



Sustainable Water Governance in the Brazilian Pantanal Biome: Challenges and Lessons

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Problems caused by land-use change and climate change transcend territorial boundaries, but often management of natural heritage sites can only influence what happens within the local area. Therefore, we need innovative conservation strategies that also transcend territorial boundaries. Hence, the approach to managing our natural heritage sites may need innovative strategies to ensure their effective conservation. This study examines the conservation approach in the Pantanal biome, which houses multiple centers of decision-making across Brazil, Bolivia and Paraguay. Despite the region's significant contribution in providing ecosystem services and playing an integral part in local cultural heritage and Native communities, Pantanal has suffered from a lack of clear rules and strategies, challenges in implementation, capacity and coordination across different governance scales. This contribution synthesizes key challenges and potential opportunities through co-production and information sharing to ensure a socio-ecological approach to promoting the conservation and resilience of the Pantanal biome.

Keywords: conservation, integrated water resource management, monitoring, co-production, wetlands



KEY THEMES



< Fig. 1 Close-up view: Pantaneiro in a typical Pantanal canoe (Source: Ana Raquel S. Hernandez 2011, CC-BY-SA 2.0, via Wikimedia Commons).

Overview of the Pantanal Biome

Spanning Brazil, Bolivia and Paraguay, the Pantanal biome is the world's largest tropical wetland (Schulz et al. 2019). It offers significant ecosystem services, including carbon sequestration, and is abundant in cultural, recreational and economic resources. It also plays a role in maintaining water quality and supply (Clarkson et al. 2013). However, this region faces critical climate- and land-use change pressures that threaten its sustainability and resilience. Although UNESCO's Pantanal Conservation Area covers a total area of 187,818 ha, it only makes up 1 per cent of the entire biome (UNESCO 2024a; TNC 2024). The interconnected nature of this biome – both relating to its needs and the ecosystem services it provides – makes this geographic area one that UNESCO has declared of Outstanding Universal Value – that is, “cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity” (UNESCO 2024b). Thus, addressing the threats to the Pantanal biome requires attention to social, economic and ecological interests and needs at the biome level and a concerted international effort to ensure its continued sustainability.

This article begins by discussing how the Pantanal's cultural heritage is integrated with its biophysical composition. It then offers a review of changes and challenges to the sustainability of this socio-ecological system (SES), directing particular attention to the strengths and shortcomings of its governance structure and institutions (i.e. rules, norms and strategies). After reviewing the Pantanal's status, we consider new sustainable strategies that take into account water, culture and heritage practices. Finally, we offer closing thoughts and recommendations for how academics, professionals

and stakeholders from diverse backgrounds can help rethink the relationship between water and heritage.

The Pantanal's ecological diversity and dynamism parallels that of its cultural richness. Seasonal dry and wet periods in this area contribute to its high biodiversity (Wantzen et al. 2008), which is critical for providing ecosystem services integral to the Pantaneiro culture (Almeida-Gomes et al. 2022). This culture is rooted in a wide range of ethnicities and histories, including those of Native people and descendants of enslaved Africans and colonizers, all of whom are dependent on the Pantanal's resources for their livelihoods (Ikeda-Castrillon et al. 2023). For the Pantaneiros (fig. 2), this biome not only provides critical resources needed for riverine fishing, agriculture, animal husbandry and traditional pharmaceutical purposes but it also plays a central role in how the Pantaneiros understand themselves and their history, in turn shaping how they engage with the natural environment (Wantzen et al. 2008).

Nonetheless, major land-use changes dating back to the 1970s and 1980s (mainly for soy production and ranching) in Bolivia (Killeen et al. 2008), Paraguay (Caldas et al. 2015) and Brazil (Cardille 2003) marked the beginning of ongoing changes to the Pantanal's hydrological regime, with critical SES impacts. Today, agricultural intensification continues across all three countries, and related deforestation has further degraded the habitat of the Pantanal biome (Guerra et al. 2020). Recent initiatives to alter the Paraguay River for improved ease of barge-transported (fig. 3) agricultural exports through the Pantanal region will further disconnect the river from the floodplain, shrinking the wetland and contributing to major ecological degradation (Wantzen et al. 2024). The preliminary licenses issued for the installation of port



^ Fig. 2 Pantaneiro in a typical Pantanal canoe (Source: Ana Raquel S. Hernandez 2011, CC-BY-SA 2.0, via Wikimedia Commons).

infrastructure in the upper part of the Paraguay River have raised concerns regarding socio-ecological impacts. Simultaneously, the recent construction of dams adjacent to the biome has aggravated shifts in the hydrological regime, contributing to sedimentation and low flows during dry periods (Schulz et al. 2019).

Today climate change is compounding the effects of development in and around the Pantanal. Namely, climatic shifts have driven increased variability in precipitation, rising temperatures, reduced soil moisture and higher evapotranspiration rates (Marques et al. 2021). These factors have further increased sediment loads during the rainy season and have reduced wetland volume (Luo et al. 1997). Between 1985 and 2022, the wetland lost 81.7 percent (789,000 ha) of its water surface, with a more significant reduction in areas where seasonal flooding occurs. Flooded areas have been progressively smaller and

less common (Mapbiomas 2023). Lastly, these changes have spurred shifts in flows outside of the regular river channel, posing risks to the land around the Paraguay River that is needed to germinate seedlings (Jurik et al. 1994) for the vegetation that provides both levee stabilization and wildlife habitat (Bergier and Assine 2022).

Governance to Conserve the Ecosystem and Pantaneiro Lifestyle

The Pantaneiro way of life has historically operated symbiotically with the wetland's cycles of rising and falling water levels, but this may not continue without well-designed and well-implemented institutions (i.e., rules, norms and strategies) that promote conservation (Wantzen et al. 2024). Maximizing the effectiveness and efficiency of existing institutions in the Pantanal is inherently challenging. Governance of the



^ Fig. 3 Barges transporting commodities on the Paraguay River (Source: Idilio Vieira, 2018).

area is polycentric, a system with many actors operating independently, mutually adjusting in accordance with their relationships to one another (Ostrom 1999). Furthermore, unlike other biomes with extensive protected areas, most of the Pantanal is privately owned, requiring extensive coordination (Wantzen et al. 2024). Although the Pantanal has special protection status under Brazil's federal constitution, this biome has historically gained less attention and resources than natural resources in other protected sites, such as the Amazon River basin or the Atlantic Forest. Moving forward, steps to ensure the Pantanal's protection must account for i) historic, multilateral policies and management initiatives, ii) the status of involved institutions, and iii) outstanding social and ecological needs in future implementation of protective policies.

As a polycentric system, the Pantanal's governance has long embraced an Integrated Water Resource Management (IWRM) approach,

which “promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (UN 2009). The UN endorsed an IWRM approach in the 1990s to promote coordinated conservation efforts in a polycentric governance context like that of the Pantanal, but similar approaches date several decades earlier. For example, the 1969 La Plata River Treaty set a framework for multilateral decisions that foster equitable use and management of water resources (Gilman et al. 2008). Nevertheless, countries face barriers to coordination due to variation factors such as their respective abilities to monitor others' compliance with collective clean-up efforts, or financial and technical ability to divert – and ultimately – affect water quality and quantity for downstream users (Just and Netanyahu 1998).

Contemporary Challenges

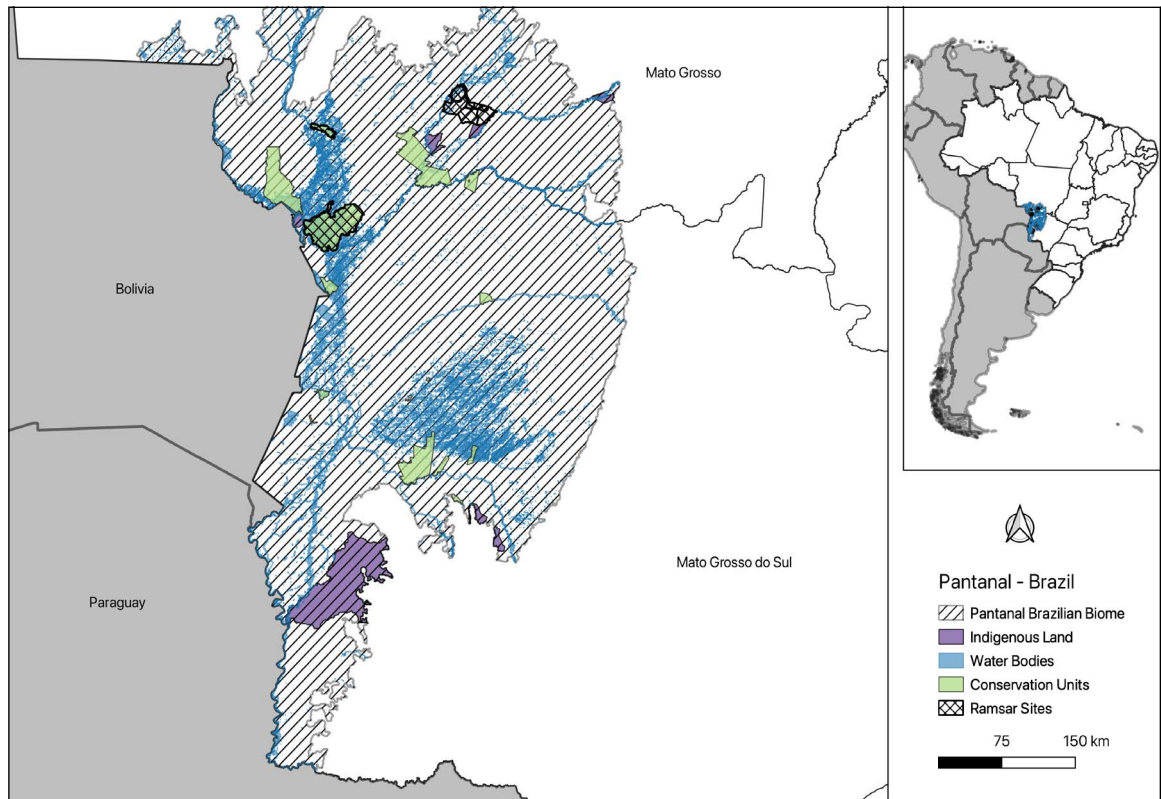
Regulatory frameworks designed to protect the Pantanal against the pressures of development and climate change have served to limit environmental degradation but they have not addressed modern social, structural, and interpretive challenges. The concurrent emergence of collaborative strategies to advance IWRM bodes well for conservation but these also face limitations. It is thus imperative to critically evaluate the strengths and challenges of these approaches to inform considerations that may help the governance of this complex SES.

A small proportion of the Pantanal is recognized as a UNESCO World Heritage Site and also has National Heritage status per the 1988 Brazilian Constitution (Supremo Tribunal Federal do Brasil 1988). World Heritage status affords part of the biome legal protection by the parties that sign the World Heritage Convention: they commit to integrate the site's protection into their regional planning, undertake conservation research and employ staff and services to these ends (UNESCO 2024b). At the national level, Brazil's Constitution states that the Pantanal "shall be used, as provided by law, under conditions which ensure the preservation of the environment, therein included the use of mineral resources" (Const. of Brasil, chap. VI, art. CCXXV).

Heritage protections require acknowledgment and effective programs and policies to ensure sustainability for the ecosystem and the livelihoods of the Pantaneiros (Chiaravalloti et al. 2023). Most of the Pantanal area is in the Brazilian state of Mato Grosso (the third-largest state in Central-West Brazil at 903,357 km²) (Fig. 4). Table 1 provides examples of how legislation that may impact riparian areas (i.e., adjacent to rivers or wetlands) is informed by the best available science, and subjective interpretation.

Collaborative IWRM strategies implemented at different scales have made great strides in improving conservation efforts but face challenges due to limited capacity and coordination (Lemos et al. 2020). These two aspects render communities increasingly vulnerable to rapid and unexpected change. One example involves planning efforts under the Brazilian National Water Resources Policy (no. 9.433/1997, art. 7), which calls for governments to develop long-term water plans at the level of the river basin, state or nation (Brazilian National Water Resources Policy 1997). Under this law and in coordination with the states, the National Water Agency (ANA) developed the 2018 Paraguay Hydrographic Region Water Resources Plan (WRP) to guide the management of the Upper Paraguay River, which falls at the headwaters of the Pantanal (ANA 2018). Challenges have arisen from the WRP's interpretation and implementation. The WRP's language classifies part of the Paraguay River as navigable, but it also proposes areas of restricted use (Wantzen et al. 2023). Furthermore, the absence of a River Basin Committee hampers the implementation of the WRP, as there is no opportunity for civil society to participate in water management decisions for the Paraguay River basin. Many river basin committees are unable to attend to the scale and nature of water governance challenges (Wantzen et al. 2023) and the needs of traditional and Indigenous communities in the Pantanal (Felipe et al. 2021).

A second, larger-scale initiative concurrently emerged with the WRP in 2018, as Paraguay, Bolivia and Brazil signed the Pantanal Declaration, an agreement to develop and coordinate plans for actions that embrace IWRM (Peña 2018). In 2023, the Inter-American Development Bank partnered with the United Nations Environment Program to co-finance the Global Environmental Facility (GEF) to strengthen IWRM and the coordination of transboundary water governance (Carreño and Vasquez-Arroyo 2023). The GEF



^ Fig. 4 The Pantanal Biome and its constituent Indigenous lands, water bodies, conservation units and Ramsar sites. (Source: Bruno P. Puga, 2024. Data sources: Instituto Nacional de Pesquisas Espaciais (INPE) <http://terrabrasilis.dpi.inpe.br/downloads/>).

Legislation	Scale	Description
Brazilian Forest Code (no. 12.561/2012)	Federal	Wetlands of “social interest” are protected but not guaranteed. Articles 10 and 11 on the removal of native vegetation: subject to the interpretation of technical research recommendations, state environmental agency authorization, and meeting needs of public utility (Brasil 2012).
Amendment: Complementary Bill (no. 17/2020)	State: Mato Grosso	Permits development of the Forest Code’s “permanent preservation areas,” or riparian areas if the projects are expected to have “low” environmental impact (ICV 2020).
Pantanal Law (no. 6.160/2023)	State: Mato Grosso do Sul	Protects and recovers the Pantanal and its springs, restricting land use and deforestation (Governo de Mato Grosso do Sul 2023).

^ Table 1. Legislation Impacting the Pantanal Biome.

approach is intended to manage endemic species (e.g., jaguar, capybara, riparian forest, and floodable grassland) and tackle root causes of degradation by leading activities, including organizational capacity building and integrating regional concerns into sustainable economic development (GEF 2023). However, the GEF reports continued barriers in addressing threats to the Pantanal (e.g., fire, land-use change, degradation of water resources and poor planning) that stem from the limited technical, managerial and financial capacity of communities – all of which are needed for successful program operations (UNDP and GEF 2021).

Conclusion and Recommendations for IWRM Needs

This evaluation of Pantanal's water resource governance reveals the importance of i) carefully considering the diversity of needs, interests and expertise of those invested in water governance, and ii) how these factors align with management at different temporal and spatial scales.

In theory, IWRM is a robust strategy to govern complex socio-ecological systems, given imperfect information and dynamic climatic conditions (Ludwig et al. 2014). One way to fortify IWRM may be through the co-production of knowledge with Pantaneiro and Indigenous communities by collectively identifying problems and solutions based on science and community knowledge and desires (Chambers et al. 2021). Steps toward such a goal may entail establishing a platform (e.g., an in-person initiative and/or digital space to maximize reach and inclusivity) with guidelines and procedural rules that create a safe and equitable space for different groups to express values and understandings, despite tension and asymmetrical power dynamics (Chambers et al. 2021). Finally, large-scale change will

require finding well-connected and embedded actors (e.g., the Brazilian Network of River Basin Organizations) to effectively synthesize and broker the latest scientific information, the unique experiences of different Pantanal inhabitants, and co-produced knowledge (e.g., including shared terminology and vision) for decision-makers.

Policy Recommendations

Drawing on insights from current Pantanal governance arrangements, there are opportunities to speak to the current needs of those impacted by water-governance decisions across different geographic scales over time. This article offers three recommendations that address these accordingly:

- *Diverse needs, interests and expertise:* Promote the co-production of knowledge in existing and new IWRM planning committees to cover spatial, temporal and knowledge-based gaps (for SDGs 6 and 17).
- *Support co-production with science and community knowledge:* Monitor ecological (particularly hydroclimatic) conditions and use citizen science to collect data that inform technical research and budgeting needs for capacity building and that can complement co-productive conversations about innovative adaptations to land-use change and climate change (for SDG 9).
- *Synthesize and broker information:* Develop strategies to identify and include actors that can effectively communicate community-informed needs and experiences to decision-makers responsible for the future of national policy, strategy and planning (for SDG 13).

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