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PERSPECTIVE

Eight basic principles for the elaboration of public policies and development projects for the Pantanal

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Abstract

The Pantanal is considered the largest continuous freshwater wetland in the world, and its sustainable use requires a unified conceptual framework. The lengthy process to establish public policies has contributed to the increasing vulnerability of the Pantanal. Given the need for a conceptual basis to help this process, we elaborate a list of eight basic principles based on the accumulated scientific evidence: (i) Consider the Paraguay River Basin a management unity; (ii) Establish rules that follow the concept of restricted use approach; (iii) Ensure the ecologically sustainable use of the Pantanal; (iv) Maintain the environmental heterogeneity and functionality in the Pantanal landscapes; (v) Maintain the hydrological integrity and connectivity; (vi) Ensure the environmental representativeness of the protected areas network; (vii) Provide economic incentives for conservationist use of the land; and (viii) Recognize and protect traditional people, their values, resources, and way of living. However, the elaboration of public policies should be a participatory and inclusive decision-making process towards a more just and sustainable future.

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KEYWORDS

conservation, decision-making, ecologically sustainable use, legislation, public policies, upper Paraguay River basin, wetlands

1 | INTRODUCTION

The Pantanal wetland extends throughout 179,000 km^2 in Brazil (78%), Bolivia (18%), and Paraguay (4%), with 65% of the Brazilian side located in Mato Grosso do Sul state, and 35% in Mato Grosso (Tomas et al., 2019). It is considered the largest continuous freshwater wetland in the world. The Brazilian Constitution recognizes the Pantanal as a National Heritage, and the international recognition of its importance is expressed by the implementation of a Biosphere Reserve and the concession of a "World Heritage" status by UNESCO. The Pantanal is a convergence zone influenced by five ecoregions: the Cerrado, the Chaco, the Atlantic Forest, the Chiquitano Forest, and the Amazon Rainforest. The Pantanal is a hotspot for ecosystem services, biodiversity, and ways of life adapted to its ecological conditions (Bolzan et al., 2022; Chiaravalloti et al., 2022; Costanza et al., 1997; Tomas et al., 2019).

The annual flood pulse, determined by rainfall and geomorphology of the upper Paraguay River basin (UPRB), produces a mono-modal hydrologic signature (Junk et al., 1989; Junk & Wantzen, 2004; Penatti et al., 2015). These seasonal floods influence the plant and animal communities, the nutrient cycling, and primary productivity in the floodplain (Junk & Nunes da Cunha, 2005). The landscapes are composed of a mosaic of floodable and nonfloodable grasslands, forests (monodominant, semi-deciduous, dry, riparian, and *cerradão* forests), open woodland savannas (*cerrado*, *campo cerrado*, *campo de murundu*, monodominant savannas, palm savannas), and permanent and temporary aquatic environments (rivers, freshwater ponds, brackish water ponds, oxbows, marshes, and *vazantes*). The biological diversity is considerable, with over 2500 plant species (Pott et al., 2011; Pott & Pott, 2021) and at least 1200 vertebrate species (Britski et al., 1999; Ferreira et al., 2017; Gimênes Junior & Rech, 2022; Nunes et al., 2021; Souza et al., 2017; Tomas et al., 2010; Tubelis & Tomas, 2003). The Pantanal shelters vigorous populations of many endangered species (Tomas et al., 2019; Tomas et al., 2015), despite its relatively small number of endemic species, such as the snake *Helicops boitata* (Moraes-da-Silva et al., 2019) and nine plant species (Pott & Pott, 2021).

Historically, the regional economy is based on traditional, extensive cattle ranching, practiced for over 200 years (Machado & Costa, 2018). As private properties occupy ~94% of the Pantanal, its conservation depends on the proper land use (Chiaravalloti et al., 2023; Tomas et al., 2019). The second major economic activity in the Pantanal is fishing, both professional small-scale and sport fishing (Barletta et al., 2016; Mateus et al., 2011), generating over US$ 300 million per year (Amazonas et al., 2020). Ecotourism has been growing substantially in the region as a function of Pantanal's abundant wildlife, unique landscapes, and abundant fisheries (Almeida-Gomes et al., 2022).

The sustainable use of the Pantanal requires a unified approach both at the inter-state, national, and international levels to avoid conflict among conservation targets and outcomes. Several federal legislations aiming to fulfill the Article 225, Paragraph 4 from the Brazilian Constitution have been proposed, but the very slow legislative process, as well as the lack of a conceptual framework to provide the basis for it, contribute to the increasing vulnerability of the Pantanal. In 2024, Mato Grosso and Mato Grosso do Sul states enhanced and approved new state-level legislations for the Pantanal (Laws 8830/2008 plus Decree 774/2024, and Law 6160/2024, respectively), imposing restrictions and providing guidelines for ecosystem management and conservation, including biodiversity corridors and limiting suppression of the native vegetation.

In this context, one important step to support the legislative process is the proposal of a conceptual understanding to support the elaboration, discussion, and consolidation of federal and state-level policies. Additionally, development projects must consider the fundamental aspects of the ecosystem functioning and conservation challenges. We elaborated a list of eight basic principles based on the accumulated scientific evidence on the Pantanal to help in the legislative processes. We strongly recommend that policy-makers and decision-makers, as well as the entire society consider these principles aiming for conservation and sustainability in the Pantanal.

2 | PRINCIPLES

2.1 | Consider the Paraguay River basin a management unity

The management unity for the Pantanal should be the UPRB, for which differentiated public policies must be

established aiming to avoid, reduce, and mitigate the direct and indirect negative impacts in the floodplain ecosystems. As the Pantanal and its biodiversity, ecosystem services, and economic activities depend on the seasonal flood cycles, it is relevant to consider that inadequate land use outside the floodplain may cause inexorable, profound changes in its hydrology. Therefore, widespread and synergic negative impacts are expected to occur. Emblematic cases such as that of the Taquari River must be taken as a reference of the damaging potential of inadequate land use in surrounding higher lands of the UPRB. The Taquari River became completely silted due to bad soil management and erosion upstream. The consequences were river overflow and bank disruption, permanent flooding of lands that were seasonally flooded, expressive environmental impacts due to large-scale habitat loss, and profound economic impacts for the flooded cattle ranches (Assine et al., 2005; Galdino & Vieira, 2006). The land-use change scenarios for the higher lands of the UPRB, associated with climate changes, indicate increased sediment, pesticides, and fertilizers load towards the floodplain (Roque et al., 2021). Hydropower plants in the headwaters of the UPRB also may lead to a decrease in the frequency of large floods, an increase in the intensity and duration of the low-water phases, and a reduction of lateral connectivity in the floodplain (Jardim et al., 2020). Additionally, they may impose barriers for the migratory fish species during the spawning season. Draining of wetlands in the higher land of the UPPB, together with the loss of riparian forests, may also alter the quantity and quality of the water running to the floodplain, leading to a highly negative synergy with climate change. Finally, the risk of invasive exotic species must been considered as a threat, as revealed in the cases of the Amazonian fish *tucunaré* (*Cichla* spp.) and *tambaqui* (*Colossoma macropomum*), which have escaped from tanks outside the Pantanal (Córdova Junior, 2021). In this context, and considering that rules restricted to the floodplain would not be capable of preventing externally born impacts, only amplified management policies reaching the entire UPRB are capable of offering safeguards for the conservation and sustainable use of the Pantanal. However, these amplified management policies should focus mainly on specific approaches directly and indirectly linked to water conservation, soil management, pollution, and introduction of exotic species.

2.2 | Establish rules that follow the concept of restricted use

A mosaic of ecosystems determined by temporally and spatially heterogeneous flood and burning regimes characterizes the Pantanal (Damasceno-Junior et al., 2021; Damasceno-Junior & Pott, 2021). The dynamic environmental gradients and intricate habitat mosaics make it challenging to establish management rules for specific environments, creating difficulties when it comes to practical implementation and enforcement. The establishment of restriction rules designated for specific habitat types while other areas are considered as nonrestricted use would result in a mosaic of diverse regulations at local scale, jeopardizing the practicality of its application. In this context, the Pantanal has be considered entirely as a region of restricted use, according to Article 10 of the Native Vegetation Protection Law (NVPL; BRASIL, 2012), and general management rules established for the entire region, especially the limits for landscape modifications. Complimentary conservation strategies should be provided as best practices to orient landowners and other users. The general rules should be science-based and the management limits should agree with, if not originated from, the ecologically sustainable use, also determined by the NVPL in its Article 10 (see Section 2.3).

2.3 | Ensure the ecologically sustainable use of the Pantanal

The ecologically sustainable use of the Pantanal is required by Article 10 of the NVPL (Brasil, 2012), but it still requires a conceptual definition. The ecologically sustainable use implies conserving biodiversity, maintaining ecosystem services and ecosystem resilience, as well as safeguarding key ecological processes (see Chapin III et al., 1996; Mayer, 2012) regardless of the type of economic activities and management practices employed at the property or territory scale. In this sense, it is fundamental that the norms of use provide an acceptable degree of confidence in the outcome for biodiversity, services, and resilience. As such, it is necessary to establish limits for human intervention in the ecosystems, guided by the best science available, in order to favor conservation but also economic development and cultural valorization. We recommend key aspects to be addressed: (i) the proper use of fire to manage the vegetation; (ii) the limits for the suppression of native vegetation and the maintenance of habitat diversity in the landscapes; (iii) the maintenance of the hydrologic regime; (iv) the maintenance of ecological corridors; (v) the observance of grasslands carrying capacity for cattle ranching; (vi) proper grassland management practices to control woody vegetation encroachment; (vii) the use of indicators and protocols to assess the sustainability of economic activities; (viii) the incentives for the economic use of native flora products (e.g., fruits, nuts, medicinal plants)

to strengthen a local bio-economy; (ix) the implementation of public incentive policies for sustainability, certification, and differentiated financing programs, among others.

2.4 | Maintain the environmental heterogeneity and functionality in the Pantanal landscapes

The suppression of native vegetation and its replacement by cultivated invasive, exotic grass species simplify a naturally heterogeneous arrangement of habitat types (see Damasceno-Junior et al., 2021; Damasceno-Junior & Pott, 2021; Nunes da Cunha et al., 2023). This process, currently expanding in the Pantanal, may cause negative impacts on biodiversity and ecosystem functioning. Biodiversity has a strong relationship with environmental heterogeneity (Fernandes et al., 2015; Stein et al., 2014). The simplification of landscapes changes the composition and structure of plant and animal communities, affecting ecological processes, which is particularly noteworthy in naturally heterogeneous landscapes like the Pantanal. The negative effects of human interventions in the landscapes originate from (i) the suppression of native vegetation and its replacement by cultivated pastures; (ii) the fire exclusion policies, which eliminate the beneficial effects of burning in shaping the environmental heterogeneity and prevention of the encroachment; (iii) the reduction in the frequency, extension, and duration of seasonal floods; and (iv) the permanent flooding of land due to river bank disruption and overflow as a result of erosion and siltation. Additionally, as part of the environmental heterogeneity, the functionality of landscape elements should be taken into account, especially those providing connectivity at local and regional scales. In this context, the management rules and policies need to consider these aspects in order to maintain biodiversity and the ecosystem services, regardless of the type of economic activity, as these are fundamentals of the ecologically sustainable use of the Pantanal (see Section 2.3).

2.5 | Maintain the hydrological integrity and connectivity

The flood pulse is the main environmental factor that characterizes the Pantanal as a region containing diversified ecosystems (Wantzen et al., 2005). Human activities, as well as biodiversity and ecosystem services, are directly associated with this hydrological regime (Chiaravalloti et al., 2022; Wantzen et al., 2023). Changes in this flood cycle have the potential to affect biodiversity, ecosystem services, and the *pantaneiros* way of living (Chiaravalloti et al., 2022; Curado, 2004; Galdino & Vieira, 2006; Wantzen et al., 2023). Additionally, changes in the hydrological regime alter the dynamic of the native vegetation, causing the colonization of open grasslands by woody plants (encroachment), with impacts on the biodiversity, and the carrying capacity of these grasslands for the cattle. The encroachment also increases the plant biomass, favoring the occurrence of catastrophic wildfires such as those that affected the Pantanal in 2019 and 2020 (Garcia et al., 2021; Tomas et al., 2021). Within the floodplain, the hydrological changes originated from human intervention to facilitate the use of certain wetland areas (such as dikes and artificial drains) or the implementation of transportation infrastructure (like roads and riverbed interventions to improve navigation) may present similar negative effects in the ecosystems (Hamilton, 1999). The fisheries, which are the basis of a production chain centered on artisanal fishing and fishing tourism, depend mainly on migratory species (Mateus et al., 2011). However, during the development phase, these species rely on the hydrologic conditions in the floodplain, especially the aquatic connectivity and flood duration, as it is where the feeding areas for larvae and hatchlings survive and develop (Fernandes et al., 2015; Sousa et al., 2023; Ziober et al., 2012). In this sense, the implementation of hydropower plants planned for the higher areas of the UPRB would have a considerable impact on fish resources, by blocking the migratory routes and affecting the food security in the traditional communities (Peluso et al., 2022).

2.6 | Ensure full environmental representativeness of the protected areas network

The sparing of sample areas of the Pantanal for integral protection should prioritize balanced representativeness and complementarity of the ecological heterogeneity in the floodplain, considering biogeographic and hydrologic aspects. Presently, this heterogeneity is not well represented in the set of protected areas, both federal and state-owned areas. The Pantanal presents a great regional variation of the flood regime, which is represented by diverse flood permanence periods Additionally, the variation of soil types and the influences of adjacent ecoregions such as Cerrado, Amazon Rainforest, Chaco, Atlantic Forest, and Chiquitano forests (e.g., Souza et al., 2010; Tomas et al., 2019) contribute to increasing ecological heterogeneity, including an uneven distribution of its biodiversity. The current set of protected areas covers <5% of the floodplain (Tomas et al., 2019), and is

mostly representative of lower areas subjected to permanent or long-lasting floods (e.g., Pantanal National Park, Rio Negro State Park, Taiamã Ecological Station), or of mostly forested areas (e.g., Encontro das Águas State Park). Large portions of savannas and areas under the biogeographical influence of specific eco-regions, such as the Chaco, are underrepresented or are not covered by any protection status. Rare ecosystems are not yet represented in the protected areas network, such as the region where brackish water ponds (*salinas*) do occur. In this context, it is essential to prioritize better representativeness of the protected areas in the Pantanal within the planning process for achieving the goals to which Brazil has agreed under the Convention of Biological Diversity. One relevant step is to improve and strengthen the mapping of the priority areas for biodiversity conservation, which is periodically updated by the Brazilian government (MMA, 2018).

2.7 | Provide economic incentives for conservationist use of the land

As the Pantanal is declared a National Heritage in the Brazilian Constitution, it is perfectly defensible that those that prime to conserve its biodiversity and ecosystem services deserve recognition due to the services they offer to Brazilian society. In this sense, the public sector should adopt the principle of conservationist-incentive recipient (in contrast with the term polluter-payer present in the Brazilian legislations) as the basis for the establishment of public policies aiming to provide direct and indirect compensation for these landowners and traditional communities that effectively conserve the Pantanal. Several opportunities may be considered, such as biodiversity credits, carbon credits, payment for ecosystem services, public incentive policies, access to lower interest rates for financing the operations, and similar measures. However, the use of a science-based set of indicators to evaluate the eligibility performance of rural properties and traditional land as receptors deserving these advantages is fundamental, as credibility and avoidance of greenwashing are key issues in any compensation program. Moreover, continuous monitoring and enforcement compliance are crucial for the effectiveness of these efforts.

2.8 | Recognize and protect traditional people, values, resources, and way of living

Human beings have been occupying the Pantanal for over 8000 years (Bespalez, 2015; Power et al., 2016; Vialou et al., 2017), and there is some evidence that this period may extend to more than 20,000 years (Nic Eoin, 2023). Presently, only a few of the indigenous people remain in the floodplain, such as the Guató, the Boe Bororo, the Kadiwéu, the Kinikinau, the Terena, and the Chiquitano. However, since the arrival of Europeans in the region and, lately, the people brought from Africa as slaves, a gradual process of miscegenation occurred. This led to the establishment of several *mestiço* communities, including cattle ranch workers. These communities developed a local culture well adapted to the environmental conditions in the Pantanal, mixing cultural traces of the indigenous people and creating their own adaptations. Their resilience depends on accessing their traditional territories and resources in an ever-changing environment. For instance, riverside communities move in the floodplain according to the connectivity provided by secondary canals and lakes, searching for the best fishing places (Chiaravalloti et al., 2022); ranchers move the cattle along flood gradients according to the variation of the forage provision; fire is used to manage the vegetation according to the seasonality of floods and the vegetation quality, creating environmental heterogeneity that favors biodiversity and local communities themselves (Chiaravalloti et al., 2022, 2023). As such, the Pantanal is considered a cultural landscape resulting from this long and complex history of human–environment interaction, and its conservation implies the conservation of its cultures. To achieve this, it is necessary to ensure the recognition and valorization of the traditional extensive cattle ranching (see Section 2.7), of the artisanal fishing, of the use of natural resources, and of the right to access traditionally used territories and resources. This right may be provided by establishing protected areas of sustainable use in specific situations to avoid conflicts, threats, and loss of cultural heritage. The biggest challenge in this sociocultural context is the implementation of a truly participatory, and inclusive decision-making process towards a more just and sustainable future.

It is relevant that legislators, state and federal decision-makers, as well as national and international development agencies carefully analyze the implications of different activities, policies, and projects under the eight principles listed here (see Table 1). In this process, it is fundamental to define strategies aiming at the prevention of scale-dependent effects of environmental impacts, resulting from geographic extension and synergies among human-induced changes in the ecosystems.

The elaboration and establishment of public policies and development projects should be a participatory process, engaging all the society sectors, both directly and indirectly, concerned with the Pantanal and its conservation. All principles outlined here require a science-based approach, or at least, the adoption of a scientifically guided orientation in defining management rules, conducting impact evaluations, and seeking solutions for the

TABLE 1 Activities, practices, management, and regulatory mechanisms related to the eight basic principles for the elaboration of public policies and development projects in the Pantanal.

Principles	Activities, practices, management, and regulatory mechanisms
I—Consider the Paraguay River basin a management unity	Agriculture Mining Hydropower projects Water use rights and permissions Draining of wetlands Urban sewage Urban garbage Navigation Deficit of mandatory native vegetation protection
II—Establish rules that follow the concept of restricted use	Land use rules Vegetation management practices Territorial planning at the property level Biodiversity corridors Mandatory protection of native vegetation
III—Ensure the ecologically sustainable use of the Pantanal	Suppression of native vegetation Burning as management tool Maintenance/recovery of native grasslands Draining of wetlands Construction of dikes Transportation infrastructure Ecological corridors Traditional cattle ranching Intensified cattle ranching Tourism Fishing Extractivism
IV—Maintain the environmental heterogeneity and functionality I the Pantanal landscapes	Suppression of the native vegetation Burning as management tool Maintenance/recovery of native grasslands Draining of wetlands Construction of dikes Transportation infrastructure Ecological corridors Certification Payment for ecosystem services Biodiversity credits Carbon credits Restoration
V—Maintain the hydrological integrity and connectivity	Draining of wetlands Construction of dikes Transportation infrastructure Hydropower projects Navigation Fishing Maintenance/recovery of native grasslands Tourism
VI—Ensure full environmental representativeness of the Protected Areas network	Priority areas for conservation Priority areas for restoration Public and private protected areas Protected areas for sustainable use
VII—Provide economic incentives for conservationist use of the land	Public incentives for conservation Public incentives for restoration Differential financing policies Incentives for certification programs Payment for ecosystem services Biodiversity credits Carbon credits Restoration
VIII—Recognize and protect traditional people values resources, and way of living	Artisanal fishing Extraction of live baits Access to territories Product certification Cultural incentive programs Financial support Access to energy Access to education Access to health assistance Solidary marketing programs

major environmental, economic, and social challenges. The scientific community is able to provide the information to help the decision-making process, but it is the society, acting through its institutions (houses of representatives at state and federal levels) and available pathways to influence legislators and decision-makers, that ultimately makes the decision of adopting them.

In fact, such processes were present during 2022 and 2023 discussion of the Mato Grosso and Mato Grosso do Sul state-level legislations for the Pantanal. The new regulations approved in both states in 2024 follow most of the principles discussed in this article, satisfying the expectancies of the society. Both state consulted the scientific community as well opened up the discussion with different sectors, such as landowners and non governmental organizations (NGOs).

On the other hand, the Federal legislation is still in discussion in the Brazilian Congress to fulfill the Article 225 of the Brazilian Constitution. For this instance, we emphasize that the conservation of the Pantanal will depend on how this process is conducted, and how diverse expectations on sustainability are fulfilled. As such, the principles listed here may serve as a guideline to help the discussion and elaboration of this relevant public policy aiming the conservation of the Pantanal.

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All authors contributed in the elaboration of arguments, review, editing, and preparation of the article.

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