegetation greater than 30% of the cell size and around 2 km around the land use classes of agriculture were designated as sufficient for pollination dependent production. Pollinator habitats were defined as covering the soil with native vegetation, which can be secondary vegetation and pastures (Kremen et al. 2007, Tscharntke et al. 2012, Kennedy et al. 2013). The use of 2 km around agricultural production areas as the distance most found in the literature was used to predict ecosystem pollination services (Kennedy et al. 2013). This produces a sufficiency map of natural pollination, where each cell of the agricultural class is a value between 0 and 1, where 1 indicates> 30% of natural habitat in the 2 km around the cultivated land and a value of 0 to 1 indicates the proportion of 0 to 30%.

An important consideration is that to represent pollination in large areas, it is necessary to vastly simplify the various species of pollinators (e.g., bees, beetles, butterflies, flies, bats, etc.), thus generating a pollination proxy. The model was based on general principles of flight distances and pollinator foraging. It is worth mentioning that there are uncertainties and that this approach does not assume any pollination habitat value in the harvest itself and, as noted above, a foraging range of 2 km, which further reinforces the upper limit estimate for the value of the natural habitat close to agricultural land (Kremen et al. 2007).

For pollination, the maximum potential benefit was considered as the level of dependence on production by pollinators. The pollination-dependent production that is produced is the potential benefit provided by nature (NC), determined by the existence of sufficient natural habitat around the agricultural cell to be analyzed to provide natural pollinators and, therefore, adequate pollination for crops. In this sense, nature's contribution to meeting pollination needs is the proportion of pollinated production (i.e., pollination dependent production for which pollination needs are met, according to the habitat around agricultural land) for production pollination-dependent (i.e., the maximum amount of potential pollination-dependent production). The difference between the pollinated production and the potential production dependent on pollinators can be considered as the loss of production due to lack of pollinator, meaning the benefit gap.

The population exposed to pollination gaps is considered where local pollination-independent macro and micronutrient production does not exceed nutritional requirements of the local population (“local” here is defined as 1x1 degree). Dietary requirements are calculated according to recommended intake levels of different demographics (Chaplin-Kramer et al. 2019).

Non-material dimension

Tourism and sacred areas

For this approach, we considered two variables: touristic areas and sacred areas (fig. 4). To evaluate the natural touristic areas, we used native vegetation as a proxy for the benefits of visiting a region. The layer of the maximum potential benefit was composed of two layers 1) number of tourist activities taken from the Register of Tourist Service Providers of the Ministry of Tourism (CADASTUR 2019) using as a filter the tourism activities that are within the limits of our study area and 2) Sacred places: natural areas that people attribute special significance and meaning, usually saying that these areas connect them to something greater than themselves and, in some cases, associating with faiths in a higher power. In the Upper Paraguay River Basin, there are important areas related with religiousness and spirituality, such as Christianity, Buddhism, Afro-religions (e.g., Candomblé), Indigenous Traditions, Spiritualism, and Mysticism. This data was built through interviews from interlocutors of non-governmental organizations with experience on traditional communities on the region and search in scientific publications (Wantzen et al. 2023). We overlapped the layer of tourism and the map of sacred places to create a synthetic map of non-material significance. We consider each activity to have a value of 1, although there are possibilities of having more than one identity value or purpose in the same place.

Datasets

To map the different dimensions, we used the following databases:

- Nature's contributions to water quality regulation and erosion prevention with resolution of 300x300 meters (Chaplin-Kramer et al. 2019);
- Nature's contributions to pollination-dependent with resolution of 300x300 meters (Chaplin-Kramer et al. 2019);
- People's need for water quality regulation with resolution of 300x300 meters (Chaplin-Kramer et al. 2019);

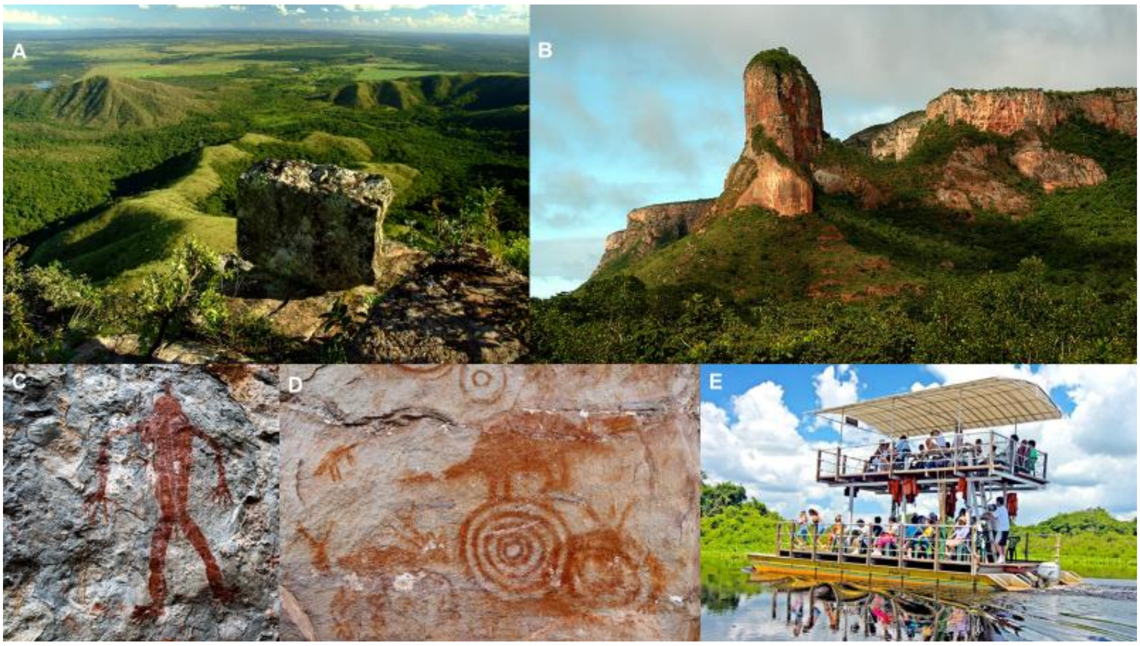

Figure 4. Examples of the non-material dimension: A) Natural Monument Geodesic Center of Latin America - Mato Grosso; B) Morro do Japão - Mato Grosso; C and D) Symbolic expressions of the Santa Elina archaeological site - Mato Gross and E) Ecotourism in the Pantanal - Mato Grosso do Sul. Credits: A) to D), Mário Friendlander and E) Fazenda São Francisco.

- People's need for erosion prevention with resolution of 250x250 meters (Guerra et al. 2020a);
- People's need for pollination-dependent food production with resolution of 300x300 meters (Chaplin-Kramer et al. 2019);
- People's need for cultural services (sacred places and tourism), with resolution of 10x10 kilometers (Wantzen et al. 2023);
- Population exposed in 2020 to the material dimension with resolution of 300x300 meters(Center for International Earth Science Information Network - CIESIN 2017):
    - Water quality regulation, Erosion control and Pollination with resolution of 1x1 degreed (Chaplin-Kramer et al. 2019);
- Population exposed in 2020 to the non-material dimension with resolution of 100x100 meters (Center for International Earth Science Information Network - CIESIN 2017).

Payment for socio-ecological services

Ecological Fiscal Transfer - ICMS Ecológico

As an exercise of evaluating the interface between nature's contributions to people and public nature conservation policies, we used the case of the ICMS Ecological (ICMS-E - Tax on the circulation of goods and services under an ecological bias). This public policy instrument of Ecological Fiscal Transfer (EFT) has been operating in Brazil for almost three decades. It is described as the most established TFE mechanism to date, receiving continuous improvement since its creation, and it can serve as a model for adaptations in other parts of the World (Droste et al. 2018). However, there are significant gaps in relation to this political instrument, including whether the local application related to the transferred resources contributed to the improvement of socioeconomic well-being in a broad way to the whole community (Verde Selva et al. 2020).

The TFE can contribute to the decentralization of responsibility for managing natural capital, providing financial incentives at the municipal level to implement protected areas or take other conservation measures, with these decisions theoretically determined according to local preferences. It can contribute to the incorporation of local knowledge and points of view in conservation (Droste et al. 2015), and due to the possibilities of implementing improvements in the mechanism, using concepts and parameters in order to make it more congruent with trends and current guidelines.

Considering our study area, there is a possibility of using parameters for the transfer of ICMS-E resources that can dialogue beyond political borders, especially due to the existence of two States that divide the UPRB as well as the Pantanal. Thus, when we consider that socio-ecological processes go beyond political boundaries, an approach from the perspective of nature's contributions to people can increase the functioning and effects of the ICMS-E, mainly by encouraging local attributes and preferences (Sauquet et al. 2014). In general, in both States, transfers are made using criteria such as the presence of Protected Areas in municipal territories. It is worth mentioning that, under Brazilian law, both Conservation Units and Indigenous Lands are considered Protected Areas. Thus, when considering this aspect of TFE, with transfers from the state to the municipal entity, to guide a potential distribution of transfers under the dimension of NCP, we need to bring this information to the municipality level.

Considering the municipalities in our area of work as our samples, we extracted basic statistics for the material dimension in our three approaches (i.e., water quality regulation, erosion control and pollination) as well as for the density layer and population positioning (population exposed). To represent the overlap of layers, we multiply the averages of nature's contributions with the average of people's needs. Finally, the layers used to represent the exposed population were overlapped on the result of the multiplication in order to visualize the co-occurrence of the NCP.

Data analysis and integration

We explored the data at two spatial approaches: landscape scale (Upper Paraguay River watershed and in the Pantanal) and at the scale of the political-economic instrument for nature conservation (i.e., municipalities). We overlapped the layers of the contributions of nature (green gradient) to that of people's needs (pink gradient) at each approach. Finally, we added the layer of representation of the exposed population (grey gradient). The overlaps output indicates the congruence between the contributions of nature and the people's need added to their population exposure. Finally, we carried out the exercise of extracting the NCP for each municipality, thus representing the ordering of the municipalities by the NCP as a model for distributing the ICMS-E resources. Finally, we ran a Pearson correlation to check for potential synergies and trade-offs between NCP and ICMS-E (i.e., municipal environmental index - MEI).

Results and discussion

Pearson's correlation analysis (fig. 5) and spatialization of NCP approaches for the Upper Rio Paraguay Basin (fig. 6, 7, 9 and 9 on the left) and cut by municipalities (fig. 6, 7, 8 and 9 on the right) represent our results. The correlations analysis indicated a low correlation between the different NCP, except between the Municipal Environmental Index and non-material NCP, with a moderate positive correlation (0.471). For our three approaches to the material dimension, although there was no correlation between municipalities, the UPRB plateau region concentrated the largest NCP

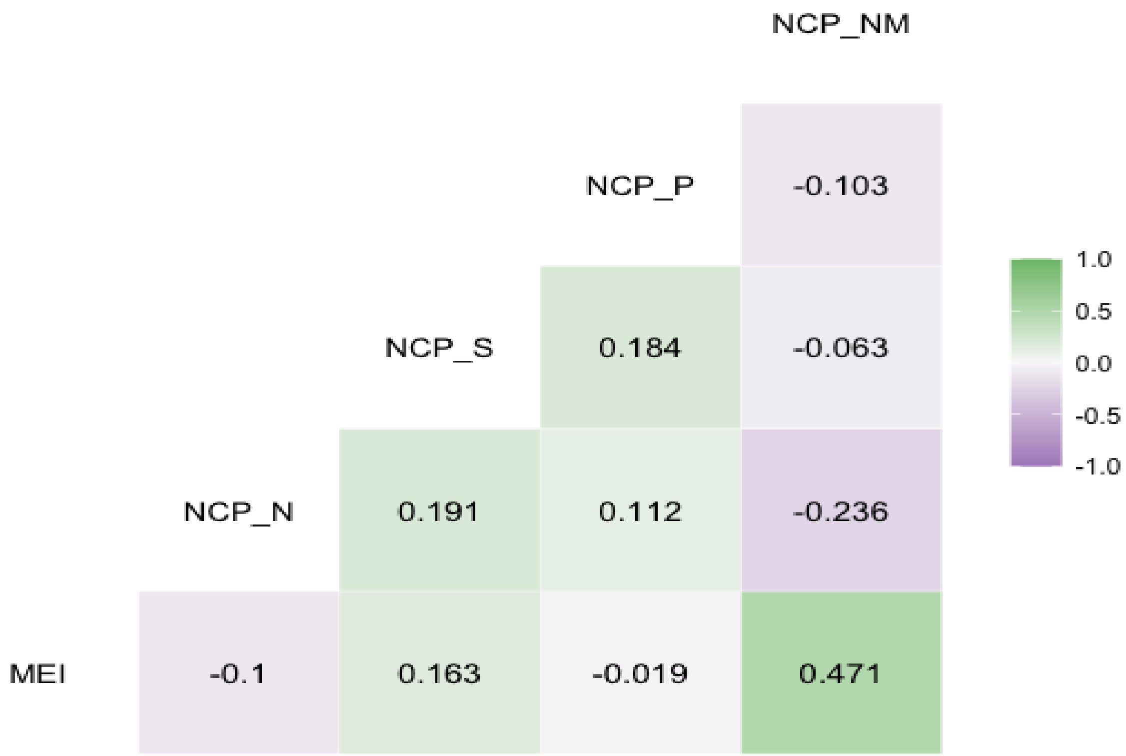

Figure 5. Result of the correlation of NCP on the municipal scale. MEI (Municipal Environmental Index), NCP_N (NCP for water quality regulation), NCP_S (NCP for erosion control), NCP_P (NCP for pollinator-dependent grain pollination) and NCP_NM (NCP for the tourism / identity purpose).

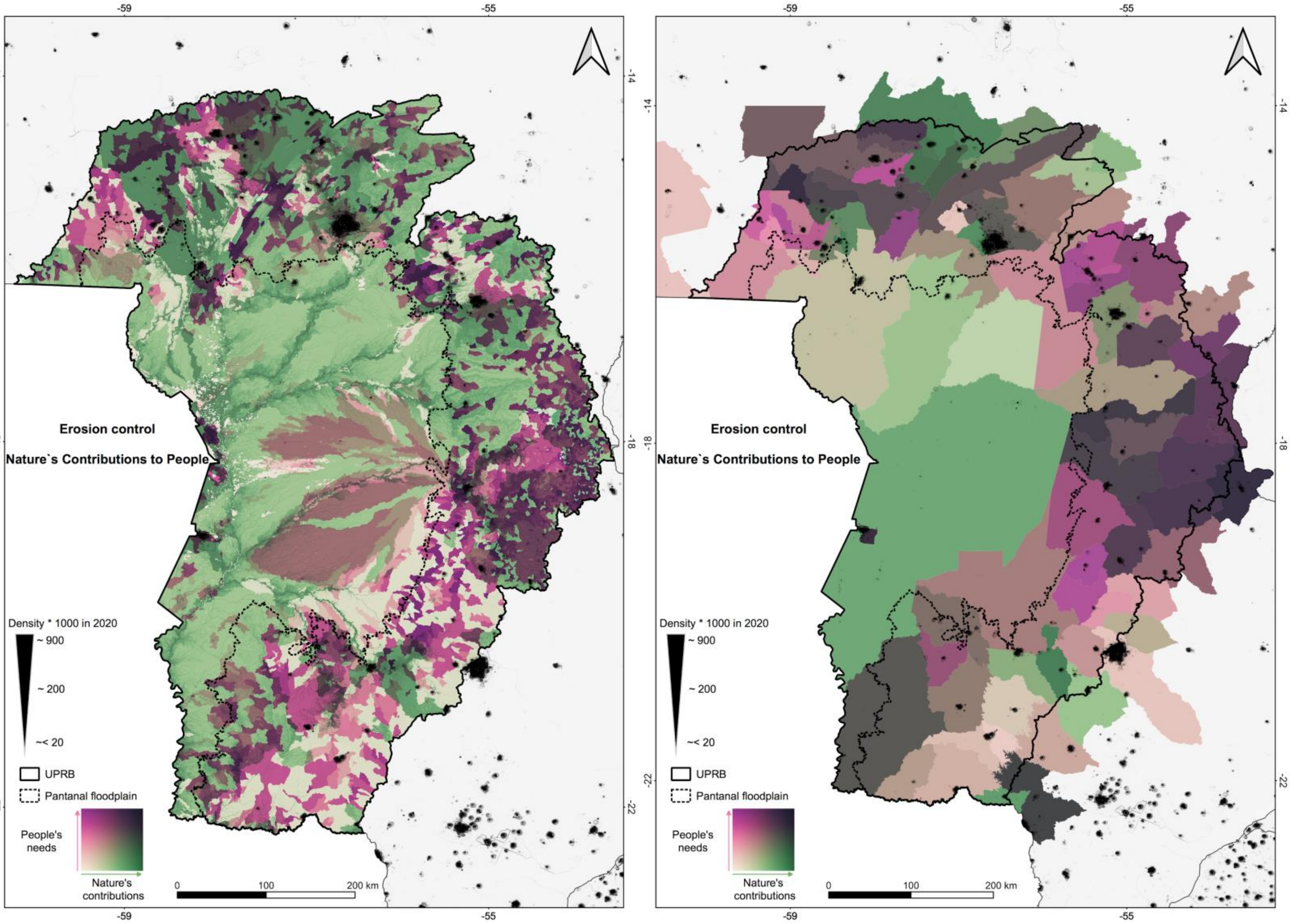

Figure 6. These maps represent the NCP for the water quality regulation approach. On the left, the overlapping of the NC, PN raster and the population exposed on the UPRB scale. The same information on the right but clipped by municipalities. Darker colors represent overlapping where nature's contributions with people's needs is greater. The size of the black patches/spots represents the population density.

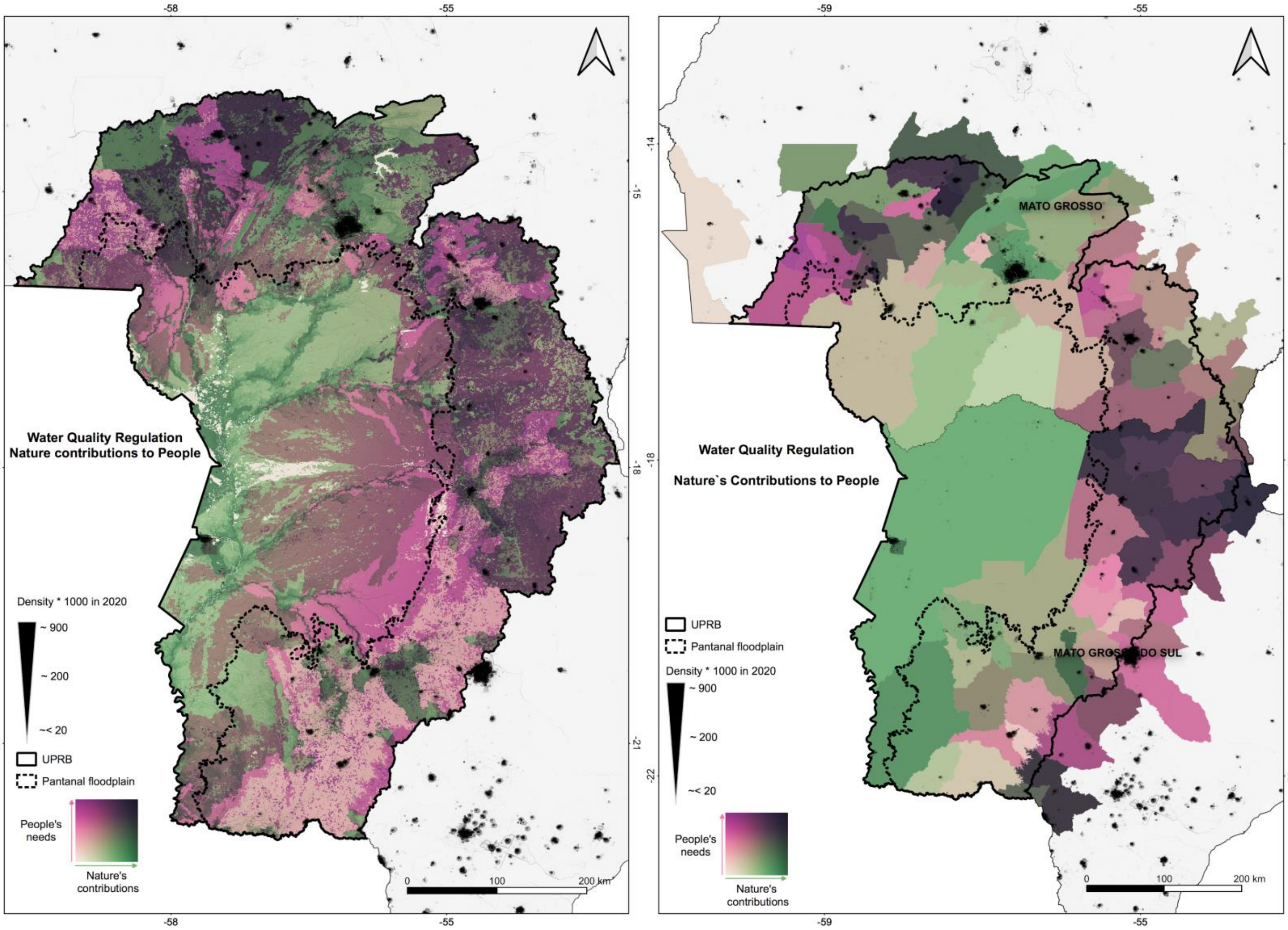

Figure 7. These maps represent the NCP for the erosion control approach. On the left, the overlapping of the NC, PN raster and the population exposed on the UPRB scale. The same information on the right, but on the scale of municipalities. Darker colors represent overlapping nature's contributions with people's needs. The size of the black spots represents the positioning and population density.

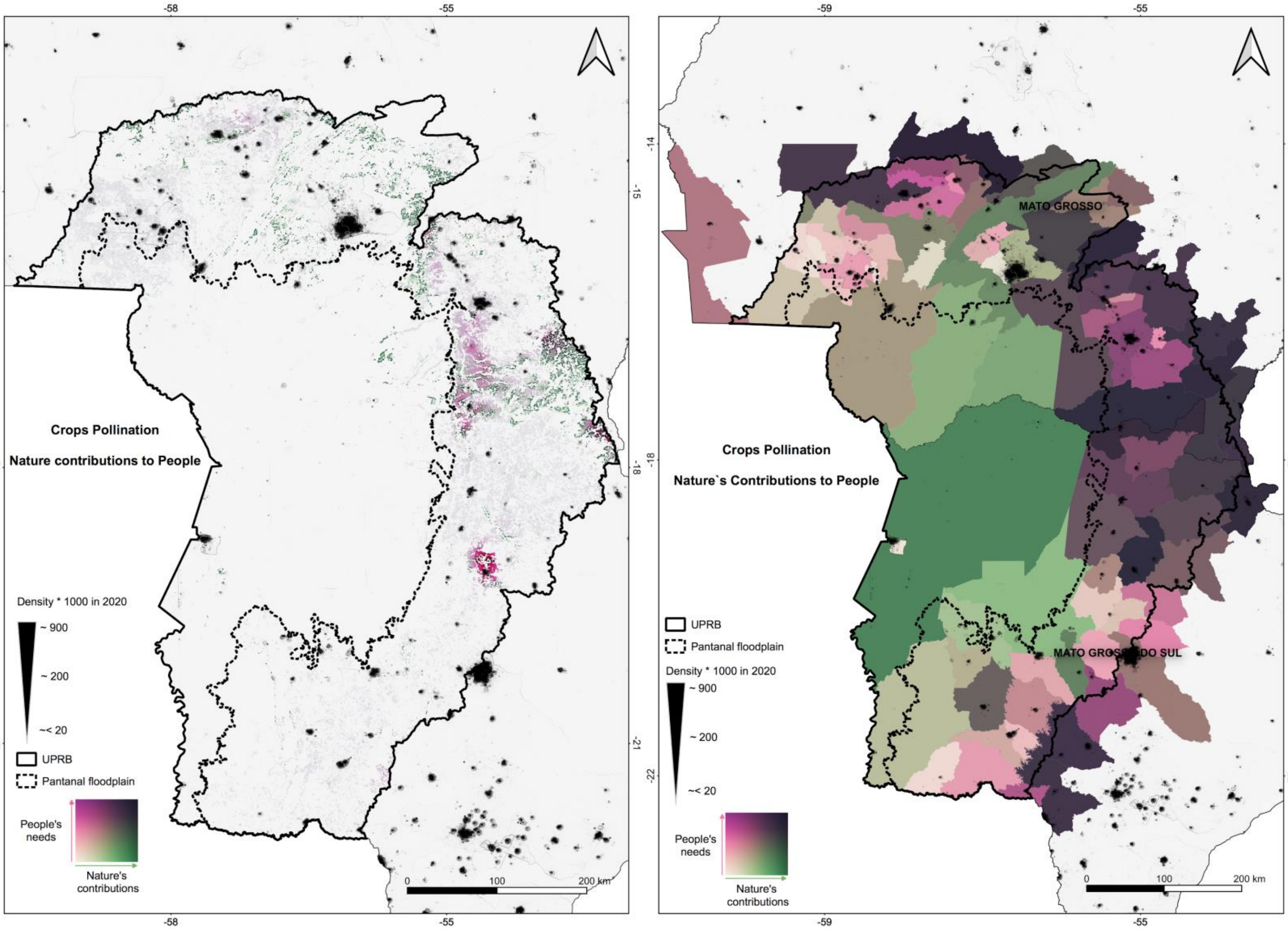

Figure 8. These maps represent the NCP for the pollinator dependence approach to grain pollination. On the left, the overlapping of the NC, PN raster and the population exposed on the UPRB scale. The same information on the right, but on the scale of municipalities. Darker colors represent overlapping nature's contributions with people's needs. The size of the black spots represents the positioning and population density.

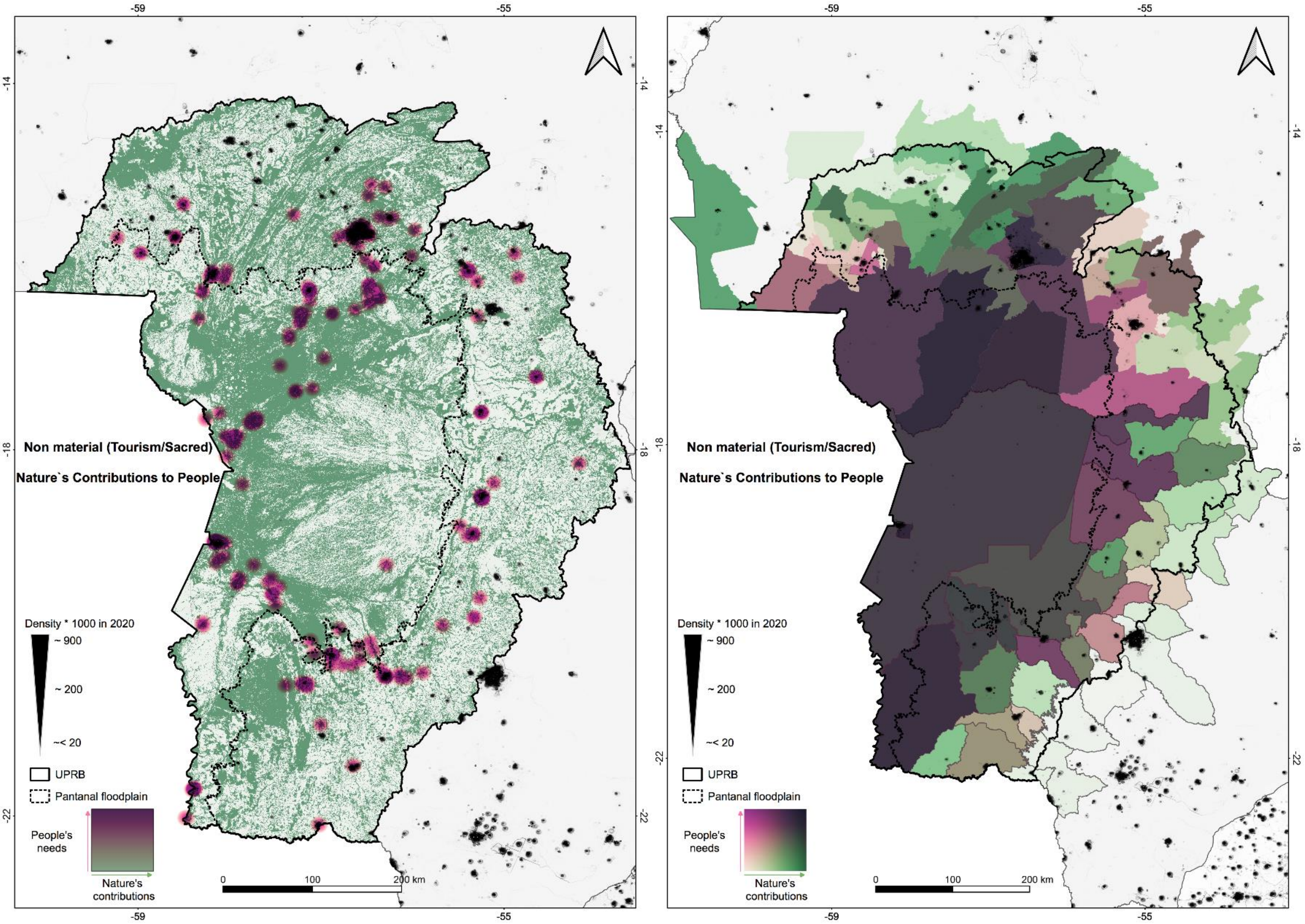

Figure 9. These maps represent the NCP for the Non-Material approach to tourism and sacred places. On the left, the overlapping the layers of native vegetation and tourism and sacred hotspots with the population exposed on the UPRB scale. The same information on the right, but on the scale of municipalities. Darker colors represent overlapping nature's contributions with people's needs. The size of the black spots represents the positioning and population density.

represented by the darker colors, mainly on regulation ecosystem services of water quality regulation and erosion control approach. This may reflect the greater concentration of human activities uplands (plateau) that demand more contributions from nature (i.e., higher nature's contributions to people's need). For the NPC map of pollinator-dependent grains, we have a vast blank area, mainly influenced by land use, due to the dominance of activities linked to livestock production (Roque et al. 2016, Guerra et al. 2020b). Additively, we still observe in the few patches of nature's contributions and people's need, that there is no overlap with the exposed population. Therefore, we have both unrealized benefits and no people affected (fig. 8), but it does not imply in concluding that the pollinators ecosystem services are not important to human well-being (Ferreira et al. 2013, Kennedy et al. 2013, Carstensen et al. 2016, Potts et al. 2016). In this sense, the development of layers that portray the NCs to produce beef, and reinforced by the export characteristic of this activity where the benefit is realized by spreading across the planet (Carrasco et al. 2017, Liu et al. 2019), are of paramount importance if you want to have a better understanding of the NCP in our area of study (Liu et al. 2019, Balogh and Jámbor 2020, Monica et al. 2021).

It is important to emphasize here the work of Liu et al. 2019) where they explore telecoupling concept and framework, examining its applications in land system science. The concept of the "telecoupling" to refers to the environmental and socioeconomic interactions between distant regions of the world and, such as through international trade and information flows that involve addressing its structure, processual nature, roles of sending and receiving systems, comprehensiveness, flexibility, feasibility, entry points, system dynamics, boundaries, and scale dependencies. In the context of biodiversity conservation, telecoupling can both pose challenges and offer opportunities. For example, the high demand for agricultural and wildlife products by high-income and emerging economies can put pressure on land protection and management, while the strength of telecoupled information flows can generate strong pressure on multinationals and governments to adopt sustainable practices. Overall, telecoupling is changing the architecture of threats to biodiversity, creating both challenges and opportunities for conservation efforts (Carrasco et al. 2017, Liu et al. 2019).

In the lowland region (Pantanal), the predominantly green colors in erosion control and water quality regulation maps (fig. 7 and 8 respectively) indicate that there is a higher potential for benefits provided by nature, however with a low people's need (i.e., maximum potential benefit overlapped by the exposed population), excepted on the Taquari River, that forms the largest megafan of the Pantanal (Galdino et al. 2003, Assine 2005, Assine et al. 2015, Louzada et al. 2021). The presence of the pink color in the fan indicates a PN that may be linked to the need to retain sediments and improve the quality of the water provided by the alluvial fan (Metcalfe et al. 2018), although the exposed population in this territory is very low. Therefore, there may be a deficit of contributions from nature, which due to the conditions of land use and cover, in addition to the inherent connection between the plateau and the plain (Alho et al. 2019), point to a high demand for NC.

As for the plateau, the people's need is greater indicated by the mixture of green and pink gradient and by the darker shades, which are reinforced by the greater concentration of population exposed in the plateau region. On the other hand, we found the largest NCP of the non-material dimension in the lowlands, valued by the presence of both high contributions from nature and the greater concentration of tourist activities and sacred places (Almeida-Gomes et al. 2022, Wantzen et al. 2023). However, when looking at the population density on the lowlands, we realized that there are large spaces with low or no presence of population density. In this sense, the population exposed to the NCP for tourism and sacred places seems to be low and fluctuating, with this map representing the maximum potential benefit (i.e., hotels and places with identity purposes that enjoy the high conservations landscape in lowland) concentrated in the pink tones and the potential benefit provided by nature in the entire floodplain.

Under this perspective, the benefits go beyond the limits of our study area, dissipating to where people reside (Carrasco et al. 2017, Meyfroidt et al. 2020, Carmenta et al. 2023). Under a territorial management perspective, our results indicate that different strategies should be applied to the lowlands and uplands when including the concept to “Wetspots” and NCP in the UPRB (Guerra et al. 2020b, Colman et al. 2021, Garcia et al. 2021). For example, the results using the municipal limits as a weighting mechanism based on NCP for the transfers of the ICMS-E highlight these differences. In the plateau, it is necessary to conserve natural capital at a minimum level that guarantees the benefits provided by nature (i.e., contributions from nature) (Roque et al. 2016, Zeilhofer et al. 2016) in maximizing the potential benefits (i.e., people's needs) (Guerra et al. 2020b, 2020a) and consequently the realized benefit (i.e., potential NCP after actions anthropogenic) (Chaplin-Kramer et al. 2019). On the lowland, where non-material NCPs are higher, and considering that they are strongly linked to the preservation of natural landscapes and cultural and sacred sites (Wantzen et al. 2023), the maximization of NCP can be facilitated by preserving the natural characteristics of the “Wetspots” by conciliating tourism and other cultural values (Almeida-Gomes et al. 2022).

Limitations and challenges

This study suggests that the approach to quantifying nature's contributions to people can be made more rigorous as data and science continue to advance. For instance, we have limitations in mapping sacred sites as well as the location of people in rural areas. In the case of the distribution of people, “Ilumina Pantanal” (Energisa 2021) can provide a detailed location of people with great precision and quality.

This study was limited to demonstrating, in a spatially explicit way, examples of the benefits of nature where people need it most. In this sense, we assume simplified associations between the NC and the PN (e.g., regulation of water quality by the filtering function of fertilizers, improving the quality of the water directly abstracted or for its sanitation). However, people may not necessarily be exposed to a particular ecosystem disservice (Blanco et al. 2019), either because we do not know where they really are and in what number and/or because we do not know if they (people) are really demanding a certain benefit from nature (Blanco et al. 2022). Understanding the dynamics of initiatives that can change the current model of people's demand for the benefits of nature is a limitation of studies like this one that used only current data.

Additionally, it highlights the need for a broader and systemic change in societal awareness of the importance of nature's contributions to people and their integration into decision-making (Dasgupta 2021). Continual improvement in data and scientific methodologies will enable us to enhance the quantification of ecosystem contributions to human well-being (Metzger et al. 2021a). As our understanding deepens regarding the diverse ways in which nature benefits people, we can provide more accurate and comprehensive information to inform policy and environmental management decisions (Hein et al. 2020). Moreover, this study emphasizes the fundamental requirement for a comprehensive and systemic shift in society's awareness of nature's contributions to people (Folke et al. 2021). This involves recognizing and valuing the ecosystem services that underpin our quality of life, health, and prosperity (Díaz-Reviriego et al. 2019).

Integrating nature's contributions into decision-making processes is essential to promote environmental sustainability and strike a suitable balance between human development and the conservation of natural ecosystems (Wiegleb and Bruns 2023) . By fully considering the value of nature, we can adopt more informed and responsible strategies to achieve a healthier and more sustainable future for both human societies and the natural world (Costanza 2020).

Conclusions

This work shows the areas where there are gaps in ecosystem services for people residing in the Alto Paraguay Basin and Pantanal. These maps can be useful for prioritizing public policies and allocating municipal resources for restoration and conservation actions in the territory (Fisher et al. 2009). The mapping of NCP allowed observing that the material and non-material benefits that increase human well-being can present synergies and trade-offs between them region and that there are significant differences between demands and offers of NCP between the lowland and the plateau. This work also introduces the “Wetspot” concept and evaluates the possibility of using NCP as an approach to explore and identify landscapes where nature's contributions are not important to people (Reyers et al. 2009).

The results presented here represent a major advance in relation to previous exercises for assessing environmental services in the Upper Paraguay Basin, particularly in the Pantanal. The big difference is the incorporation of the concept of benefits for people, in other words, we consider the local beneficiaries of ecosystem services. Our results show that many of the services and immediate beneficiaries of pollination, water and erosion control services are located on the plateau, since the most populous cities and the largest agricultural production are in this region. However, our exercise also shows extremely relevant connections between the plateau and the floodplain since the dynamics of the wetland depend heavily on the services of the plateau and vice versa. New conceptual and analytical approaches are needed to evaluate the connections of ecological services between these areas and who consider that there are NC flows (Metzger et al. 2021b) where the beneficiaries are far from the NC supply location (Carrasco et al. 2017).

In the case of the Pantanal, we still have a great challenge ahead. Current models of assessing nature's contributions to people do not consider non-resident beneficiaries. This is particularly important for places with a flow of tourism and export-based economies like Upper Paraguay River Basin. Finally, is clear that biodiversity underpins functions and services essential to agriculture by providing ecosystem services such as pollination, pest control, nutrient cycling, and soil formation and that these services are critical for maintaining agricultural productivity and food security. Biodiversity also contributes to the resilience of agricultural systems by providing genetic diversity for crops and livestock, which can help them adapt to changing environmental, social, and cultural conditions.

Final considerations

Wetlands like Pantanal, those invaluable ecosystems providing a multitude of essential services like biodiversity conservation, climate regulation, water purification, flood prevention, and coastal protection, play a pivotal role in maintaining the balance of nature and promoting human well-being. However, these vital habitats are under increasing threat due to human activities such as urbanization, intensive agriculture, and resource exploitation. The repercussions of wetland loss and degradation resonate across ecosystems, impacting both the environment and human societies.

In addition to their tangible benefits, the cultural, spiritual, and educational values associated with wetlands are of profound significance. Many communities hold deep cultural and spiritual connections to these landscapes, considering them sacred and integral to their traditions. Moreover, wetlands offer valuable opportunities for education, facilitating an understanding of ecological processes and traditional knowledge. Recognizing and respecting the non-material values of wetlands is vital in cultivating a more holistic approach to their conservation and management.

To secure the long-term sustainability of wetlands, active engagement with local communities is indispensable. Embracing indigenous and local knowledge, combined with scientific expertise, enables the development of culturally relevant and effective conservation strategies. Involving local communities fosters a sense of stewardship and shared responsibility for preserving these crucial ecosystems, forging a harmonious relationship between nature and society. Furthermore, evidence-based public policies and collaborative efforts involving diverse stakeholders are essential for enacting robust conservation measures that address the multifaceted challenges faced by wetlands.

In conclusion, safeguarding wetlands is not only an imperative for ecological preservation but also a testament to our dedication to a sustainable and balanced coexistence with the natural world. Embracing the interconnectedness of environmental, social, and cultural values in wetland conservation ensures a flourishing future for both nature and humanity.

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Appendix

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ECOSYSTEM SERVICES OF WETLANDS

Local Biodiversity Supports Cultural Ecosystem Services in the Pantanal

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Abstract
The role of local biodiversity to cultural ecosystem services (CES) has been increasingly recognized. Yet, it is still unclear how local species can represent multiple CES in the same area for different people. We comprehensively evaluated the role of local biodiversity to the provision of multiple CES in the Pantanal, the largest continuous wetland in the world. First, we assessed the use of names of local species by screening and mapping tourist accommodations and rural properties names. Second, we evaluated the tourist demand for species by screening tourist accommodation websites. Finally, we assessed differences between demand and supply using two questionnaires. While mammals and birds were more common in the names of tourist accommodations, plants were more frequent in the names of rural properties. We did not record a significant correlation between the number of records on tourist accommodation websites and the mean research interest from Google Trends (considering all species, terrestrial vertebrates, or fish). Finally, we found a mismatch between demand and supply for terrestrial vertebrates, while we found a significant and positive correlation between demand and supply for fish. Our findings emphasize the importance of Pantanal biodiversity for different CES, such as tourism and recreation, which may support biodiversity conservation and sustainable development. The use of species names varied according to the economic activity (tourism or agriculture), a novel finding for the Pantanal. Future studies should focus on the role of local biodiversity for others CES, such as spiritual and inspirational values, as well as indigenous culture.

Resumo.

O papel da biodiversidade local para os serviços ecossistêmicos culturais (SEC) tem sido cada vez mais reconhecido. No entanto, ainda não está claro como as espécies locais podem representar vários SEC na mesma área para diferentes pessoas. Neste estudo, avaliamos de forma abrangente o papel da biodiversidade local para o fornecimento de múltiplos SEC no Pantanal, a maior área úmida contínua do mundo. Primeiramente, avaliamos o uso de nomes de espécies locais por meio da triagem e mapeamento de nomes de acomodações turísticas e propriedades rurais. Em segundo lugar, avaliamos a demanda turística por espécies por meio da checagem de sites de acomodações turísticas. Finalmente, avaliamos as diferenças entre demanda e oferta usando dois questionários. Enquanto os mamíferos e as aves foram mais comuns nos nomes das acomodações turísticas, as plantas foram mais frequentes nos nomes das propriedades rurais. Não registramos uma correlação significativa entre o número de registros em sites de acomodações turísticas e o interesse médio de pesquisa do *Google Trends* (considerando todas as espécies, vertebrados terrestres ou peixes). Por fim, encontramos um descompasso entre demanda e oferta para vertebrados terrestres, enquanto que encontramos uma correlação significativa e positiva entre demanda e oferta para peixes. Nossas descobertas enfatizam a importância da biodiversidade do Pantanal para diferentes SEC, como turismo e recreação, que podem apoiar a conservação da biodiversidade e o desenvolvimento sustentável. O uso de nomes de espécies variou de acordo com a atividade econômica (turismo ou agricultura), uma descoberta inédita para o Pantanal. Estudos futuros devem focar no papel da biodiversidade local para outros SEC, como valores espirituais e inspiracionais, bem como a cultura indígena.

Keywords Wetlands · Non-material services · Plants · Animals · Recreation · Tourism

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Ecosystem services in the floodplains: Socio-cultural services associated with ecosystem unpredictability in the Pantanal wetland, Brazil

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Ecosystem services do not exist independently from human perceptions and recognition. They are socially, culturally, economically, and environmentally scale- and context-dependent. Socio-cultural services tend to be difficult to evaluate and invisible to policymakers and conservation practitioners. Based on six years' qualitative analysis of a floodplain fishery in the Pantanal wetland, Brazil, we bring an in-depth understanding of the socio-cultural ecosystem services in the region. We show that the inter- and intra-annual ecosystem dynamics variations in the flood pulse are closely associated with local people's governance structure, identity, and cosmological histories. All of them, to some extent, capture some of the unpredictable changes in the Pantanal. Our study uncovers part of the complex and rich social-cultural ecosystem service created from the interaction between local people and the ecosystem in which they are embedded. We also present the threats faced by these services in the face of current development projects in the Pantanal, such as the Waterway and Hydrometric Dams. We argue that the predicted outcome may jeopardize not only the social-cultural services in the Pantanal, but also the local people themselves and the environment that they are currently protecting.

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Reconciling biome-wide conservation of an apex carnivore with land-use economics in the increasingly threatened Pantanal wetlands

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Conservation of carnivores involves finding solutions to minimize habitat loss and human-wildlife conflict. Understanding the nature of land-use economics can allow us to mitigate both threats. In the Pantanal, the two main economic activities are cattle ranching and ecotourism, each of which directly and indirectly affect the persistence of jaguars (*Panthera onca*). To understand how the geography of these economic activities is related to jaguar populations, we developed a jaguar distribution model (JDM), livestock density model, and ecotourism lodge density model for the Pantanal. Due to the recent wildfires within the Pantanal, we also assess the impact of burnt areas that are suitable for jaguars, cattle ranching, and tourism. Our JDM indicate that 64% of the Pantanal holds suitable habitat for jaguars. However, jaguar habitat suitability was positively correlated with ecotourism, but negatively correlated with areas most suitable for intensive cattle-ranching. This demonstrates a biome-wide scenario compatible with jaguar conservation. Of particular concern, recent wildfires overlap most suitable areas for jaguars. If wildfires become increasingly frequent, this would represent a serious threat to jaguars and many other wildlife populations. We emphasize the global importance of the Pantanal wetland ecoregion as a key stronghold for long-term jaguar conservation.

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Sustainability Agenda for the Pantanal Wetland: Perspectives on a Collaborative Interface for Science, Policy, and Decision-Making

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Capítulo 4

O futuro da BAP

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